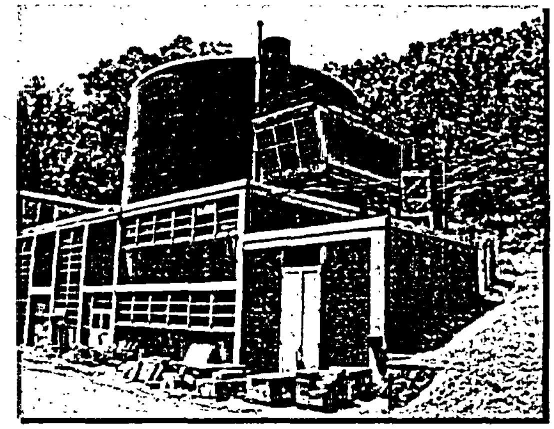
Attachment 4

The University of Virginia Reactor Decommissioning Project

UNIVERSITY of VIRGINIA

CH2MHILL



License R-66 Termination Request

Supplemental Information

- Response Letter
- Final Status Survey Report Request for Additional Information Responses
- Final Status Survey Report Revision 1
- Instrument Set 11 Revision 1

November 2004

Final Status Survey Report

EVALUATION OF RADIOLOGICAL RESULTS

RELATIVE TO TERMINATION OF NRC LICENSE R-66

UNIVERSITY OF VIRGINIA

CHARLOTTESVILLE, VIRGINIA

Prepared for

University of Virginia

Reactor Facility Decommissioning Project

Revision 1

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Approved by: Ralph Allen — 11/11/4
Reactor Decommissioning Committee Chair — Date

Approved by: Paul E Benneche — 11-11-04
UVAR Technical Director — Date

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November 2004

Approved by:	*[signature]* Radiological Controls Supervisor	12-7-04 Date
Approved by:	*[signature]* Characterization and Final Survey Supervisor	12/8/04 Date
Approved by:	*[signature]* Project Manager	11/10/04 Date

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Acronyms

ALARA	As Low As Reasonably Achievable
CAVALIER	Cooperatively Assembled Virginia Low Intensity Educational Reactor
cm	centimeter
cm^2	square centimeters
DCGL	Derived Concentration Guideline Level
dpm	disintegrations per minute
DQO	Data Quality Objective
FSS	Final Status Survey
g	gram
km	kilometer
LBGR	Lower Bound of the Gray Region
m	meter
m^2	square meters
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
mrem	millirem
NRC	Nuclear Regulatory Commission
N or n	number of data points
pCi	picocurie
QA	Quality Assurance
QC	Quality Control
SEC	Safety and Ecology Corporation
UVAR	University of Virginia Reactor
WRS	Wilcoxon Rank Sum

Executive Summary

Field activities to decommission the University of Virginia pool-type research reactor (Nuclear Regulatory Commission (NRC) License No. R-66) were conducted by CH2M HILL Constructors, Inc., assisted by several specialty subcontractors, beginning in April 2002. Decommissioning criteria established for this project were the NRC's default screening guidelines for structure surfaces and soil, which provide a conservative approach to assure that future facility uses do not result in radiation doses to the public in excess of 25 mrem per year.

The final status surveys to demonstrate that these guidelines have been satisfied were performed by one of the CH2M HILL team subcontractors, Safety and Ecology Corporation. Final surveys followed the recommendations of the Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) and other NRC guidance. Co-60 and Cs-137 were identified as primary contaminants present; however, because of the limited extent of impacted facility surfaces and media, assumptions as to other contaminants were based on limited radiological data. Conservative adjusted gross or surrogate guidelines were confirmed after the initial final survey data were evaluated.

The results of the final status surveys, documented in this report, demonstrate that the project decommissioning criteria have been satisfied and that the facility meets the requirements for termination of NRC License No. R-66.

1. Introduction

The University of Virginia operated a light-water cooled, moderated, and shielded pool-type nuclear research reactor beginning in June 1960. Reactor uses included radiation research, activation analysis, isotope production, neutron radiography, radiation damage studies, and training of Nuclear Engineering students. The reactor was initially commissioned to operate at a maximum power of one Megawatt (MW) thermal; it was upgraded to a power level of two MW in January 1971. Aluminum clad high-enriched uranium fuel was initially used; the reactor was converted to low-enriched uranium fuel in early 1994. The reactor operated under NRC License No. R-66.

In June 1998, the reactor was permanently shutdown, and the fuel was removed and shipped offsite between the shutdown date and mid 1999. Beginning in July 1999 GTS Duratek performed a radiological characterization of the reactor, the facility housing the reactor, and the surrounding fenced and gated land area, collectively referred to as the UVAR facility; results of that characterization are presented in a April 2000 Characterization Survey Report (Ref. 1). The University of Virginia submitted a Decommissioning Plan for the UVAR facility to the NRC in February 2000 (Ref. 2).

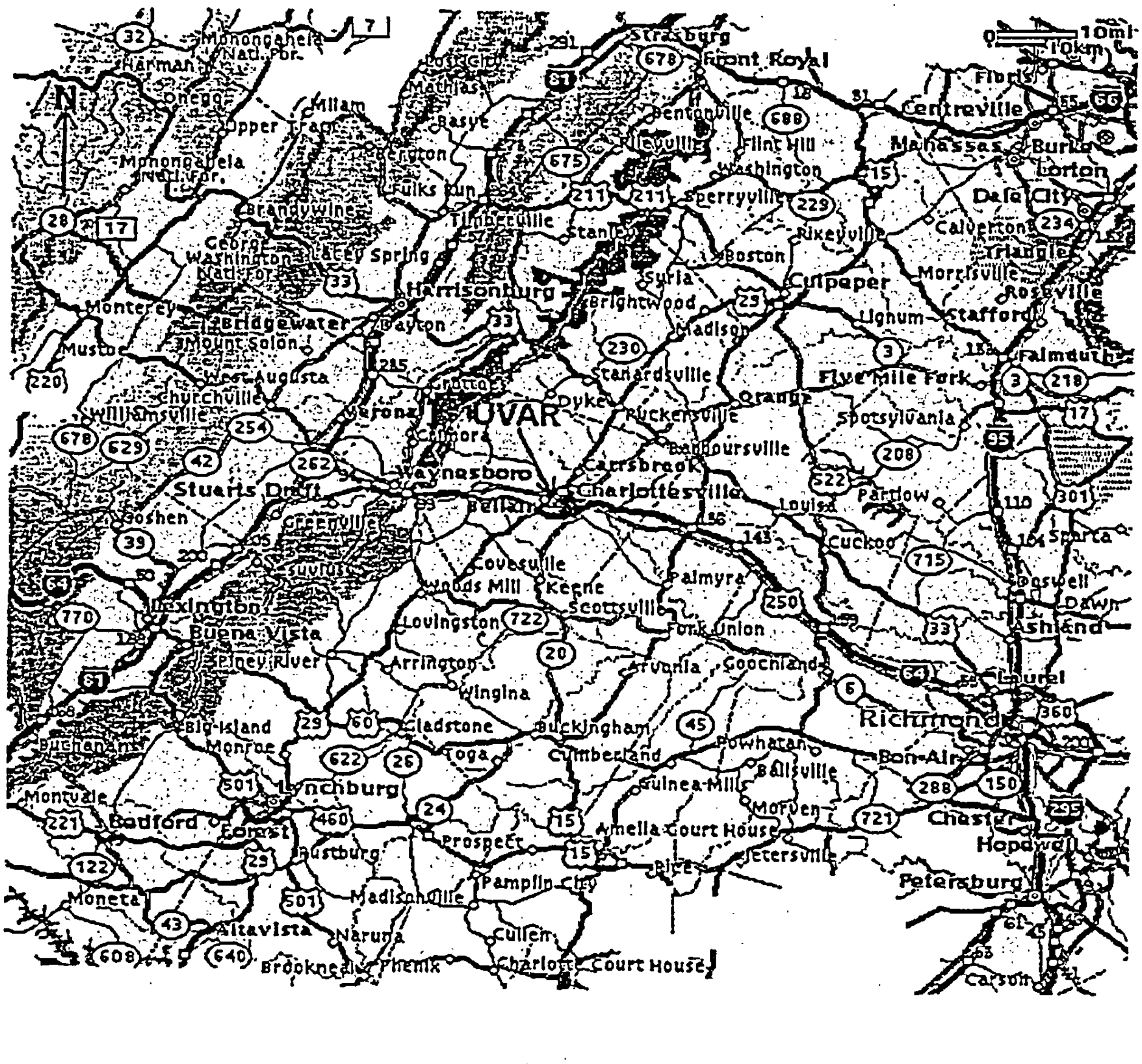
Beginning in March 2002, the University of Virginia contracted with CH2M HILL to conduct the decommissioning of the UVAR. CH2M HILL teamed with Waste Management Group, Inc. (WMG), Safety and Ecology Corporation (SEC), Bartlett Nuclear, Inc., and Parallax, Inc. to accomplish this effort. This team conducted additional characterization surveys; surveyed and released or disposed of materials, depending on radiological conditions; and performed decontamination of components, where appropriate.

Following the removal or decontamination of surfaces and materials, a Final Status Survey of the facility was performed to demonstrate that the radiological conditions satisfy NRC-approved criteria for use without radiological restrictions and termination of License No. R-66. This document describes the methodologies, results, and data evaluation for the Final Status Survey (FSS) of the UVAR facility.

2. Facility Description

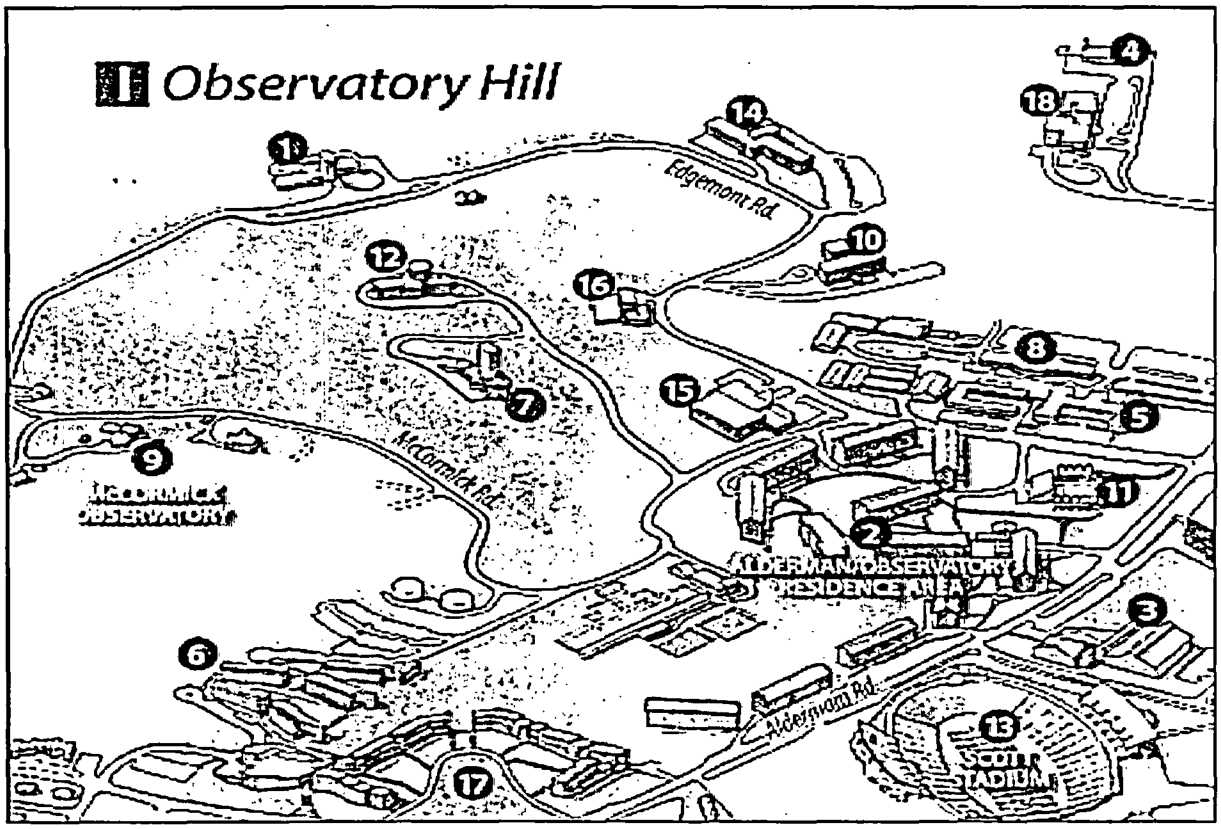
The UVAR facility is located on the Northern grounds of the University of Virginia approximately 0.6 kilometers (km) west of the city limits of Charlottesville in Albemarle County Virginia. (Figure 2-1).

Figure 2-1 Map of Charlottesville Area Surrounding the UVAR Site



The UVA Research Reactor and the decommissioned former CAVALIER facility, as well as offices for former faculty, students of the former Department of Nuclear Engineering, and the reactor staff, are housed in the facility. The CAVALIER Facility was decommissioned separately; a Final Status Survey was performed and license termination requested (see CAVALIER Final Status Report (Ref. 3) for details); the CAVALIER Facility area was added to the UVAR Facility and included in this Final Status Survey. To the north, east, and south of the facility (no closer than 0.5 km) there are city residential districts. The only access to the facility is by way of Old Reservoir Road (Figure 2-2).

Figure 2-2 Northern Grounds of the University of Virginia



Location 1:	Aerospace Research Laboratory	Location 12:	Reactor Facility
Location 2:	Alderman Observatory Residence Area	Location 14:	Shelbourne Hall
Location 6:	Hereford Residential College	Location 15:	Slaughter Recreation Facility
Location 7:	High Energy Physics Laboratory		
Location 9:	McCormick Observatory	Location 16:	Special Materials Handling Facility
Location 10:	National Radio Astronomy Observatory		

The land and facilities are the property of the University of Virginia, which is responsible for facility oversight and support. The UVAR facility site is depicted in Figure 2-3. The facility is located on the north side of a narrow valley with the land gradient falling north to south and west to east.

Figure 2-3 UVAR Facility Site

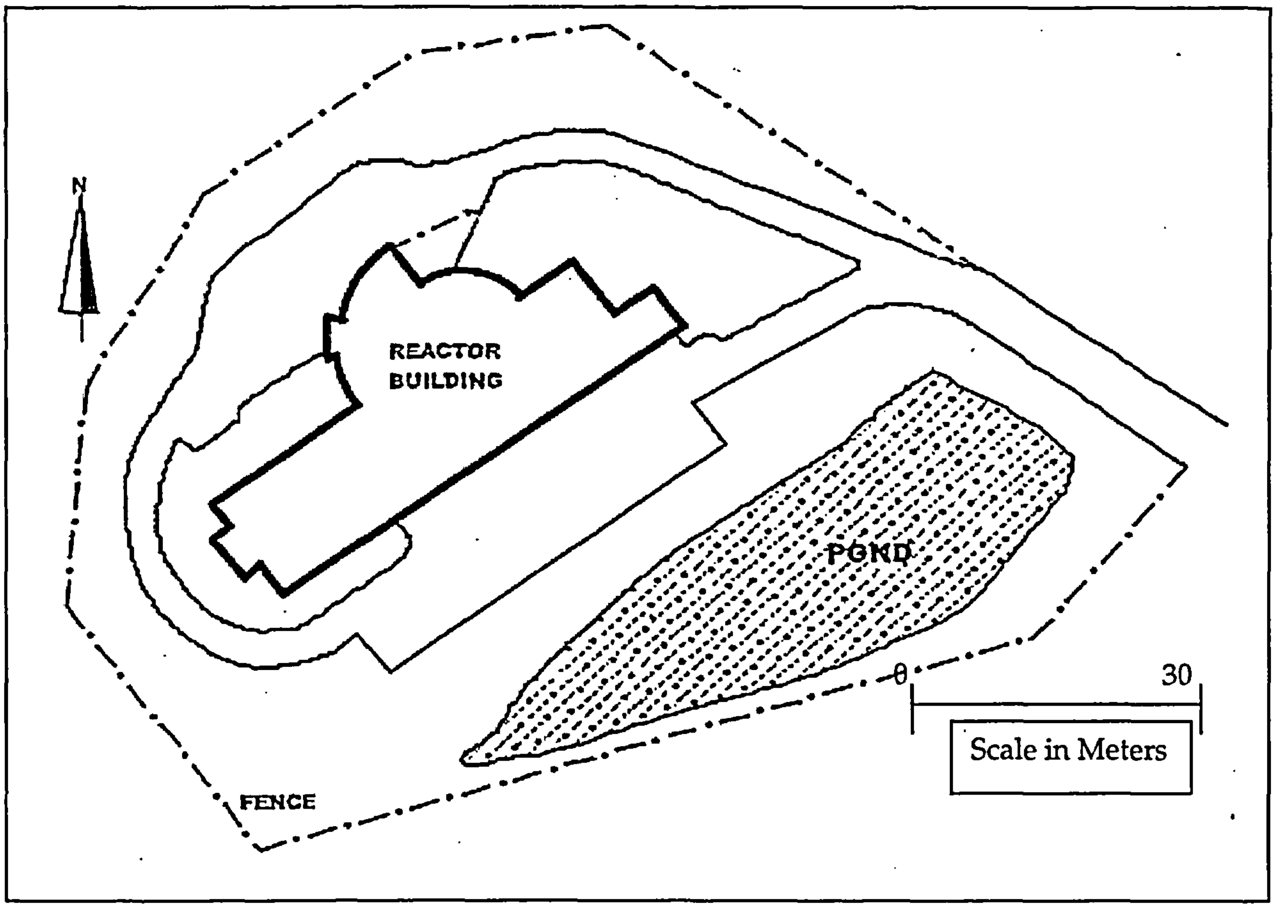
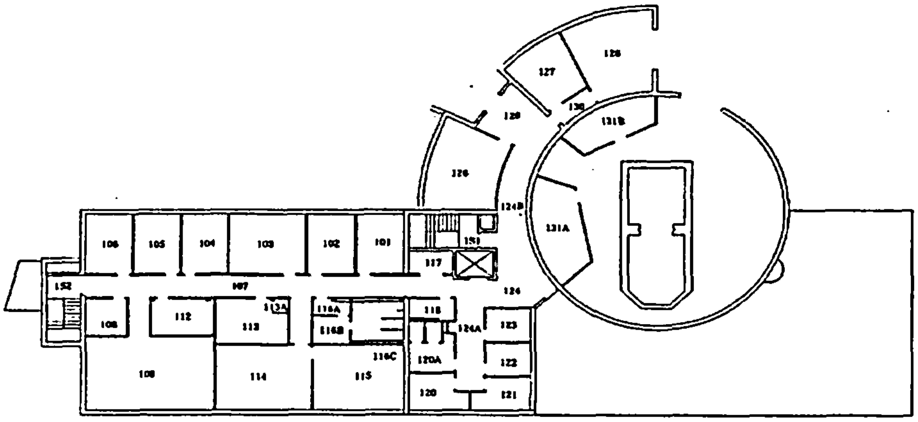


Figure 2-4 shows the three levels of the UVAR facility.

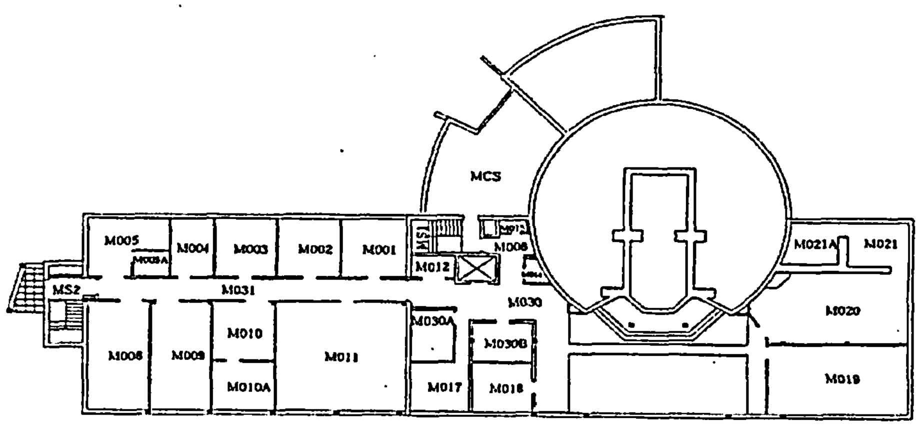
The Reactor Confinement Room (Rm 131), which housed the former UVA Research Reactor, is located on the upper floor (first floor). This room contained the 9.8 m long by 3.7 m wide by 8.2 m deep reactor pool, associated operating equipment and systems, the operating controls, and some research/experimental equipment. This room is circular and has an elevated (~10 m) ceiling. In addition, the Instrument Shop (Rm 128), the Shipping Area (Rm 127), and multiple offices and other support facilities for staff and students are located on this building level.

On the Mezzanine level were located the Demineralizer (Rm M021), Mechanical Room (Rm M020), HP Laboratory (Rm M019), several partially contaminated laboratories (Rms M005 [Tc-99 contamination] and M008 [Ni-63 contamination]), and multiple offices and other support facilities for staff and students. A crawl space (MCS) is accessed from the stairwell on the Mezzanine level.

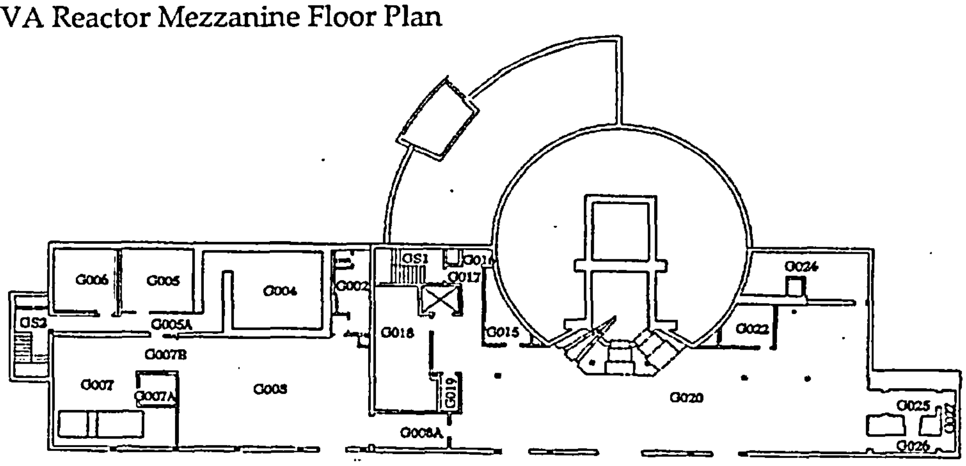
Figure 2-4 Building Plan Views



UVA Reactor First Floor Plan View



UVA Reactor Mezzanine Floor Plan



UVA Reactor Ground Floor Plan View

The ground floor contained the Heat Exchanger (Rm G024), Rabbit Room (Rm G005), Beam port/Experimental area (Rm G020), Hot Cell (Rms G025, G026, and G027), Counting Room (Rm G004), Woodworking and Machine Shop (Rm G008), Source Storage (Rms G022, G018, and G007A), the former CAVALIER facility (Rm G007), and miscellaneous support facilities and areas.

There was a cooling tower located on the roof of the Mezzanine level, adjacent to the Reactor Confinement room; this facility provided cooling for the reactor secondary system water.

The 2030 m^2 (interior floor space) UVAR facility building is situated on a 9390 m^2-fenced parcel of land. This land area included 2 sets of underground tanks for collection of potentially contaminated facility liquid wastes, a pond used for collection and holdup of facility discharges containing radioactive contamination, a tank used during fuel shipments at ground level at the front of the building, underground storm and sanitary sewer drainage systems, and miscellaneous larger materials and equipment with little or no potential for being radiologically impacted.

The UVAR building is of metal and concrete block construction with brick veneer. Floors are concrete slab. Internal walls are block and drywall.

Most impacted reactor and support systems and components were removed and disposed of as radioactive waste or surveyed and released for use without radiological restrictions.

The CH2M HILL decommissioning report records detailed information regarding the current facility status (Ref.4).

3. General Final Status Survey Approach

This survey was performed in accordance with the guidelines and recommendations presented in the *"Multi-Agency Radiation Survey and Site Investigation Manual"* (MARSSIM), NUREG-1575 (Ref. 5). Guidance provided in NUREG-1757, *"Consolidated NMSS Decommissioning Guidance"* (Ref. 6) was followed in the design, implementation, and evaluation of this final status survey. The process emphasizes the use of Data Quality Objectives and Data Quality Assessment, along with a quality assurance/quality control program. The graded approach concept was followed to assure that survey efforts were maximized in those areas having the greatest potential for residual contamination or the highest potential for adverse impacts of residual contamination.

For the purposes of guiding the degree and nature of FSS coverage, MARSSIM first classifies areas as *impacted*, i.e., areas that may have residual radioactivity from licensed activities, or *non-impacted*, i.e., areas that are considered unlikely to have residual radioactivity from licensed activities. Non-impacted areas do not require further evaluation. For impacted areas MARSSIM identifies three classifications of areas, according to contamination potential.

- Class 1 Areas: Impacted areas that, prior to remediation, are expected to have concentrations of residual radioactivity that exceed the guideline value.
- Class 2 Areas: Impacted areas that, prior to remediation, are not expected to have concentrations of residual radioactivity that exceed the guideline value.
- Class 3 Areas: Impacted areas that have a low probability, typically on the order of containing residual activity. Typically levels will not exceed 25-35% of the guideline value.

Facility history (including the Historic Site Assessment) and radiological monitoring conducted during characterization and remedial activities were the bases for classification.

See Table 3-1 for area classifications and survey unit numbering.

This survey was performed in accordance with the Master Final Status Survey Plan and eight addenda to the plan (see Appendix. A). Each addendum provided the survey approach and requirements for each common area of survey. Section Four of this report follows the addenda sections for survey approach, data summary, assessment, and evaluation. The supporting documentation for this report is contained in Appendices B and C.

Table 3-1 UVAR Survey Areas and Classifications

Room or Area	Surface	Class	Surface Area (m^2) or Survey Length (m)	Survey Unit No.
131 Reactor Room, West	Floor	1	92	1
131 Reactor Room, East	Floor	1	92	2
131 Reactor Room	Lower Walls	1	103	3
Reactor Pool, South	Floor and Walls	1	117	4
Reactor Pool, North	Floor and Walls	1	117	5
M005/005A	Floor and Lower Walls	1	65	6
M008	Floor and Lower Walls	1	89	7
M019	Floor and Lower Walls	1	107	8
M020	Floor and Lower Walls	1	104	9
M021/021A	Floor, Walls, and Ceiling	1	158	10
Bio Shield Surfaces	Wall	1	54	11
G005	Floor, Walls, and Ceiling	1	99	12
G007/G007A	Floor, Pit and Lower Walls	1	167	13
G018	Floor, Walls, and Ceiling	1	92	14
G020, West	Floor and Lower Walls	1	55	15
G020, Center	Floor and Lower Walls	1	67	16
G020, East	Floor and Lower Walls	1	120	17
G022	Floor, Walls, and Ceiling	1	48	18
G024	Floor, Walls, and Ceiling	1	105	19
G025/G026/G027	Floor, Walls, and Ceiling	1	146	20
Pond	Sediments	1	160	21
Waste Tank Area	Soil	1	350	22
Reactor Stack	Ductwork, stack, blowers	1	N/A	24
Ventilation System 1	Ductwork, stack, blowers	1	N/A	25
Ventilation System 2	Ductwork, stack, blowers	1	N/A	26
Heat Exchanger Piping	Piping interior	1	13 m	27
Reactor Pool Drains	Piping interior	1	20 m	28
Reactor room floor drains	Piping interior	1	19 m	29
Sanitary sewer release path	Piping interior	1	21 m	30
Drain to LWST	Piping interior	1	11 m	31
Hot Cell Drain	Piping interior	1	13 m	32
Reactor Drains to Pond	Piping interior	1	36 m	33
Fill Around Reactor Pool	Soil	1	1000	N/A
Soil Beneath Reactor Pool	Soil	1	140	N/A
Reactor Pool cores "M" and "B" areas	Soil	1	12	N/A
Demineralizer room wall core	Soil	1	<10	N/A
Outside reactor room Roll-up door	Asphalt	1	<10	62
Ventilation System 3	Ductwork, stack, blowers	1	N/A	61

Table 3-1 (Continued) UVAR Survey Areas and Classifications

Room or Area	Surface	Class	Surface Area (m^2) or Survey Length (m)	Survey Unit No.
131 Reactor Room	Upper Walls and Ceiling	2	690	34
127/128/130	Floor, Walls, and Ceiling	2	176	35
107/124/124A/124B	Floor and Lower Walls	2	311	36
M005/005A	Upper Walls and Ceiling	2	50	37
M008	Upper Walls and Ceiling	2	56	38
M019	Upper Walls and Ceiling	2	72	39
M020	Upper Walls and Ceiling	2	76	40
M006/M014/M015/M030/ M031	Floor and Lower Walls	2	259	41
MCS (crawl space)	Floor, Walls, and Ceiling	2	153	42
G004/G005A	Floor and Lower Walls	2	154	43
G006	Floor and Lower Walls	2	64	44
G007B/G008/G008A/G016 /G017/G019	Floor and Lower Walls	2	362	45
Stairwell 1	Floor and Lower Walls	2	119	46
Stairwell 2	Floor and Lower Walls	2	184	47
Reactor Confinement Roof	All	2	214	48
Main Building Roof	All	2	863	49
Outside Paved Areas	All	2	2236	50
Outside soil areas	Soil	2	6264	52
CAVALIER Facility Drain	Piping Interior	2	22 m	51
Storm and sanitary drains	Basins and piping	2	34 m	23
MCS Soil Floor	Soil	2	43	53
G007/G007A	Upper Walls and Ceiling	3	104	54
G020	Upper Walls and Ceiling	3	437	55
107/124/124A/124B	Upper Walls and Ceiling	3	220	56
M006/M014/M015/M030/ M031	Upper Walls and Ceiling	3	192	57
G004/G005A	Upper Walls and Ceiling	3	107	58
G006	Upper Walls and Ceiling	3	31	59
G007B/G008/G008A/G016 /G017/G019	Upper Walls and Ceiling	3	280	60
G002	All	3	71	63
Elevator	All	3	21	64
Mezzanine Offices	All	3	1190	65
First Floor Offices	All	3	1934	66
Outside Exterior Walls	Doors, vents	3	1362	67

N/A = Not Applicable

3.1 Radiological Contaminants and Criteria

The GTS Duratek initial characterization survey and continuing characterization by the CH2MHILL team indicated that the radiological contamination present was generally low level and was limited to the fenced grounds. Depending on the mechanism of contamination and the medium, radionuclides and their relative ratios varied. The overall predominant radionuclides were Co-60 and Cs-137; smaller activities of fission and activation products, namely C-14, Fe-55, and Eu-152 were identified in some media. Ni-63 and Tc-99 were surface contaminants from research projects in labs M008 and M005, respectively. Elevated levels of uranium decay series nuclides were identified in the pond sediments; pool fill soil and surface soil of the facility grounds, however, these were considered to be of natural origin and not to have originated from licensed reactor operations.

The Decommissioning Plan established the criteria for residual radioactive material contamination on UVAR facility surfaces and in facility soil. UVAR facility criteria also referred to as derived concentration guideline levels (DCGLs) were selected from the tables of NRC default screening values (refer to NUREG-1757; Ref. 6 and NUREG/CR-5512, Vol. 3, Ref. 7). The screening values for total surface contamination for radionuclides anticipated at UVAR are listed in Table 3-2; guideline levels for removable activity are 10% of the values in that table. Screening values for anticipated contaminants in soil are listed in Table 3-3. These screening criteria were based on assuring that estimated doses to facility occupants and the public during future facility use do not exceed annual doses of 25 mrem; default screening criteria were based on conservative exposure scenario and pathway parameters and are generally regarded as providing a high level of confidence that the annual dose limits will not be exceeded.

The criteria described in this section are net (above background) concentrations and activity levels of radionuclides; appropriate adjustments for instrument background levels were made to survey data before comparing data to the respective criteria.

Use of default screening values as decommissioning guidelines does not allow for areas of elevated activity. Therefore, there are no area factors for small areas of contamination, and all surface activity levels and radionuclide concentrations in soil must satisfy those guideline levels and methodology of Appendix E of NUREG-1757 (Ref. 6). In addition, because of use of the conservative default screening values, further evaluations and actions, relative to demonstrating the final conditions satisfy ALARA, are not required.

Table 3-2 Acceptable License Termination Screening Values of Common Radionuclides for Structure Surfaces

Radionuclide	Symbol	Screening Value (dpm/100 cm²)	Source
Hydrogen-3 (Tritium)	H^3	1.2E+08	NUREG-1757
Carbon-14	C^{14}	3.7E+06	NUREG-1757
Sodium-22	Na^{22}	9.5E+06	NUREG-1757
Sulfur-35	S^{35}	1.3E+07	NUREG-1757
Chlorine-36	$C1^{36}$	5.0E+05	NUREG-1757
Manganese-54	Mn^{54}	3.2E+04	NUREG-1757
Iron-55	Fe^{55}	4.5E+06	NUREG-1757
Cobalt-60	Co^{60}	7.1E+03	NUREG-1757
Nickel-63	Ni^{63}	1.8E+06	NUREG-1757
Strontium-90	Sr^{90}	8.7E+03	NUREG-1757
Technetium-99	Tc^{99}	1.3E+06	NUREG-1757
Iodine-129	I^{129}	3.5E+04	NUREG-1757
Cesium-137	Cs^{137}	2.8E+04	NUREG-1757
Europuium-152	Eu^{152}	1.3E+04	NUREG/CR-5512, Vol. 3
Plutonium-238	Pu^{238}	3.1E+01	NUREG/CR-5512, Vol. 3
Plutonium-239	Pu^{239}	2.8E+01	NUREG/CR-5512, Vol. 3
Plutonium-241	Pu^{241}	1.4E+03	NUREG/CR-5512, Vol. 3
Americium-241	Am^{241}	2.7E+01	NUREG/CR-5512, Vol. 3

Notes:

a Screening levels are based on the assumption that the fraction of removable surface contamination is equal to 0.1. For cases when the fraction of removable contamination is undetermined or higher than 0.1, users may assume for screening purposes that 100 percent of the surface contamination is removable, and therefore the screening levels should be decreased by a factor of 10. Users may calculate site-specific levels using available data on the fraction of removable contamination and DandD version 2.

b Units are disintegrations per minute (dpm) per 100 square centimeters (dpm/100 cm²). One dpm is equivalent to 0.0167 becquerel (Bq). Therefore, to convert to units of Bq/m², multiply each value by 1.67. The screening values represent surface concentrations of individual radionuclides that would be deemed in compliance with the 0.25 mSv/y (25 mrem/y) unrestricted release dose limit in 10 CFR 20.1402. For radionuclides in a mixture, the "sum of fractions" rule applies (see Part 20, Appendix B, Note 4).

Table 3-3 Acceptable License Termination Screening Values of Common Radionuclides for Surface Soil

Radionuclide	Symbol	Screening Value (pCi/g)	Source
Hydrogen-3 (Tritium)	H^3	1.1E+02	NUREG-1757
Carbon-14	C^{14}	1.2E+01	NUREG-1757
Manganese-54	Mn^{54}	1.5E+01	NUREG-1757
Iron-55	Fe^{55}	1.0E+04	NUREG-1757
Cobalt-60	Co^{60}	3.8E+00	NUREG-1757
Nickel-63	Ni^{63}	2.1E+03	NUREG-1757
Strontium-90	Sr^{90}	1.7E+00	NUREG-1757
Technetium-99	Tc^{99}	1.9E+01	NUREG-1757
Iodine-129	I^{129}	5.0E-01	NUREG-1757
Cesium-137	Cs^{137}	1.1E+01	NUREG-1757
Europium-152	Eu^{152}	8.7E+00	NUREG/CR-5512, Vol. 3
Plutonium-238	Pu^{238}	2.5E+00	NUREG/CR-5512, Vol. 3
Plutonium-239	Pu^{239}	2.3E+00	NUREG/CR-5512, Vol. 3
Plutonium-241	Pu^{241}	7.2E+01	NUREG/CR-5512, Vol. 3
Americium-241	Am^{241}	2.1E+00	NUREG/CR-5512, Vol. 3

Notes:

a These values represent superficial surface soil concentrations of individual radionuclides that would be deemed in compliance with the 25 mrem/y (0.25 mSv/y) unrestricted release dose limit in 10 CFR 20.1402. For radionuclides in a mixture, the "sum of fractions" rule applies; see Part 20, Appendix B, Note 4.

b Screening values are in units of (pCi/g) equivalent to 25 mrem/y (0.25 mSv/y). To convert from pCi/g to units of Becquerel per kilogram (Bq/kg), divide each by 0.027. These values were derived using DandD screening methodology (NUREG/CR-5512, Volume 3). They were derived based on selection of the 90th percentile of the output dose distribution *for each specific radionuclide* (or radionuclide with the specific decay chain). Behavioral parameters were set at "Standard Man" or the mean of the distribution for an average human.

3.2 Data Quality Objectives

The objective of the FSS was to demonstrate that the radiological conditions of the facility satisfy the decommissioning criteria established in the NRC-approved Decommissioning Plan. The Data Quality Objectives (DQOs) demonstrated at the 95% confidence level that these criteria have been met. Decision errors were 5% for both Type I and Type II errors. Such a Type I (alpha) decision error provides a confidence level of 95% that the statistical tests will not determine that a surveyed area satisfies criteria when, in fact, it does not. The Type II (beta) decision error provides a confidence level of 95% that the statistical tests will not determine that a surveyed area does not satisfy criteria when, in fact, it does. Measurement sensitivities will enable quantification of contaminants at or below the DCGL values at the 95% confidence level.

Data quality indicators for precision, accuracy, representativeness, completeness, and comparability, have been established.

- Precision is determined by comparison of replicate values from field measurements and sample analyses; the objective is a relative percent difference of 20% or less at 50% of the guideline value.
- Accuracy is the degree of agreement with the true or known value; the objective for this parameter is +/- 20% at 50% of the guideline value.
- Representativeness and comparability do not have numeric values. Performance is assured through selection and proper implementation of sampling and measurement techniques.
- Completeness refers to the portion of the data that meets acceptance criteria and is thus acceptable for statistical testing; the objective for this survey is 90%.

3.3 Final Status Survey Tasks

- Surface Beta Radioactivity Scan Surveys
- Gamma Surface Scans
- Integrated Direct Surface Beta Radioactivity Measurements
- Smear Sample Collection and Analysis
- Volumetric Sample Collection and Analysis

3.4 Survey Instrumentation and Methods

Table 3-4 lists the instrumentation used for survey activities described in this FSS Report, along with nominal operating parameters and estimated detection sensitivities. Instrument response was based on use of an average surface efficiency of 0.25 (per recommendations of ISO 7503) (Ref. 8). This conservatively low efficiency, based on Tc-99, underestimates the true detector response for the higher beta energies associated with Cs-137 and Co-60. Thus, for areas with no Tc-99 present, calculated quantities will be higher than those actually present.

Detection sensitivities were estimated, using the guidance in NUREG-1575 (MARSSIM) and NUREG-1507 (Ref. 9). Instrumentation and survey techniques were chosen to obtain detection sensitivities below the applicable DCGLs for both scanning and direct measurement, with the objective of achieving ≤ 25% of the DCGL. This objective was not achievable for gamma scans of land surfaces using Model 44-10 gamma scintillation detectors and piping scans using a Model 491-30 GM detector, but these survey activities were sufficient to assure identification of areas of elevated activity of a size and activity level that could adversely affect the average for the survey units.

All instruments had current calibrations using NIST-traceable standards. Operational and background checks were performed at the beginning of each day of FSS activity and whenever there was reason to question instrument performance.

Table 3-4 Instrumentation for UVAR Final Status Survey

Detector	Type	Make	Meter	Application	Sensitivity (dpm/100 cm², except as noted)	
					Scanning	Static Count of 1 minute
43-68	Gas Proportional	Ludlum	2221	Beta scan & measurement	1200	500
43-37	Floor Monitor	Ludlum	2221	Beta scan	800	N/A
43-68	Gas Proportional	Ludlum	2221	Alpha measurement	200	70
Tennelec LB5100	Gas Proportional	Tennelec	N/A	Alpha smear measurement	N/A	5
Tennelec LB5100	Gas Proportional	Tennelec	N/A	Beta smear measurement	N/A	10
44-10	NaI	Ludlum	2221	Gamma scan	3.3 pCi/g Co -60 6.4 pCi/g Cs-137	N/A
491-30	GM	Victoreen	2221	Beta scan & Measurement	4600	2300

3.4.1 Surface Beta Radioactivity Scan Surveys

Beta scanning of structure surfaces was performed to identify locations of residual surface activity. Gas-flow proportional detectors were used for beta scans. Floor monitors with 580 cm² detectors were used for floor and other larger accessible horizontal surfaces; hand-held 125 cm² detectors were used for surfaces not assessable by the floor monitor. Scanning was performed with the detector within 0.5 cm of the surface. Scanning speed was no greater than 1 detector width per second. Audible signals were monitored and locations of elevated direct levels identified for further investigation.

Minimum scan coverage was 100% for Class 1 surfaces, 25% for Class 2 surfaces, and 10% for Class 3 surfaces (Ref. 10). Coverage for Class 2 and Class 3 surfaces was biased towards areas considered by professional judgment to have highest potential for contamination.

3.4.2 Gamma Surface Scans

Gamma scanning surfaces were performed on structure and land surfaces to identify locations of residual surface activity. NaI gamma scintillation detectors (2" x 2") were used for these scans. Scanning was performed by moving the detector in a serpentine pattern, while advancing at a rate of approximately 0.5 m per second. The distance between the detector and the surface was maintained within 5 cm. Audible signals were monitored and locations of elevated direct levels identified for further investigation.

Minimum scan coverage was 100% for Class 1 surfaces, 25% for Class 2 surfaces, and 10% for Class 3 surfaces (Ref. 10). Coverage for Class 2 and Class 3 surfaces was biased towards areas considered by professional judgment to have highest potential for contamination.

3.4.3 Integrated Direct Surface Beta Radioactivity Measurements

Measurements of surface beta radioactivity were performed using a Ludlum Model 43-68 handheld 125 cm^2 gas proportional detectors coupled to a Ludlum Model 2221 ratemeter/scalers. These Model 43-68 detectors were outfitted with 0.8 mg/cm^2 windows and calibrated for response to Tc-99 beta particles except for those locations where Ni-63 was a potential contaminant of concern; in locations with potential Ni-63 contamination, e.g., Room M008, the Model 43-68 detectors were outfitted with 0.4 mg/cm^2 windows and specifically calibrated for response to Ni-63 beta particles. Counts were integrated for a one-minute counting interval to obtain measurement sensitivity less than the DCGL. Two measurements were performed at each measurement location. The first of these was a surface measurement, performed in the typical manner (i.e., with the detector face uncovered); this measurement included contributions from beta particles emitted from the surface and interactions of ambient gamma photons with the detector. The second measurement was performed at the same location with the detector face covered by a layer of material. A piece of wood approximately 1.27 cm (½-inch) thick, which contained no significant beta-emitting component and which has sufficient density thickness to shield out the beta particles, but not reduce the gamma photon level. The detector response for this second measurement was representative of the contribution from gamma radiation only. The difference between measurements with an uncovered (unshielded) detector and covered (shielded) detector represented the level of beta activity, only, which was then compared with the surface contamination criterion. Instrument beta response factors (efficiencies) incorporate considerations for source efficiency, due to potential adverse surface conditions. As recommended in International Organization for Standardization (ISO) 7503 for beta emitters with maximum energies less than 0.4 megaelectron volts (MeV), a source efficiency factor of 0.25 was used in determining the effective total instrument efficiencies. Total efficiency factors for the various instruments used for direct beta measurement were within very close agreement. Effective total instrument efficiencies were used for converting count-rate data to activity units.

3.4.4 Smear Sample Collection and Analysis

Smear samples for removable activity were collected by wiping a 5 cm (2-inch) diameter cloth disc over approximately 100 cm^2 (15.5 in^2) areas of the surface, while applying moderate pressure. Smear samples were obtained at each location of direct surface activity measurement. Smear samples were counted on a Tennelec LB 5100 automatic gas proportional counter for alpha and beta radioactivity. The primary purpose of collecting smear samples was to provide data to confirm the assumption of the dose assessment that transferable radioactivity is less than 10% of total radioactivity. The DQO for smear samples was to insure that the dose model assumptions used to develop the criteria were appropriate.

3.4.5 Volumetric Sample Collection and Analysis

Volumetric samples were collected as prescribed in the FSS plan. Samples were managed under chain-of-custody procedures and submitted to Severn Trent Laboratory, located in Earth City, Missouri and Eberline Services, Oak Ridge laboratory, Oak Ridge, Tennessee for gamma spectroscopy and 10 CFR Part 61 analyses for hard to detect nuclides.

3.5 Quality Assurance

Instruments used for the Final Status Survey were maintained and calibrated to manufacturers' specifications to ensure that required traceability, sensitivity, accuracy, and precision of the equipment/instruments was maintained. The SEC laboratory located in Knoxville, Tennessee followed standard procedures per ANSI N323A-1997 and used National Institute of Standards and Technology (NIST) traceable sources to calibrate the equipment/instruments.

Before and after daily use, instruments were quality control (QC) checked by comparing the instruments' response to designated radiation sources and to ambient background. These performance checks were performed at a predetermined site reference location within the UVAR facility.

Instrument responses to the designated QC check sources were plotted on control charts and evaluated against the average established at the start of the field activities. A performance criterion of ±20% of this average was used as an investigation action level. No instruments were removed from service for not meeting operational requirements.

During QC checks, instruments used to obtain radiological data were inspected for physical damage, current calibration, and erroneous readings in accordance with applicable procedures and/or protocols. Instrumentation not in compliance with the specified requirements of calibration, inspection, or response check was removed from operation. If the instrument failed the QC response check, any data obtained to that point, but after the last successful QC check were considered invalid due to faulty instrumentation. No data were rejected during the FSS due to QC criteria.

3.5.1 Data Quality Controls

Project data were recorded in a Project Data Logbook or on standard, preprinted data forms. Records were reviewed daily.

Sample chain-of-custody was maintained for volumetric samples.

Duplicate sampling and measurements were performed for 20% of the sampling/measurement locations.

The analytical laboratory performed laboratory spike and blank analyses. Relative percent differences were determined for the spike results and compared to a project performance criterion of ±20%. Blank sample results were compared with a performance criterion of no detectable activity.

3.6 Data Assessment and Evaluation

Data was reviewed to assure that the type, quantity, and quality were consistent with the Final Survey Plan and design assumptions. Data standard deviations were compared with the assumptions made in establishing the number of data points. Individual and average data values were compared with guideline values and proper survey area classifications were confirmed. Individual measurement data in excess of the guideline level for Class 2 areas and in excess of 25 % of the guideline for Class 3 areas prompted investigation. Patterns, anomalies, and deviations from design assumption and Plan requirements were identified. Need for investigation, reclassification, remediation, and/or resurvey was determined; a resolution was initiated and the data conversion and assessment process repeated for new data sets.

3.7 Background Determination and Reference Areas

The UVAR Decommissioning Plan identified Ragged Mountain Reservoir as a comparable area to the UVAR facility to obtain background soil samples. However, further evaluation indicated that the soils at UVAR facility contained higher levels of naturally occurring radionuclides that those at Rugged Mountain Reservoir. Therefore, samples from the immediate vicinity of UVAR, but without a potential of being impacted by site operations, were obtained to determine background levels of radionuclides in the area. Static count backgrounds were determined at the time of survey, utilizing a shielded/unshielded probe approach. No background reference areas were determined for this Final Status Survey.

4. Final Status Survey

4.1 Background

4.1.1 General

Radionuclides, which are potential contaminants of concern due to licensed UVAR activities, are not naturally occurring in site soil or construction materials at concentrations greater than 10% of the project DCGLs. Therefore reference areas for evaluation of soil contamination are not applicable to the UVAR Decommissioning Project. Survey designs were based on data requirements for the Sign Test, with evaluation of soil survey data to be based on comparison of specific radionuclides with default screening DCGLs or surrogate DCGLs, established for a soil area of interest.

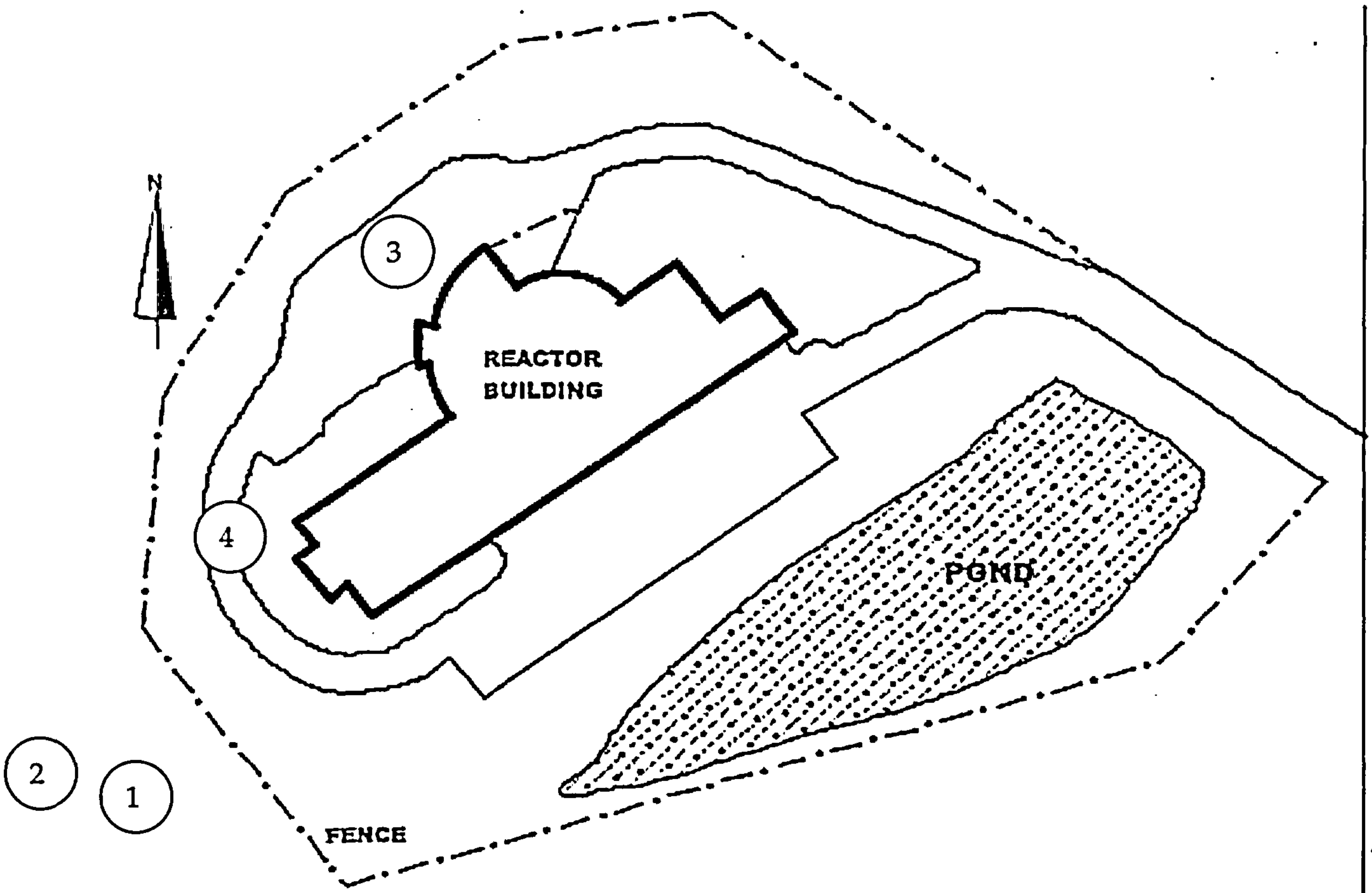
Direct measurement gamma and beta background levels were noted to be variable and occasionally elevated throughout the facility and surrounding land areas. This was due to local geologic formations containing naturally occurring K-40, uranium, and thorium; a wide-variety of construction materials, also containing varying levels of naturally occurring radionuclides; and localized areas of elevated ambient radiation from stored radioactive sources regulated under other licenses. Because this background variability was not conducive to establishing background reference areas, it was decided that individual direct measurement locations would have unshielded and shielded gross activity determinations and the difference would be the basis for determining activity for comparison with established guideline levels. Since reference areas were not used, the statistical design of required data points was based on the Sign test.

4.1.2 Survey Activities and Results

The UVAR Decommission Plan identified Ragged Mountain Reservoir as a potential offsite location for soil background determination. However, because of the reasons indicated in Section 4.1.1, it was decided that a soil reference area was not necessary, and, furthermore, that the geology of the Ragged Mountain Reservoir area was not comparable with the naturally occurring nuclides at the UVAR site. Although a soil reference area was not to be used in final status survey evaluation, it was necessary to establish the identity and activity range of the naturally occurring radionuclides in site soils and thus enable these radionuclides to be eliminated from consideration in the evaluation.

Streambed samples were obtained from two locations (#1 and #2) approximately 200-m and 250-m upstream from the pond. Rock face and fill samples were obtained by hand auger at two locations (#3 and #4) upgradient from the UVAR Building; three samples from each location represented the 0-15 cm, 15-45 cm and 45-75 cm depths. See Figure 4-1 for sample locations.

Figure 4-1 Background Soil Locations



Results of soil analyses are summarized in Table 4-1. Concentrations of C-14 and the uranium series are consistent with those typically present in background soils, while K-40 and thorium series radionuclides are slightly (2 to 4 times) higher than typically noted in soil. It is believed that the elevated levels of these radionuclides are likely due to the bedrock underlying the site.

Positive concentrations (up to 1.8 pCi/g) of Eu-155 were also reported for these samples. This radionuclide is not naturally occurring and is not typically identified as a contaminant of reactor origin, particularly considering that Eu-152 and Eu-154, which are of reactor origin, were not identified in these samples. Considering the cross-sections of activation and natural abundances of the stable elements from which these Eu-isotopes are produced, the Eu-155 level would be expected to be lower than of Eu-152 and Eu-154. Finally, the photon energies of Eu-155 are very close to X-ray and gamma photon energies present due to naturally occurring radionuclides. For these reasons, the Eu-155 by gamma spectrometry is considered a misidentification, and not a contaminant of reactor origin.

Table 4-1 Concentration of Radionuclides in Background Soil

Sample Location	Activity (pCi/g)			
	C-14	K-40	U-Series	Th-Series
1	6.5 ± 2.55	22.6 ± 4.2	1.6 ± 0.4 (c)	1.6 ± 0.3 (e)
2	2.99 ± 1.54	29.3 ± 3.8	1.6 ± 0.4 (c)	1.9 ± 0.4 (e)
3-1	N/D (a)	34.9 ± 4.4	1.4 ± 0.3 (d)	2.8 ± 0.4 (b)
3-2	N/D (a)	42.8 ± 5.2	1.4 ± 0.3 (d)	2.9 ± 0.4 (b)
3-3	N/D (a)	41.1 ± 5.1	1.3 ± 0.3 (d)	3.3 ± 0.5 (b)
4-1	N/D (a)	20.8 ± 2.8	0.9 ± 0.2 (d)	2.2 ± 0.3 (b)
4-2	N/D (a)	32.3 ± 4.2	1.8 ± 0.3 (d)	4.5 ± 0.5 (b)
4-3	N/D (a)	38.7 ± 4.8	1.5 ± 0.3 (d)	4.0 ± 0.5 (b)
Note a	Not Determined			
Note b	Based on Ac-228 measurement			
Note c	Based on U-238 measurement			
Note d	Based on Bi-214 measurement			
Note e	Based on Th-232 measurement			

Variable gamma radiation levels were noted with 2" x 2" NaI detectors, used for surface scanning surveys. General background levels outside the building were approximately 8,000 cpm, but ranged up to 28,000 cpm in contact with rock outcroppings on the site. Such levels are not unexpected, considering the natural content of K-40 and thorium in site soil and rock. Gamma levels were also elevated and highly variable (up to 88,000 cpm) in the vicinity of the Hot Cell doors, due to the presence of radioactive source in storage in that facility. Inside the building, gamma background levels generally ranged from about 6,000 to 12,000 cpm. Higher values (up to 30,000 cpm) were observed in portions of the structure, where materials such as concrete, ceramic tile, cinder block, and brick, containing naturally occurring radioactive materials, were present, where geometry was enhanced due to small rooms and at interfaces of two or more surfaces, and in areas adjacent to source storage.

Beta backgrounds on instruments used for scans and direct requirements also varied, depending on the specific detector, the surface material, and the ambient gamma levels from radioactive sources in the immediate area.

For direct beta measurements, adjustment for background was made by conducting unshielded and shielded measurements at each data point; the difference represented the surface activity level, conservatively over-estimating the true activity present by not correcting for naturally occurring activity in the surface.

4.2 Underground Waste Tank Excavation

4.2.1 Description

Two sets of underground metal tanks, located southeast of the UVAR facility adjacent to the pond, were used for collection/holdup of liquid wastes, which were potentially contaminated with low concentrations of radioactive materials (Figure 4-2). Two of these tanks (HCTs) serviced the hot cell facility and two tanks (LWSTs) were used for collection of demineralizer regeneration liquids from the 2-MW UVA Reactor. Both of these tank sets were initially equipped for environmental discharge to the pond, provided the liquid met appropriate release criteria following dilution with pond water. However, the demineralizer regeneration liquid tanks were later replumbed to discharge directly into the pond spillway. All tanks, associated piping, valves, pumps, etc., have been removed along with their concrete enclosures and foundations. The floor of the LWST enclosure contained small quantities of contaminated soil-like materials near the tanks which were removed. The resulting excavation was approximately 175 m^2 in area and ranged up to approximately 3 m in depth; including the unexcavated soil edges. The area addressed by this survey was approximately 350 m^2.

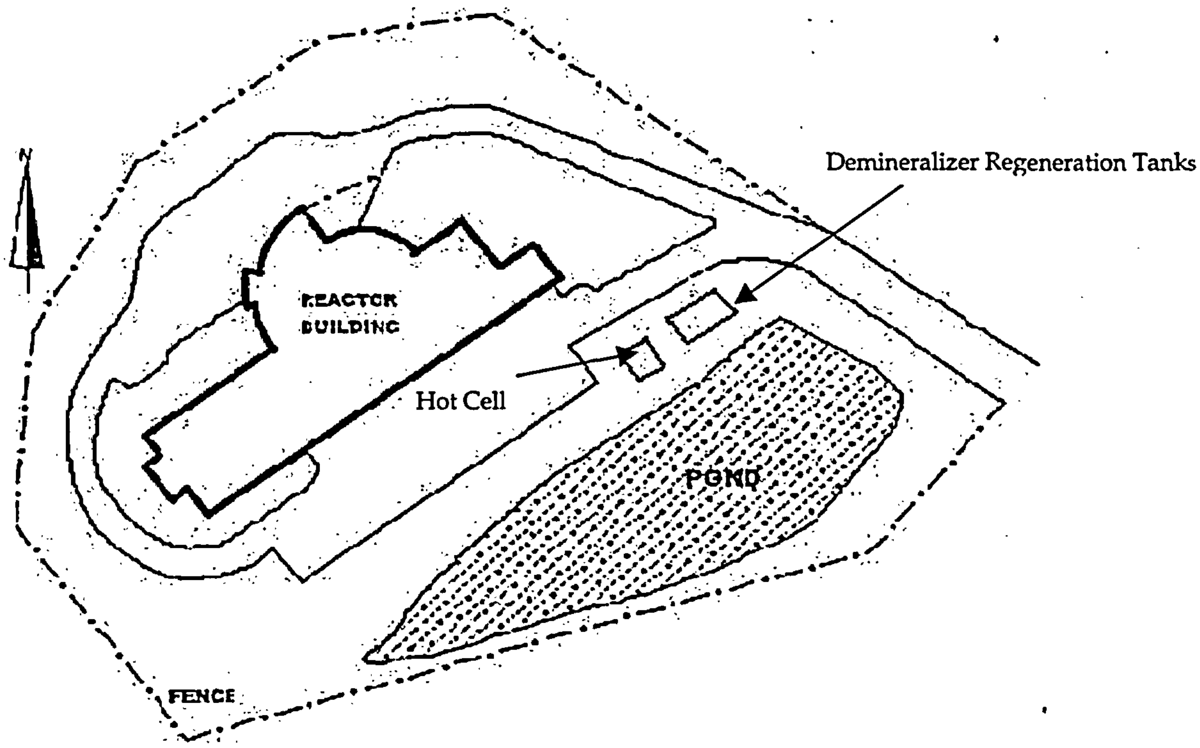
Before excavation of the tanks, a sample of waste tank sludge, composed of resin fines and sediments, was collected from the demineralizer regeneration liquid tanks and found to contain 6,930 pCi/g of Co-60, 8,142 pCi/g of H-3, 1,110 pCi/g of Fe-55, and much smaller or non-detectable concentrations of multiple other radionuclides (refer to Final Status Survey Plan, Addendum 001, in Appendix A). Only four radionuclides, (Co-60, H-3, Mn-54, and Sr-90) were present at levels which would potentially be responsible for greater than 1% of the total dose from the mixture. These results are consistent with expected liquids from a pool-type reactor with minimal fuel leakage and stainless steel and aluminum components. Co-60 at a $DCGL_{surrogate}$ of 3.4 pCi/g was established as the guideline for evaluation of excavation soils for compliance.

During waste tank removal, a small area of contaminated soil was identified at the base of the waste tank blockhouse interior. Samples from this location identified only Co-60 and Cs-137 at detectable concentrations. Additional soil was removed to a depth of approximately 0.5 m from the interior of the blockhouse excavation, where these samples were obtained. Hand augured samples from three other locations did not contain detectable concentrations of facility related gamma-emitting radionuclides. Approximately 40 additional samples of excavated (non-impacted) soil were collected and analyzed by gamma spectrometry. No gamma-emitting radioactive contaminants were identified at detectable levels in these samples.

4.2.2 Survey Activities

A 5-meter grid was established over the excavation area and extended to unexcavated soil surrounding the excavation. This grid was an extension of the reference grid established for the survey of the Pond Sediments, thus enabling the sampling locations to be related to the federal and/or state planar coordinate system. Figure 4-3 illustrates the reference grid system's relationship to the excavation. Based on facility use history and identification of contaminants of license origin in the soils of this area, the survey area is designated Class 1 for FSS planning and implementation purposes. The area of the excavation and surrounding soil is approximately 350 m^2; this is within the MARSSIM-recommended area of 1,000 m^2 for Class 1 open land survey units. Therefore, the area is a single survey unit.

Figure 4-2 UVAR Facility and Environs Indicating Location of Waste Tanks



Gamma walkover surface scans were performed using a 2"X 2" NaI detector (Ludlum Model 4-10) coupled with a Ludlum Model 2221 ratemeter/scaler. The detector was maintained within 5 to 10 cm of the soil surface and moved from side to side in a serpentine pattern while noting any indication of elevated count rate, which might indicate the presence of radioactive contamination. Results (count rate) were documented on survey area maps. Locations of elevated response were noted for further investigation. Scanning coverage was 100% of the soil surface.

Compliance with decommissioning requirements was demonstrated by comparison of results of FSS sample analyses with the Co-60 $DCGL_{surrogate}$. Because radionuclides identified as potential contaminants are not present in background soil at concentrations, which are significant fractions of the release guidelines, correction of FSS sample data for background levels was not required. Statistical testing of results utilized the Sign test to reject or accept the null hypothesis that the residual contamination exceeds the release criteria. Decision errors are 0.05 (Type I and Type II).

The number of data points required for the Sign test was determined to be 17 (refer to Section 4.5 of Addendum 001). A triangular pattern, based on 17 samples and 350 m^2 area, was used to determine sampling locations. The distance between samples was 5.0 m. A random start point of 7.9 m N and 11.2 m W for the pattern was based on survey unit dimensions and random numbers from the MARSSIM random number table. Because only 14 locations fell onto soil surfaces, an additional line of locations at -0.7 m N was added; the resulting number of sampling locations was 19. Figure 4-3 indicates the sampling locations.

Surface (0 to 15 cm) soil samples of at least 500 g were collected at the 19 systematic sampling locations. If a sample could not be obtained from a pre-identified location, one was obtained from the nearest soil location available, and the deviation noted in the survey record. The licensee and the NRC Inspector witnessed the soil sampling and selected samples for confirmatory purposes. Requested samples were homogenized and split. This process was used to accelerate backfilling to maintain slope stability. Samples were assigned unique identification numbers and a chain of custody record and analytical request were prepared.

Samples were screened by on-site gamma spectrometry and then sent to an off-site commercial laboratory for individual gamma analyses. Results of these gamma analyses are the basis for demonstrating compliance with the NRC screening DCGL release criteria.

The radionuclide mixture for potential contamination of this survey unit was based on a single characterization sample, and many of the analyses for hard-to-detect (10 CFR Part 61) radionuclides in this sample resulted in concentrations that contributed a very small fraction of the total potential dose and/or were less than the measurement sensitivities of the analytical procedures. Consistency in the ratios of hard-to-detect radionuclides could therefore not be demonstrated; however, there was not sufficient indication of the presence of these radionuclides to warrant costly analyses of a large number of the final status survey samples for the complete suite of hard-to-detects. It was therefore decided that, if the individual analyses for gamma emitters demonstrated compliance with release criteria, a composite sample, consisting of 20 grams from each of the individual systematic samples, would be prepared and analyzed by the off-site laboratory for hard-to-detect radionuclides, identified in characterization sampling as potential contaminants. Absence of positive or otherwise significant levels of these hard-to-detect radionuclides in the composite provides an increased level of confidence in the approach of using the surrogate gamma-emitter to demonstrate compliance. The analysis of the composite is for supplemental information only, and therefore the number of samples in the composite is not limited, as would be appropriate, if the data were intended for use in demonstrating compliance.

4.2.3 Survey Results

Detailed field survey data forms are included in Appendix B. (survey number UVAR-FS-449). Gamma scans ranged from 11,000 cpm to 31,000 cpm; for comparison, ambient gamma levels in the immediate vicinity of the excavation ranged from approximately 10,000 cpm to 15,000 cpm. Scan levels were higher within the excavation, where detector – source geometry was optimized, and at locations of exposed or near-surface bedrock and areas of rock fill; elevated gamma scan levels were not observed to be associated with possible contamination by materials from the tanks. An additional ("biased") soil sample was collected from the location of highest gamma scan level, near reference grid coordinate 5N, 10W.

FIGURE 4-3
WASTE TANK SURVEY UNIT, INDICATING THE GRID FOR SURVEY AND SAMPLE LOCATIONS

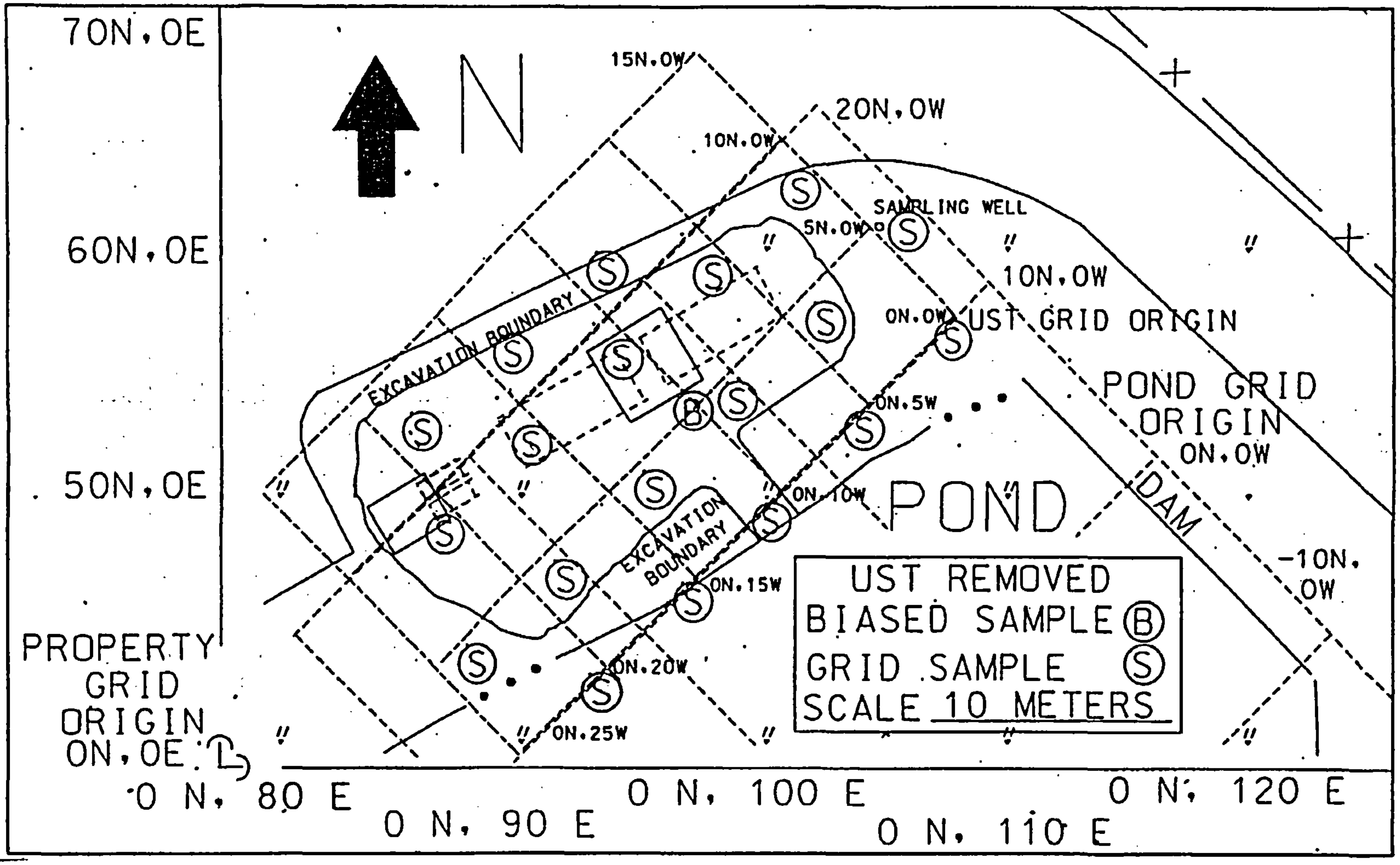


Table 4-2 presents the results of gamma spectrometry analyses for the 19 systematic soil samples and 1 soil sample from the location of highest scan gamma level. None of the samples contained detectable levels of Co-60. Four samples contained Cs-137 activity above the detection sensitivity; the maximum Cs-137 concentration was 0.56 pCi/g. No other gamma emitters of license origin were present at detectable concentrations. All samples contained well below the Co-60 $DCGL_{surrogate}$ of 3.4 pCi/g. The average and standard deviation of Co-60 concentrations for the systematic samples is <0.17 pCi/g and 0.05 pCi/g respectively. Retrospective calculation of the relative shift yields approximately 65, which is much greater than the survey design value, thus indicating adequate data points were obtained.

The sample from the location of highest gross gamma scan results did not contain any detectable gamma-emitting radionuclides of facility origin. Analyses of the composite of 19 systematic samples, performed for supplemental informative purposes, are summarized in Table 4-3. Of the hard-to-detect radionuclides of potential license origin identified during area characterization, only Fe-55 had a detectable level of activity. The concentration of Fe-55 in the composite was 1.99 pCi/g. If all Fe-55 was contained in one of the systematic final status survey samples, the maximum that could be present is 37.8 pCi/g (19 X 1.99 pCi/g), which is below the Fe-55 screening DCGL of 10,000 pCi/g. These results confirm the absence of significant levels of hard-to-detect contaminants and provide confidence in the approach of using the surrogate gamma emitter to demonstrate compliance with decommissioning criteria.

Table 4-2
Results of Soil Sampling from Waste Tank Excavation

Sample Location		Co-60	Cs-137	Other (c)
North	West	(pCi/g)	(pCi/g)	Nuclides
-0.7	1.2	<0.22	<0.17	None Detected
-0.7	6.2	<0.19	0.46	None Detected
-0.7	11.2	<0.12	0.1	None Detected
-0.7	16.2	<0.15	<0.14	None Detected
-0.7	21.2	<0.26	0.56	None Detected
3.6	-1.3	<0.16	<0.14	None Detected
3.6	3.7	<0.17	<0.16	None Detected
3.6	8.7	<0.17	<0.14	None Detected
3.6	13.7	<0.11	<0.10	None Detected
3.6	18.7	<0.21	0.28	None Detected
3.6	23.7	<0.16	<0.31	None Detected
7.9	1.2	<0.14	<0.12	None Detected
7.9	6.2	<0.15	<0.14	None Detected
7.9	11.2	<0.17	<0.14	None Detected
7.9	16.2	<0.22	<0.21	None Detected
7.9	21.2	<0.12	<0.11	None Detected
12.2	8.7	<0.10	<0.23	None Detected
12.2	13.7	<0.21	<0.18	None Detected
12.2	18.7	<0.10	<0.11	None Detected
5	10	<0.17	<0.14	None Detected

Table 4-3
Analyses of Composite of Samples from Waste Tank Excavation

Potential* Radionuclide	Concentration (pCi/g)
Co-60	<0.15
Fe-55	1.99 ± 1.75
H-3	<3.74
I-129	<0.61
Mn-54	<0.12
Ni-63	<2.32
Sr-90	<0.65
Tc-99	<0.16

* From characterization sampling

4.2.4 Conclusion

All individual systematic samples contain well below the Co-60 $DCGL_{surrogate}$ of 3.4 pCi/g, and no significant levels of other contaminants of license origin in this survey area were detected. Statistical testing is not required for data evaluation relative to the established guideline. These results demonstrate that the soils of the Waste Tank Excavation satisfy the established project decommissioning criteria.

4.3 Facility Piping

4.3.1 Description

The bulk of known potentially contaminated piping was removed from the UVAR Facility during remediation activities, but sections of radiologically impacted piping previously associated with the reactor coolant system and various drains from the reactor facility remain. This remaining piping is embedded in concrete or buried beneath concrete or asphalt paving and soil. The piping is generally of small diameter (2 in (5 cm) to 4 in (10 cm) ID); however there are several short sections of larger diameter. All or portions of the following impacted piping remain:

- Heat exchanger lines: Stainless Steel (SS), 6 in ID x 22 ft and 6 in ID x 32 ft.
- Reactor pool drains: SS, 2 in ID x 32 ft and 2 in ID x 36 ft.
- Reactor Room floor drains: Cast Iron (CI), 2 in ID x ~160 ft (multiple sections).

- Ground floor drains to Pond standpipe: CI, 2 in ID x 40 ft and 4 in ID x 140 ft.
- Reactor Demineralizer drain to outside underground collection tanks: CI, 2 in ID x 75 ft.
- Hot Cell drain to outside underground collection tanks: Duriron with PVC repair, 2 in ID x 55 ft.
- Ground floor Bulk Access Facility drains to Pond hillside: CI, 2 in ID x 40 ft and terra cotta, 4 in ID x 80 ft.
- Sanitary sewer from liquid release point to sewer manway: 4 in CI by 40 ft.
- Drain lines from CAVALIER facility to Pond hillside.

Additional, non-radiologically impacted piping includes building and pool footing drains, storm drains, and the portion of the sanitary sewer drains and the portion of the sanitary sewer not on the liquid release path. These lines are located underneath the building floors and underneath the paved parking area between the building and the pond.

Figures 4-4 through 4-6 illustrate the locations of the reactor facility piping.

Visual (boroscope) inspection of the internal surfaces of reactor piping revealed breaks or blockages in the floor drain piping system beneath the Reactor Room floor. This inspection also identified accumulations of scale and loose debris, concentrated on the bottom surfaces of the piping. Visual inspection of the sanitary system piping was performed and the lines appeared clean and free from scale. Visual inspection of the storm drain system was not conducted.

Broken or damaged areas of piping were accessed, and contaminated pieces of pipe and soil were identified and removed. Dashed lines on Figure 4-6 denote piping removed from the reactor room. Hydrolazing of reactor piping internal surfaces was performed to remove scale and loose debris. Piping access points were created to enable the performance of the final status survey.

Preliminary scans, direct measurements, swabs, and water rinses of remaining piping were performed to identify the presence of contamination. Contaminated surfaces were removed or remediated.

Soil removed during excavation of the underground waste tanks, soil from the vicinity of piping breaks, debris collected from piping, and pieces of removed piping were analyzed on site by gamma spectroscopy. These analyses identified Co-60 as the primary potential contaminant in most of the remaining piping. Cs-137 was the major potential contaminant associated with the Hot Cell drain. Because piping did not contain sufficient activity levels to enable meaningful determinations of the contaminant mixture, particularly for the hard-to-detect radionuclides, it was assumed that the mixture in the reactor piping was the same as that reaching the waste tanks (refer to Master Final Status Survey Plan (FSSP) Addenda 001 and 002-Appendix A). This activity mixture is dominated by Co-60 (39%) and H-3 (46%). On a dose basis, Co-60 contributes 87.7% of the dose and Pu-241 contributes 12.2% of the total dose from this mixture.

The Decommissioning Plan established the criteria for residual radioactive material contamination on UVAR facility surfaces. UVAR facility criteria, also referred to as derived concentration guideline levels (DCGLs), are selected from the table of NRC default screening values. The $DCGL_{gross}$ for all radionuclides at the activity fractions present is 15,200 dpm/100 cm^2. Based on only beta emissions from Co-60, Mn-54 and Sr-90 being measurable (i.e., 41.4% of the radionuclides present will be detectable), the approach described in Appendix A of the Master Final Status Survey Plan yields a $DCGL_{gross}$ of 7,390 dpm/100 cm^2 and an $DCGL_{adjusted\ gross}$ of 6,320 dpm/100 cm^2. This latter value (6,320 dpm/100 cm^2) was used as the applicable total gross β criteria for all facility piping. Removable activity criteria are 10% of this value. This criteria represents a conservative approach for Hot Cell piping, in which the contaminant is more likely to be Cs-137 with a less restrictive guideline value.

4.3.2 Survey Activities

Nine facility piping survey units were identified; Table 4-4 is a listing of those survey units. Based on the facility use history and identification of contaminants of license origin in the remaining impacted piping, the reactor facility piping surfaces were designated Class 1. Storm drains, building and pool footing drains, the CAVALIER Facility drains, and the non-release path portion (west line) of the sanitary sewer system were designated Class 2.

Table 4-4
Facility Piping Survey Units

Survey Unit	Description	Class
23	Sanitary Sewer, Storm Drain, French Drain	2
27	Heat Exchanger Piping	1
28	Reactor Pool Drains	1
29	Reactor Room floor Piping	1
30	Room G022 to Track Pit Drain	1
31	Demineralizer Piping	1
32	Hot Cell Drain	1
33	Reactor Header Drain	1
51	CAVALIER Piping	2

Compliance with decommissioning requirements was demonstrated by comparing the results of FSS with $DCGL_{adjusted\ gross}$ of 6,320 dpm/100 cm^2. Because of the variability in instrument background levels due to varying levels of naturally occurring radionuclides in soil, rock and building construction materials and piping materials, appropriate reference areas were not applicable. Instead, shielded and unshielded measurements were performed at the same locations and the difference compared to the contamination criteria. Statistical testing of results utilized the Sign Test to reject or accept the null hypothesis that the residual contamination exceeds the release criteria. Decision errors are 0.05 (Type 1 and Type 2).

Figure 4-4 D4rains from CAVALIER Facility

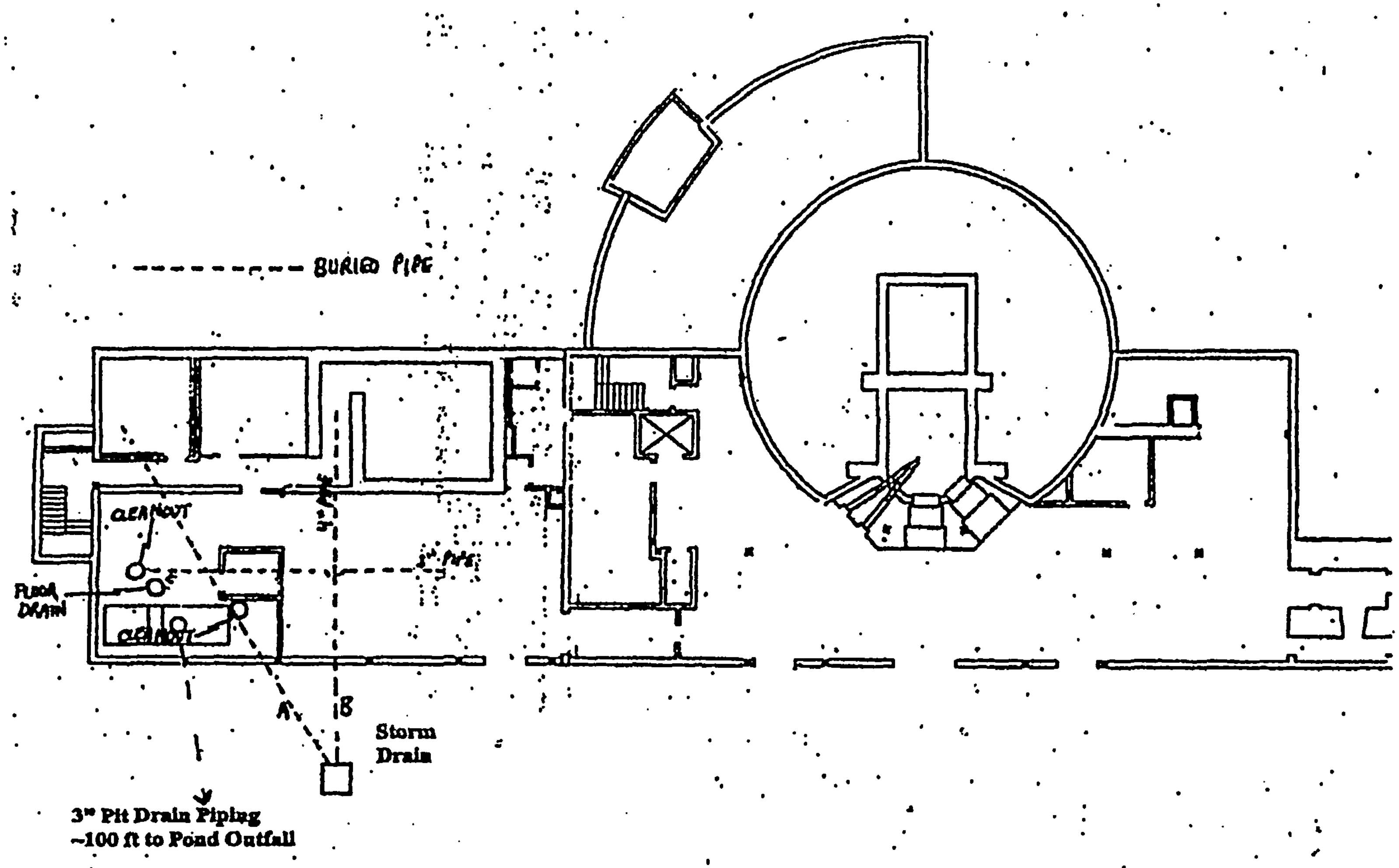


Figure 4-5 Ground Floor and Exterior Piping

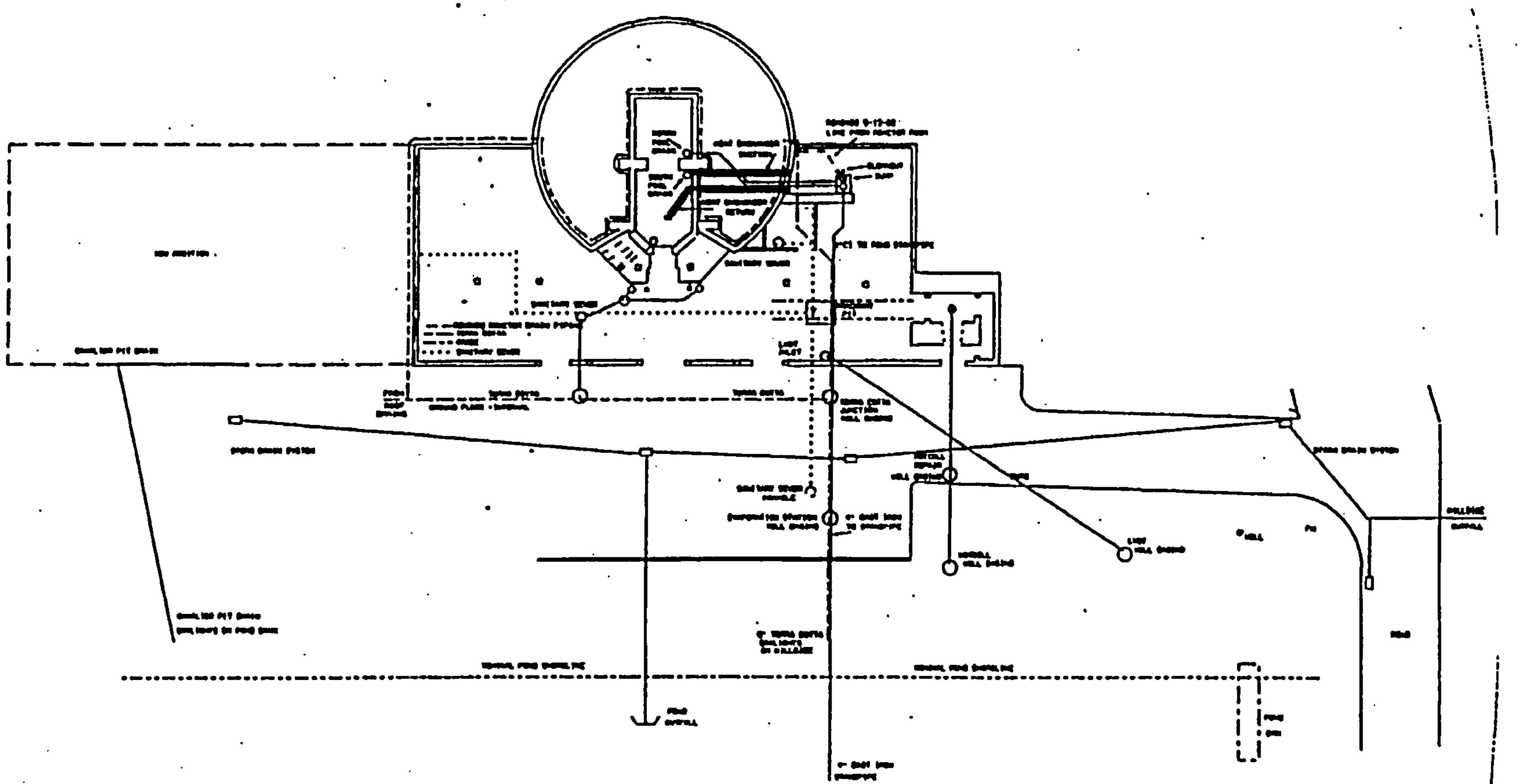
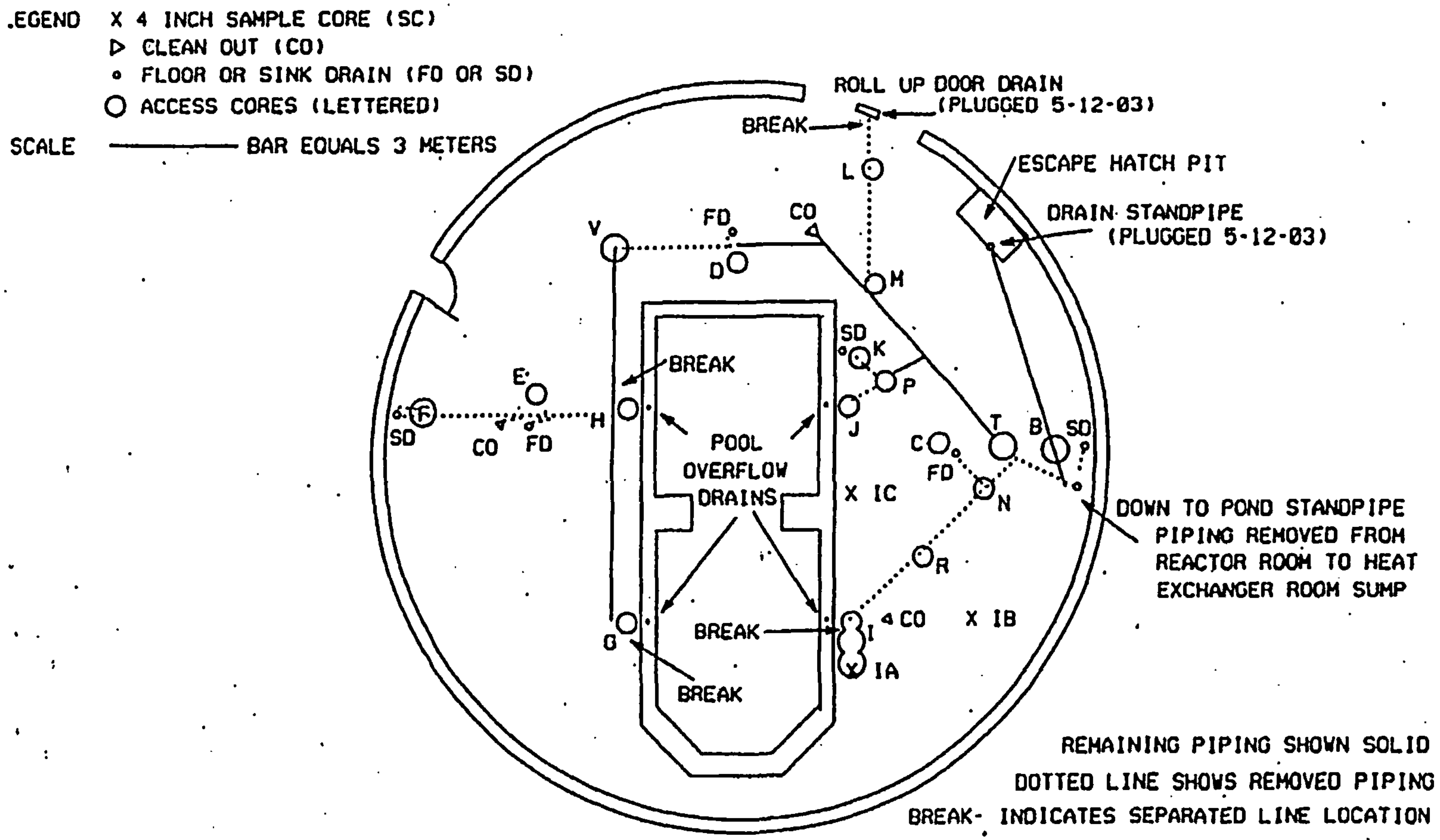


Figure 4-6 Reactor Room Piping



The number of data points required for the Sign Test was determined to be 20 (refer to Section 4.5 of FSSP Addendum 002). Direct measurements were obtained at equally spaced intervals along the piping to assure a minimum of 20 data points. Although the relative shift (Δ/σ) would be higher and the number of data points required would be lower for Cs-137 as the contaminant, for consistency the minimum number of data points (i.e., 20) remained the same for all piping survey units.

Scans and surface activity measurements of interior surfaces of 6 in (or larger) ID piping were performed using Ludlum Model 43-68 gas proportional detectors. Piping which was not accessible with this detector was surveyed using a Victoreen Model 491-30 GM detector. This latter detector has a 30 mg/cm^2 wall thickness and in an unshielded configuration had an effective field of view of slightly more than 100 cm^2 in a 2 in ID pipe. The overall diameter of the 491-30 detector assembly is approximately 2.9 cm, enabling access to most piping surfaces. Detector response to Co-60 in piping was determined by cross calibration, using a section of contaminated piping containing a measured activity level. The detection sensitivity of the 491-30 detector and survey technique was estimated as 2,292 dpm/100 cm^2 for static measurements and 4,643 dpm/100 cm^2 for scans (refer to Appendix A of FSSP Addendum 002). Although these sensitivities did not satisfy the target objective of 25% of the DCGL, both were less than the DCGL, providing a high level of confidence that any significant residual contamination would be identified.

Interior piping surfaces were scanned by passing the detector through the pipe. The rate of detector movement was approximately 1 detector width/sec for the gas proportional and pancake GM detectors and 2.5 to 3.0 cm/sec for the 491-30 GM detector. Model 2221 scaler/ratemeters used with the detectors was monitored for changes in audible signal and indication of elevated count rate, suggesting possible presence of radioactive contamination, was noted for further investigation. Scan coverage was 100% of the length of Class 1 piping and 25% of the length of Class 2 piping. One-minute static beta counts were performed at the designated systematic locations and at locations of elevated count rate identified by scans.

A Masslinn swab was passed through each pipe section to collect removable activity and scanned for activity using a 125 cm^2 gas proportional detector. Detector sensitivity for this technique was 500 dpm/100 cm^2. A static one-minute beta measurement was performed at the location of maximum activity, or at a representative location, if elevated activity was not identified.

Following FSS activities, piping access points were covered to prevent recontamination and to allow for future NRC confirmatory actions.

4.3.3 Survey Results

Table 4-5 presents the results of the beta scans. Scans utilizing a model 43-68 gas proportional detector ranged from 255 cpm to 960 cpm; those utilizing a model 491-30 GM detector ranged from 12 cpm to 110 cpm. Higher ambient levels were observed in piping embedded in concrete and in piping drains of terra cotta construction. No specific locations of elevated activity were identified.

Table 4-5
Beta Scan Results for Facility Piping

Survey Number	Survey Unit	Location	Counts Per Minute		Instrument Set
			Minimum	Maximum	
UVA-FS-74	23	Sewer, Storm & French Drains	17	61	15 (a)
UVA-FS-74	23	Sewer, Storm & French Drains	280	500	9 (b)
UVA-FS-72	27	Heat Exchanger Piping	300	960	9 (b)
UVA-FS-75	28	Reactor Pool Drain	20	74	15 (a)
UVA-FS-31	29	Reactor Room Floor Drains	280	475	10 (b)
UVA-FS-12	30	Room G022 to Track Pit Drain	50	110	14 (a)
UVA-FS-12	30	Room G022 to Track Pit Drain	255	280	9 (b)
UVA-FS-73	31	LWST Drain Lines	28	85	14 (a)
UVA-FS-04	32	Hot Cell drain	54	110	14 (a)
UVA-FS-77	33	Reactor header drain	12	61	15 (a)
UVA-FS-76	51	CAVALIER Drains	13	55	15 (a)
Notes:					
(a) GM Detector					
(b) Gas Proportional Detector					

Total activity measurement results are summarized in Table 4-6. The maximum activity level was 3,152 dpm/100 cm^2 in the Heat Exchanger piping. All systematic measurements were below the $DCGL_{adjusted\ gross}$ of 6,320 dpm/100 cm^2, thus statistical testing is not necessary to demonstrate compliance with the guidelines.

Table 4-6
Facility Piping Beta Activity Measurement Summary

Survey Unit	Instrument Type	Number of Measurements	Beta Activity (dpm/100 cm^2)			
			Minimum	Maximum	Mean	Std Dev
23	491-30	20	-185	446	86	137
	43-68	7	163	1491	724	427
27	43-68	19	208	3152	1681	1049
28	491-30	20	-185	338	55	149
	43-68	2	252	310	281	41
29	491-30	20	-519	1556	604	478
30	491-30	30	-444	2593	37	846
	43-68	7	163	1491	724	427
31	491-30	20	-46	400	132	140
32	491-30	20	-305	712	119	207
	43-68	2	22	208	11	132
33	491-30	25	-123	262	73	27
51	491-30	19	-46	508	83	135
	43-68	3	230	816	452	318

From 19 to 37 data points were obtained for each survey unit as compared to the design number of 20. The maximum standard deviation of direct measurements was 1049 dpm/100 cm² in Survey Unit 30. The relative shift for this standard deviation is approximately 3.4. This is greater than the design basis relative shift of 1.4 for 20 data points; sufficient data points were therefore obtained for each survey unit. (The design number of data points includes an additional 20% for potential data losses and quality control purposes; therefore the actual number of data points are adequate to satisfy the design number of 20).

Masslinn swabs were passed through piping sections to determine if loose surface contamination was present. Beta scans were performed on each masslinn swab to determine the highest activity location on the swab. A static measurement was performed on each masslinn swab in the highest activity swab location to determine relationship to the loose surface activity inside the piping. No removable activity above criteria was identified (refer to Table 4-7).

Table 4-7
Masslinn Swabs of Piping

Unit	Survey Number	Location	Beta Scans Counts per Minute	Static Counts (dpm/100 cm²)	
				Lowest	Highest
23	UVA-FS-74	Sanitary Sewer, Bulk Access, Storm & French Drains	280-500	69	630
27	UVA-FS-72	Heat Exchanger Piping	190-270	140	181
28	UVA-FS-75	Reactor Pool 2" Drain Line	270-420	128	389
29	UVA-FS-31	Reactor Room Floor Piping	280-400	-66	84
30	UVA-FS-12	Room G022 to the Track Pit Drain	255-280	-83	-83
31	UVA-FS-73	LWST Drain Lines	200-280	5	5
32	UVA-FS-04	Hot Cell Drain Line	225-315	11	106
33	UVA-FS-77	Reactor Header Drains	330-430	246	374
51	UVA-FS-76	CAVALIER Drains	250-400	117	416

During characterization and remediation activities, gamma scans and on-site gamma spectrometry of soil at piping access locations identified potential soil contamination as a consequence of piping breaks beneath the reactor room floor and the reactor pool. Sampling to demonstrate adequate remediation of these piping break locations is described in Section 4.8 of this report.

4.3.4 Conclusion

Surveys demonstrate that remaining potentially impacted facility piping does not contain residual contamination in excess of established project guidelines.

4.4 Pond Sediment

4.4.1 Description

Storm runoff from the adjacent land areas and overflow from the storm drain on the UVAR site were collected in a small pond, located to the south of the UVAR Building (see Figure 4-7). The pond covers a surface area of about 1,600 m², and ranges in depth from approximately 2 to 4 m. The pond bottom is covered with sediments, ranging from a few cm to several m thick.

Figure 4-8 is a plot plan of the pond, indicating pertinent features. Some laboratory drains, floor drains, and other sources of non-sanitary wastewater with low potential for radiological or other hazardous constituents also routinely discharged to this pond. Two underground waste tanks serviced the Hot Cell, and two tanks were used for collection of demineralizer regeneration liquids from the reactor. Both of these sets of tanks were originally plumbed to allow the contents to be discharged to the pond, provided the liquid met appropriate release criteria following dilution with the pond water; the demineralizer regeneration tanks were later replumbed so they could be discharged directly into the pond spillway.

During facility operation, there were several intentional and unintentional discharges of low-level contaminated liquids to the pond occurred. Two of these occurred in laboratories M005 and M008, and involved contamination by Tc-99 and Ni-63, respectively. Reactor Pool water discharges to the pond were made in the 1960's. A break in the piping from the demineralizer regeneration tanks resulted in release of low-level contaminated liquids, containing primarily Cs-137 and Co-60, onto the bank of the pond. Because of this history, there was a potential for the sediments to be contaminated with facility-derived radionuclides. Pond sediments analyzed during the 1999 GTS Duratek characterization identified positive levels of Cs-137, Co-60, Eu-152, and Pu-241 in some samples; however, many analyses did not identify activity levels above the method detection limits.

Sampling during the CH2M HILL continuing characterization identified only Cs-137, Ni-63, and Pu-241 as contaminants of license origin (refer to FSSP Addendum 003 in Appendix A). Based on these findings, Cs-137 will be used as a surrogate for all potential contaminants at a DCGL of 5.9 pCi/g.

In September 2002, the pond was drained and additional characterization was performed. This characterization was designed and implemented such that the data could be used for FSS purposes, if appropriate. Detailed field survey data forms are included in Appendix B (survey number UVAR-0245).

4.4.2 Survey Activities

A 10-m reference grid was established over the pond area. This grid is shown in Figure 4-8. Based on use history and previous characterization findings, the pond sediments were classified as Class 1; the area comprises one survey unit of the pond sediments to the high-water mark and the immediately adjacent north bank, where building drains discharged.

Gamma walkover surface scans were performed using a 2" x 2" NaI detector (Ludlum Model 44-10) coupled with a Ludlum Model 2221 ratemeter/scaler. The detector was maintained within 5-10 cm of the sediment surface and moved from side to side in a serpentine pattern while noting any indication of elevated count rate, which might indicate the presence of radioactive contamination. Surface gamma scans were performed over 100% of the pond sediment surface, the north bank, and the pond discharge stream for approximately 20 m downstream of the spillway. Locations of elevated gamma radiation were noted for further investigation.

Surface (0-15 cm) sediment samples of approximately 500 g were collected at 16 systematic and 18 judgmental sampling locations. In soft sediments, sediment columns were obtained by driving PVC pipe to refusal, capping and removing the pipe. In more resistant sediments, boreholes were augured through the sediment s to the underlying soil using a 2-in diameter bucket auger. Some locations required a combination of both methods. The resulting samples were obtained from depths of 15 to 45 cm, 45 to 75 cm, and 75 to 105 cm. where thickness of sediment allowed. If a sample could not be obtained from a pre-identified location, one was obtained from the nearest sediment location available; the survey/sampling record noted this situation. A total of 92 samples were obtained. Duplicate samples were collected at 4 locations. Samples were assigned unique identification numbers and a chain of custody record and analytical request were prepared.

Boreholes were gamma logged at 30 cm intervals from the surface to the bottom of the borehole; where necessary to maintain a borehole open, thin-walled PVC piping was inserted into the borehole as the auger was advanced.

Sample cores were scanned for gamma and beta activity. All samples were analyzed in the on-site laboratory by gamma spectrometry. Based on the results of surface scans, borehole logging, sample core scans, and on-site analyses, samples from 6 locations were sent to an off-site commercial laboratory for gamma spectrometry and analysis for hard-to-detect (10 CFR Part 61) radionuclides. Results of these analyses were used to develop a $DCGL_{surrogate}$ for Cs-137. All FSS samples were analyzed for gamma emitters and results compared with the Cs-137 $DCGL_{surrogate}$ to demonstrate compliance with the decommissioning criteria.

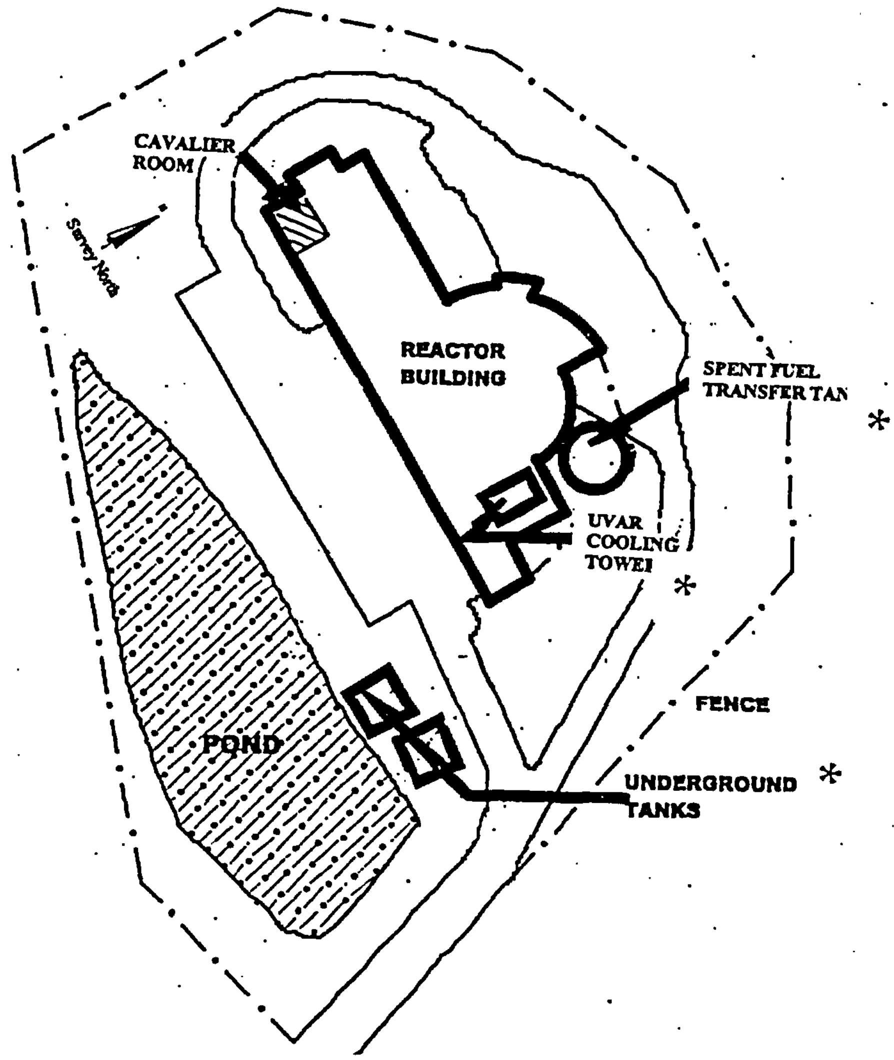
4.4.3 Survey Results

Gamma scans of pond sediments surveyed from 9,000 to 24,000 cpm, the highest levels were near the spillway and locations where facility drains discharged to the pond. Samples from these locations of elevated surface gamma levels were analyzed to establish the contaminant mix for the sediments. No elevated gamma levels were identified in the creek, downstream of the pond discharge.

Analyses of systematic samples, summarized in Table 4-8, identified only Cs-137 as a gamma-emitting radionuclide of potential license origin; the highest concentration was 1.75 pCi/g in the sample near the location where the former underground waste tanks had discharged into the pond. All results were below the Cs-137 surrogate DCGL of 5.9 pCi/g and therefore the sample results demonstrate the established project criteria are satisfied without need for further statistical evaluation. The average Cs-137 level is 0.39 pCi/g with a standard deviation of 0.41 pCi/g. These results yield a retrospective relative shift of 13.1; this is higher than the design relative shift, indicating that adequate systematic data points for evaluation were obtained.

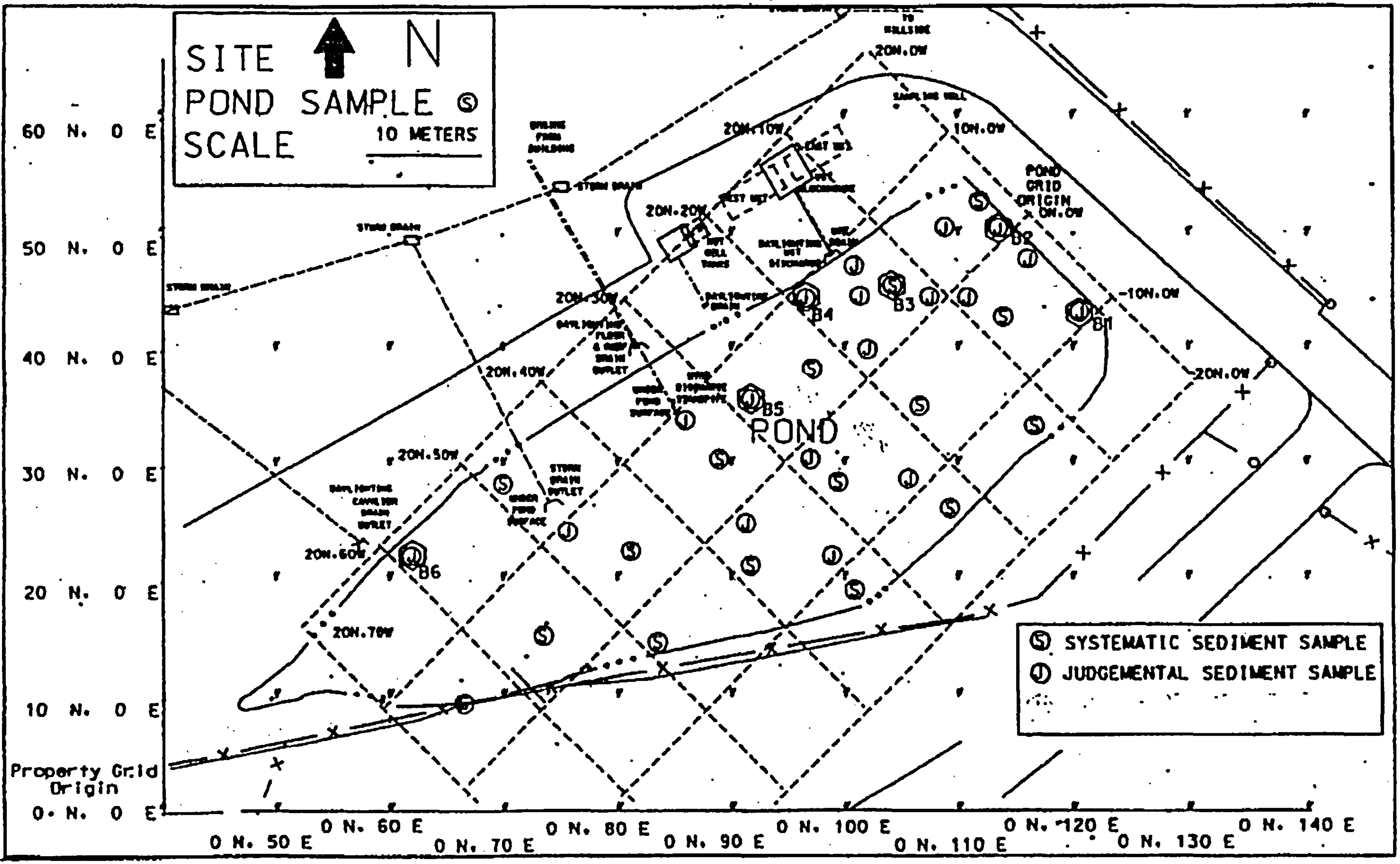
As described in the Final Status Survey Plan for Pond Sediments (Addendum 003), analyses of judgmental samples for the purpose of determining the contaminant mix, clearly identified only Cs-137 (maximum 3.46 pCi/g), Ni-63 (maximum 22.9 pCi/g), and Pu-241 (maximum 15.8 pCi/g). There was not sufficient evidence of significant levels of hard-to-detect radionuclides in characterization samples to warrant costly analyses of the final status survey samples for the complete suite of hard-to-detects.

Figure 4-7
University of Virginia Reactor Facility and Environs



*Removed during decommissioning

Figure 4-8
Plot Plan of Pond, Indicating Reference Grid and Sampling Location.



No individual radionuclide concentration in these samples was above its specific default screening DCGL and none of the samples yield a sum of fractions value greater than 1 (one).

Table 4-8
Results of Gamma Analyses of Systematic Samples

Sample Location		Concentration (pCi/g)		
		Cs-137	Co-60	Other Radionuclides
4.9 S	7.3 W	0.25 ± 0.15	<0.21	None Detected
4.9 S	17.8 W	0.31 ± 0.10	<0.11	None Detected
49. S	28.3 W	0.23 ± 0.16	<0.16	None Detected
4.9 S	38.8 W	<0.15	<0.16	None Detected
4.9 S	49.3 W	<0.17	<0.17	None Detected
13.9 S	12.5 W	0.26 ± 0.09	<0.09	None Detected
13.9 S	23.0 W	0.16 ± 0.09	<0.12	None Detected
13.9 S	33.5 W	0.89 ± 0.21	<0.16	None Detected
4.1 N	2.0 W	0.89 ± 0.22	<0.15	None Detected
4.1 N	12.5 W	1.74 ± 0.36	<0.20	None Detected
4.1 N	23.0 W	0.41 ± 0.11	<0.15	None Detected
4.1 N	33.5 W	<0.15	<0.15	None Detected
4.1 N	45.0 W	0.47 ± 0.17	<0.14	None Detected
4.1 N	55.5 W	<0.22	<0.18	None Detected
4.1 N	66.0 W	0.58 ± 0.20	<0.17	None Detected
13.1 N	49.3 W	0.18 ± 0.19	<0.16	None Detected
Drainage Creek #1		<0.16	<0.14	None Detected
Drainage Creek #2		<0.14	<0.15	None Detected
Drainage Creek #3		<0.09	<0.14	None Detected

4.4.4 Conclusion

Results of direct survey and sampling demonstrate that contaminants of license origin in UVAR pond sediments satisfy the Cs-137 $DCGL_{surrogate}$. Judgmental characterization samples did not contain significant levels of hard-to-detect radionuclides. On the basis of these results the radiological status of the pond sediments satisfies established project decommissioning criteria.

4.5 Interior Structure Surfaces

4.5.1 Description

The three-story UVAR building housed the UVA Research Reactor and the CAVALIER facility, as well as offices for the reactor staff and faculty and students of the Department of Nuclear Engineering, miscellaneous laboratories, and other support facilities for the reactors and Department of Nuclear Engineering.

Figures 4-9 through 4-11 show the three levels of the UVAR facility. The upper level has approximately 620 m^2 of floor area. The Reactor Confinement Room (Rm 131), which housed the former UVA Research Reactor, is located on the upper floor (first floor). This room contained the 9.8 m long by 3.7 m wide by 8.2 m deep reactor pool, associated operating equipment and systems, the operating controls, and some research/experimental equipment. This room is circular and has an elevated (~10 m) ceiling. In addition, the Instrument Shop (Rm 128), Shipping Area (Rm 127), and multiple offices and other support facilities for staff and students are located on this building level.

On the approximately 670 m² Mezzanine level were located the Demineralizer (Rm M021), Mechanical Room (Rm M020), HP Laboratory (Rm M019), several partially contaminated laboratories (Rms M005 [Tc-99 contamination] and M008 [Ni-63 contamination]), and multiple offices and other support facilities for staff and students. A crawl space (MCS) is accessed from the stairwell on the Mezzanine level.

The 740 m² ground floor contained the Heat Exchanger (Rm G024), Rabbit Room (Rm G005), Beam port/Experimental area (Rm G020), Hot Cell (Rms G025, G026, and G027), Counting Room (Rm G004), Woodworking and Machine Shop (Rm G008), Source Storage (Rms G022, G018, and G007A), the former CAVALIER facility (Rm G007), and miscellaneous support facilities and areas.

The UVAR building is of concrete block construction with brick veneer. Floors are concrete slab. Internal walls are block and drywall. Most offices, hallways, and small laboratories have a dropped ceiling of acoustical tile, and tile floors.

In preparation for implementing the Final Status Survey, impacted reactor and support systems and components were removed and disposed of as radioactive waste or surveyed and released for use without radiological restrictions. Contaminated facility surfaces and materials were removed or decontaminated. Major actions of this nature are described below.

Figure 4-9 UVA Reactor First Floor Plan View

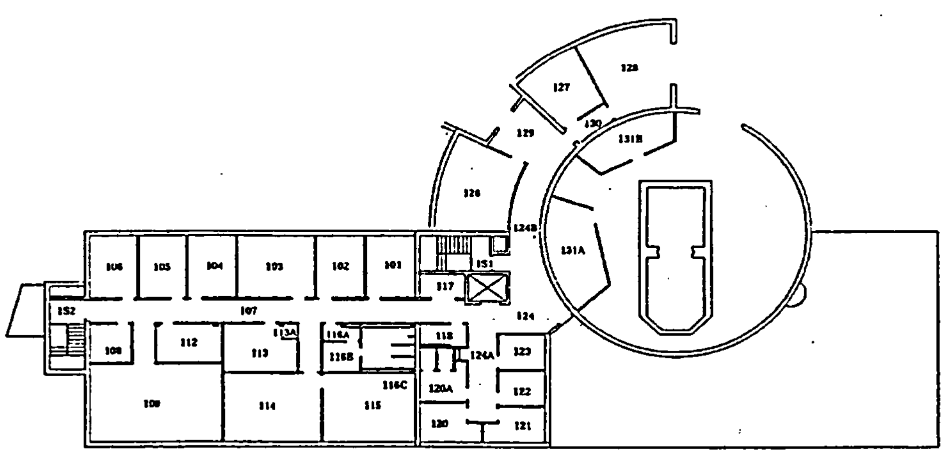


Figure 4-10 UVA Reactor Mezzanine Floor Plan

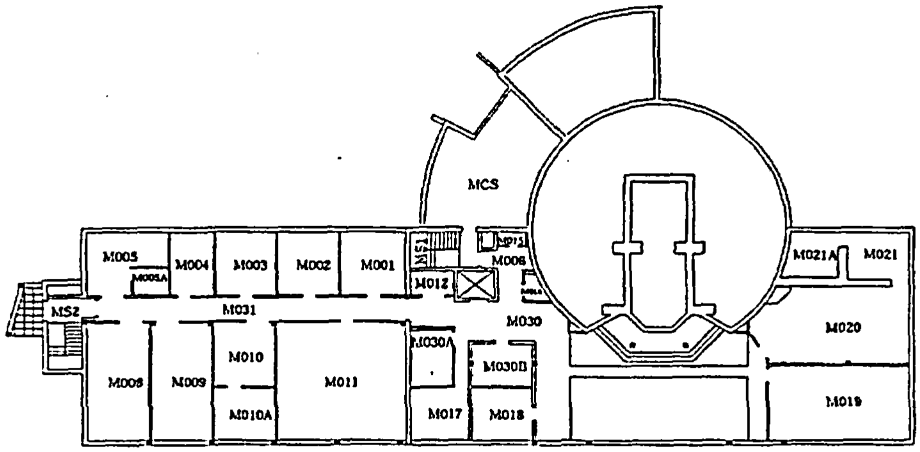
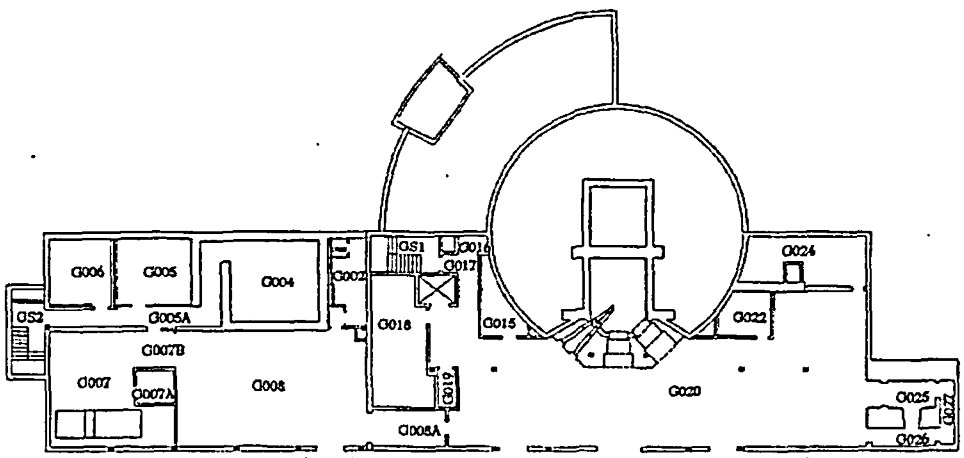


Figure 4-11 UVA Reactor Ground Floor Plan View



The neutron beamport area is located on the ground floor level, lower west side of the reactor pool in the biological shield through to the south west wall, approximately 2 meters off the pool floor. Two beam ports were located in this area. The north beam port (referred to as the hot beamport or No.1 beam port) was radioactively activated by the reactor's neutron beam and has been removed along with the activated concrete surrounding the port. The south beamport (referred to as the cold beam port or No. 2 beamport) was not used as extensively and only the first 18-inches of beam tube was removed from the pool wall with a portion of surrounding concrete. Post-remediation surveys identified residual contamination exceeding the release guidelines and additional concrete removal was performed.

Demineralizer area, rooms M021 and M021A, are located on the mezzanine floor level, northeast corner of the UVAR facility. The room contains painted block and poured concrete walls, painted precast concrete panel ceiling and poured concrete floor. The area contained the reactor pool demineralizer system (resin and charcoal vessels, pumps and associated piping and equipment) and the associated regenerating equipment. All piping, motors, pumps, resin and charcoal vessels and associated materials were removed during D&D operations.

The heat exchanger area, room G024, is located on the ground floor level, northeast corner of the UVAR facility. The room contains painted block and poured concrete walls, painted precast concrete panel ceiling and poured concrete floor. The area contained the reactor pool heat exchanger, primary and secondary side pumps and associated piping and equipment. All piping, motors, pumps, heat exchanger and associated materials were removed during D&D operations. A section of the primary suction and return piping was left in place inside the floor and wall. A valve-gallery sump was located along the middle of the south wall. It contained the valves for the reactor pool drains, heat exchanger primary suction piping drain, and a connection to the reactor room floor drain header for discharge to the pond. The sump is including in this survey; drain piping is addressed separately in Section 4.3.

The hot cell area rooms, G025, G026 and G027, are located on the ground floor level, southeast corner of the UVAR facility. The room contained painted, poured concrete walls, ceiling, and floor. The area contained the hot cell interior, manipulator arms, lead glass window and mechanical hoist. Both manipulator arms and the lead glass window were removed during D&D operations. Cs-137 activity was detected at six discrete locations on the floor and was decontaminated during D&D operations.

Laboratory rooms M008 and M005 are located on the mezzanine floor level, west end of the UVAR facility. The rooms contain painted block and poured concrete walls, a drop panel ceiling and poured concrete floor covered in tile. The areas contain laboratory soap stone counter tops, sinks, and fume hoods with HEPA filtered ventilation to the building exterior. Fume hoods and associated ventilation up to the HEPA filter housings were replaced in both rooms prior to the start of this D&D project. Counter tops were decontaminated and elevated floor tile, cabinet sections, a sink and sink drain, HEPA filters, and parts of the ventilation systems were removed during D&D operations.

The Mezzanine Crawl Space is located on the mezzanine level of the UVAR facility. Access to the area is located in the main stairwell. The room contains concrete block walls, precast concrete panel ceiling with steel support beams and a dirt floor. The dirt floor survey is described in Section 4.8.

The reactor pool structure is approximately four meters wide, ten meters long and nine meters in depth. The pool is separated into two halves by a concrete buttress that housed the reactor pool gate. The pool is oriented slightly off from true North to South. For the purpose of this survey, the pool structure interior surface was referenced in two sections consisting of the north section and its three walls, and the south section and its three walls. Half of each buttress wall was included in its adjoining wall and floor section. There are two beam ports located in the south section, on the west wall, approximately 2 meters off the pool floor. The tangential beam port area (referred to as the hot beam port or #1 beam port) was activated by the reactor's neutron beam and has been removed along with the activated concrete surrounding the port. The second beam port area (referred to as the cold beam port or #2 beam port) was not used as extensively and only the first 18-inches was removed from the poolside with a portion of surrounding concrete. The pool surface paint was removed by means of a hydrolazer. The knee wall surrounding the pool was cut off flush to the reactor room floor. Five, full-width by 12 inches-high, sections were removed from the aluminum gate guide, to provide access that allowed the determination of the condition of the underlying concrete surface. Post-remediation monitoring identified small areas of residual elevated beta activity, requiring further decontamination.

The Source room, G022 is located on the ground floor level, next to the biological shield, on the east side of the UVAR facility. The room contains painted block, ceramic and poured concrete walls, painted precast concrete panel ceiling and poured concrete floor. This room was originally a restroom and contains sanitary sewer piping that was used recently as a discharge point for treated and filtered radioactive liquids. The original rest room was converted to store high-level radioactive materials. All associated materials were removed during D&D operations. Small areas of elevated activity were identified by post-remediation surveys and further decontamination was performed.

The GTS Duratek initial characterization and continuing characterization by the CH2M HILL team showed that radiological contamination was generally low level and was limited to a small portion of the structure interior. Major structural contamination was generally limited to surfaces exposed to or in contact with reactor coolant, reactor neutron fields, and materials containing high levels of activity (e.g., the Hot Cell). Depending on the mechanism of contamination and the medium, radionuclides and their relative ratios varied. The overall predominant radionuclide was Co-60 with smaller activities of Cs-137. Remaining structural components did not contain detectable levels of activation products. Ni-63 and Tc-99 contaminants were present on facility surfaces from research projects in labs M008 and M005, respectively.

The Decommissioning Plan established NRC default screening values as the criteria for residual radioactive material contamination on UVAR facility surfaces. Structure surfaces did not have sufficient activity levels to enable a meaningful determination of the facility contaminant mixture – particularly with respect to hard-to-detect radionuclides. Final Status Survey Plan-Addendum 004 (Appendix A), establishes an beta $DCGL_{adjusted\ gross}$ of 6320 dpm/100 cm^2 as the basis for evaluating the final radiological status of the structure surfaces. An exception to this guideline is labs M005 and M008, where the contaminants are Ni-63 and Tc-99, respectively; DCGLs for these radionuclides are 1.8 E+6 dpm/100 cm^2 for Tc-99 and 1.3 E+6 dpm/100 cm^2 for Ni-63. A DCGL of 1.3 E+06 dpm/100 cm^2 will be applicable for both of these facilities. Guidelines for removable structure contamination are 10% of the value for total surface activity. This assures a conservative approach for satisfying the NRC dose-based criteria for future facility use.

4.5.2 Survey Activities

One meter reference grids were established on Class 1 and Class 2 surfaces and 5 meter grids in Class 3 floor and lower wall surfaces. Upper walls surface (ceiling and overhead) locations were referenced to the grid established for the floor beneath.

A listing of building interior surfaces and their MARSSIM classifications by contamination potential is contained in Table 4-9. Facility history (including the Historic Site Assessment) and radiological monitoring conducted during characterization and remedial activities were the bases for these classifications. Table 4-9 also lists the survey units for building interior surfaces.

Table 4-9 Survey Units for UVAR Building Interior Surfaces

Room or Area	Surface	Class	Surface Area (m^2)	Survey Unit No.
131 Reactor Room, West	Floor	1	92	1
131 Reactor Room, East	Floor	1	92	2
131 Reactor Room	Lower Walls	1	103	3
Reactor Pool, North	Floor and Walls	1	117	4
Reactor Pool, South	Floor and Walls	1	117	5
M005/005A	Floor and Lower Walls	1	65	6
M008	Floor and Lower Walls	1	89	7
M019	Floor and Lower Walls	1	107	8
M020	Floor and Lower Walls	1	104	9
M021/M021A	Floor, Walls, and Ceiling	1	158	10
Bio Shield Surfaces	Wall	1	54	11
G005	Floor, Walls, and Ceiling	1	99	12
G007/G007A	Floor, Pit and Lower Walls	1	167	13
G018	Floor, Walls, and Ceiling	1	92	14
G020, West	Floor and Lower Walls	1	55	15
G020, Center	Floor and Lower Walls	1	67	16
G020, East	Floor and Lower Walls	1	120	17
G022	Floor, Walls, and Ceiling	1	48	18
G024	Floor, Walls, and Ceiling	1	105	19
G025/G026/G027	Floor, Walls, and Ceiling	1	146	20
131 Reactor Room	Upper Walls and Ceiling	2	691	34
127/128/130	Floor, Walls, and Ceiling	2	176	35
107/124/124A/124B	Floor and Lower Walls	2	311	36
M005/005A	Upper Walls and Ceiling	2	50	37
M008	Upper Walls and Ceiling	2	56	38
M019	Upper Walls and Ceiling	2	72	39
M020	Upper Walls and Ceiling	2	76	40
M006/M014/M015/M030/ M031	Floor and Lower Walls	2	259	41
MCS (crawl space)	Floor, Walls, and Ceiling	2	153	42
G004/G005A	Floor and Lower Walls	2	154	43
G006	Floor and Lower Walls	2	64	44
G007B/G008/G008A/G016 /G017/G019	Floor and Lower Walls	2	362	45 & 45A
Stairwell 1	Floor and Lower Walls	2	119	46
Stairwell 2	Floor and Lower Walls	2	184	47
G007/G007A	Upper Walls and Ceiling	3	104	54
G020	Upper Walls and Ceiling	3	437	55
107/124/124A/124B	Upper Walls and Ceiling	3	220	56
M006/M014/M015/M030/ M031	Upper Walls and Ceiling	3	192	57

Room or Area	Surface	Class	Surface Area (m^2)	Survey Unit No.
G004/G005A	Upper Walls and Ceiling	3	107	58
G006	Upper Walls and Ceiling	3	31	59
G007B/G008/G008A /G016/G017/G019	Upper Walls and Ceiling	3	280	60
G002	All	3	71	63
Elevator	All	3	21	64
Mezzanine Offices	All	3	1190	65
First Floor Offices	All	3	1934	66 & 66A

Due to the variability in background levels resulting from construction materials and radioactive sources stored within the facility, it was not practical to establish meaningful reference areas. Instead, unshielded and shielded measurements were performed at each surface activity data point, and the Sign test was used for evaluating direct measurements, relative to the established criteria. The Null Hypothesis is that the activity levels in the survey unit exceed the criteria. Rejection of the Null Hypothesis is required to demonstrate that the release criteria are satisfied. Decision errors are 0.05 (Type 1 and Type 2).

The number of systematic data points required for the Sign test evaluation was determined to be 14 (refer to Section 4.6 of FSSP Addendum 004). For Class 1 and 2 survey units the data point pattern was triangular with a spacing determined on a case- by- case basis, depending on the survey unit surface area. Data points in Class 3 survey units were selected by the survey supervisor, based on judgment as to the contamination potential.

Gamma surface scans were performed using a 2"X2" NaI detector (Ludlum Model 44-10) coupled with a Ludlum Model 2221 ratemeter/scaler. The detector was maintained within 5 to 10 cm of the surface and moved from side to side in a serpentine pattern while noting any indication of audible elevated count rate. Results (count rate) were documented on survey area maps. Locations of elevated response were noted for further investigation. Gamma scanning coverage was minimum 100 % for Class 1, 25% for Class 2 and 10% for Class 3 surfaces.

Beta scans of surfaces were performed using a Ludlum Model 43-68 gas proportional detector coupled with a Ludlum Model 2221 ratemeter/scaler. The detector was maintained within 1 cm of the surface while advancing the detector at a rate of approximately on detector width per second. Scan speed was adjusted, as necessary to assure detection sensitivities were less than 50% of the release criteria. Audible response was monitored for indication of an elevated count rate. Results (count rate) were documented on survey area maps. Locations of elevated response were noted for further investigation. Beta scanning coverage was 100% for Class 1 surfaces and a minimum of 25% for Class 2 and 10% for Class 3 surfaces.

Surface beta activity measurements were performed at the systematic and judgmental locations. One-minute static measurements were conducted using a Ludlum Model 43-68 gas proportional detector coupled with a Ludlum Model 2221 ratemeter/scaler. Smears for removable activity were performed at locations of direct activity measurements.

4.5.3 Survey Results

Field data forms, containing detailed results of surveys, are included in Appendix B. Identification numbers for surveys of interior structure surfaces are listed in Table 4-10.

Table 4-10 Survey Results Forms for UVAR Building Interior Surfaces

Survey Unit	Room or Area	Surface	Survey Form Number
1	131 Reactor room, West	Floor	UVA-FS-20
2	131 Reactor Room, East	Floor	UVA-FS-19
3	131 Reactor Room	Lower Walls	UVA-FS-17
4	Reactor Pool North	Floor and Walls	UVA-FS-14
5	Reactor Pool South	Floor and Walls	UVA-FS-15
6	M005 / M005A	Floor and Lower Walls	UVA-FS-22
7	M008	Floor and Lower Walls	UVA-FS-16
8	M019	Floor and Lower Walls	UVA-FS-24
9	M020	Floor and Lower Walls	UVA-FS-27
10	M021/M021A	Floor, Walls and Ceiling	UVA-FS-21
11	Bio Shield Surfaces	Wall	UVA-FS-66
12	G005	Floor, Walls and Ceiling	UVA-FS-32
13	G007 /G007A	Floor, Pit and Lower Walls	UVA-FS-37
14	G018	Floor, Walls and Ceiling	UVA-FS-13
15	G020 West	Floor and Lower Walls	UVA-FS-47
16	G020 Center	Floor and Lower Walls	UVA-FS-48
17	G020 East	Floor and Lower Walls	UVA-FS-65
18	G022	Floor, Walls and Ceiling	UVA-FS-10
19	G024	Floor, Walls and Ceiling	UVA-FS-23
20	G026	Floor, Walls and Ceiling	UVA-FS-01
34	131 Reactor Room	Upper Walls and Ceiling	UVA-FS-55
35	127/128/130	Floor, Walls and Ceiling	UVA-FS-54
36	107/124/124A/124B	Floor and Lower Walls	UVA-FS-51
37	M005 /M005A	Upper Walls and Ceiling	UVA-FS-25
38	M008	Upper Walls and Ceiling	UVA-FS-18
39	M019	Upper Walls and Ceiling	UVA-FS-26
40	M020	Upper Walls and Ceiling	UVA-FS-28
41	M006/M014/M015/M030/M031	Floor, Walls and Ceiling	UVA-FS-29
42	MCS (crawl space)	Floor and Lower Walls	UVA-FS-11
43	G004 / G005A	Floor and Lower Walls	UVA-FS-34
44	G006	Floor and Lower Walls	UVA-FS-35
45	G007B/G008/G008A/G016/G017 / G019	Floor and Lower Walls	UVA-FS-41
45A	G007B/G008/G008A/G016/G017 / G019	Floor and Lower Walls	UVA-FS-43
46	Stairwell 1	Floor and Lower Walls	UVA-FS-63
47	Stairwell 2	Floor and Lower Walls	UVA-FS-62
54	G007 / G007A	Upper Walls and Ceiling	UVA-FS-40

Survey Unit	Room or Area	Surface	Survey Form Number
55	G020	Upper Walls and Ceiling	UVA-FS-67
56	107/124/124A/124B	Upper Walls and Ceiling	UVA-FS-41
57	M006/M014/M015/M030/M031	Upper Walls and Ceiling	UVA-FS-30
58	G004/G005A	Upper Walls and Ceiling	UVA-FS-50
59	G006	Upper Walls and Ceiling	UVA-FS-38
60	G007B/G008/G008A/G016/G017 /G019	Upper Walls and Ceiling	UVA-FS-46
63	G002	All	UVA-FS-60
64	Elevator	All	UVA-FS-61
65	Mezzanine Offices	All	UVA-FS-33
66	First Floor Offices	All	UVA-FS-42
66A	First Floor Offices	All	UVA-FS-53

Results of gamma scans are summarized in Table 4-11. Elevated levels were noted in survey units 13, 20, 42, 43, 59, 58 and 60. Those in survey unit 13, 43, 54, 58 and 60 are associated with concrete walls on one or more sides of these areas; the concrete appears to be a different mix than other concrete in the building and has a uniform gamma level of about 20,000 cpm; about twice ambient background levels. The elevated level (up to 32,000 cpm) in survey unit 20 is due to a sealed Co-60 source, stored in the Hot Cell area, and the generally elevated level (up to 31,000 cpm) in survey unit 42 (the mezzanine crawl space) is associated with the exposed soil floor in this area. No specific locations of elevated gamma levels, indicating potential residual surface contamination, were noted.

Floor monitor scan results are summarized in Table 4-12. Generally elevated levels were noted in survey unit 17 (G020 East) as a result of a sealed source stored in the Hot Cell, which is immediately adjacent to this survey unit. No specific locations of elevated levels, indicating potential surface contamination were noted by the floor monitor scans.

Beta scan results with the hand-held 43-68 detectors are summarized in Table 4-13. Elevated scan levels were identified in survey units 4, 11, 13, 17, 38, 42, 43, 44, 54, 58, 60 and 63. Investigations of these scans identified stored sealed sources, air conditioner filters, supply ventilation grill work and construction material (concrete block and soil) with naturally occurring radioactive material content as the source of the elevated beta responses.

The highest beta result of 1916 cpm was in Room M008. This room had potential Ni-63 contamination with a DCGL of 1.8E6 dpm/100 cm^2. None of the maximum levels indicated by these scans were above the $DCGL_{adjusted\ gross}$ of 6,320 dpm/100 cm^2.

Table 4-11 Results of Gamma Scans of UVAR Building Interior Surfaces

Unit Number	Room or Area	Surface	Gamma Scans (cpm) Minimum	Maximum
1	Reactor Room West	Floor	14000	15800
2	Reactor Pool East	Floor	12000	14600
3	Reactor Room	Floor	10800	16400
4	Reactor Pool North	Floor and Walls	8500	12500
5	Reactor Pool South	Floor and Walls	9500	15000
6	M005 & M005A	Floor and Lower Walls	8100	13200
7	M008	Floor and Lower Walls	8500	15400
8	M019	Floor and Lower Walls	9200	15900
9	M020	Floor and Lower Walls	8000	14200
10	M021 & M021A	Floor, Walls and Ceiling	10200	13000
11	Bioshield Surfaces	Wall	5900	12600
12	G005	Floor, Walls and Ceiling	10000	13400
13	G007 & G007A	Floor, Pit and Lower Walls	10200	21900
14	G018	Floor, Walls and Ceiling	10500	16100
16	G020, Center	Floor and Lower Walls	9500	14300
17	G020, East	Floor and Lower Walls	14500	17500
18	G022	Floor, Walls and Ceiling	14500	17500
19	G024	Floor, Walls and Ceiling	1100	15500
20	G026	Floor, Walls and Ceiling	8400	27000
34	131 Reactor Room	Upper Walls and Ceiling	9400	15500
35	127/128/130	Floor, Walls and Ceiling	11300	16700
36	107/124/124A/124B	Floor and Lower Walls	8000	15600
37	M005 / M005A	Upper Walls and Ceiling	7400	14900
38	M008	Upper Walls and Ceiling	10100	13900
39	M019	Upper Walls and Ceiling	10100	14600
40	M020	Upper Walls and Ceiling	9100	16000
41	M006/M014/M015/M030/M031	Floor and Lower Walls	9000	14900
42	MCS (crawl Space)	Floor, Walls and Ceiling	18000	31000
43	G004 /G005A	Floor and Lower Walls	7900	20400
44	G006	Floor and Lower Walls	9000	14100
45&45A	G007B/G008/G008A/G016 G017/G019	Floor and Lower Walls	11900	16200
46	Stairwell 1	Floor and Lower Walls	11000	16900
47	Stairwell 2	Floor and Lower Walls	11200	15800
54	G007 / G007A	Upper Walls and Ceiling	10200	22200
55	G020 East	Upper Walls and Ceiling	10200	15000
56	107/124/124A/124B	Upper Walls and Ceiling	8000	15600
57	M006/M014/M015/M030/M031	Upper Walls and Ceiling	9500	15100
59	G006	Upper Walls and Ceiling	9900	13100
60	G007B/G008/G008A/G016/G017/G019	Upper Walls and Ceiling	10000	20400
63	G002 Walls	All	9700	11800
64	Elevator	All	10100	16200
65	Mezzanine Offices	All	9200	14700
66&66A	First Floor Office	All	5800	13000

Table 4-12 Results of Floor Monitor Beta Scans of UVAR Building Interior Surfaces

Unit Number	Room or Area	Surface	Scan results (cpm)	
			Minimum	Maximum
1	131 Reactor Room West	Floor	1250	1700
2	131 Reactor Room East	Floor	1100	1505
4	Reactor Pool North	Floor	930	1230
8	M019	Floor	1215	1550
9	M020	Floor	1150	1570
10	M021/M021A	Floor	1100	1520
13	G007/G007A	Floor	419	1095
14	G018	Floor	950	1225
15	G020 West	Floor	990	1310
16	G020 Center	Floor	940	1540
17	G020 East	Floor	960	2820
19	G024	Floor	1150	1500
20	G025/G026/G027	Floor	680	1100
35	127/128 / 130	Floor	748	1260
36	107/124/124A/124B	Floor	645	1058
41	M006/M014/M015/ M030/M031	Floor	775	1567
43	G004 / G005A	Floor	800	1200
45	G007B/G008/G008A/G0016/G017/G019	Floor	845	1380

Table 4-13 Results of 43-68 Detector Beta Scans of UVAR Building Interior Surfaces

Survey Unit	Room or Area	Scan Results (cpm)	
		Minimum	Maximum
3	131 Reactor Room	250	490
4	Reactor Pool North	260	1000
5	Reactor Pool South	270	600
6	M005/M005A	232	549
7	M008	286	590
8	M019	250	630
9	M020	200	581
10	M021/M021A	250	650
11	Bio Shield Surfaces	180	800
12	G005	95	614
13	G007/G007A	248	1221
14	G018	200	570
15	G020, West	223	367
16	G020, Center	248	619
17	G020, East	140	900
18	G022	210	680
19	G024	280	620
20	G025/G026/G027	200	525
34	131 Reactor Room	200	550
35	127/128/130	282	609
36	107/124/124A/124B	220	567
37	M005/M005A	322	601

Survey Unit	Room or Area	Scan Results (cpm)	
		Minimum	Maximum
38	M008	325	1916
39	M019	250	620
40	M020	250	613
41	M006/M014/M015/M030/M031	239	538
42	MCS (crawl space)	470	1070
43	G004/G005A	300	860
44	G006	315	860
45&45A	G007B/G008/G008A/G016/G017/G019	246	605
46	Stairwell 1	190	450
47	Stairwell 2	180	530
54	G007/G007A	255	838
55	G020	180	500
56	107/124/124A/124B	220	608
57	M006/M014/M015/M030/M031	247	629
58	G004/G005A	296	1022
59	G006	320	598
60	G007B/G008/G008A/G016/G017/G019	284	1016
63	G002	200	800
64	Elevator	190	450
65	Mezzanine Offices	95	290
66&66A	First Floor Offices	117	470

Table 4-14 contains a summary of the beta activity measurements in each of the building interior survey units. Activity in Room M008 (survey units 7 and 38) ranged up to 34,982 dpm/100 cm^2. Ni-63 is the contaminant in that facility and the maximum level measured is less than the DCGL established for Rooms M005 and M008 of 1.3 E+6 dpm/100 cm^2. Survey unit 20 (Hot Cell) also contained systematic measurements above the adjusted gross DCGL of 6,320 dpm/100 cm^2. The maximum level was 8,804 dpm/100 cm^2. Operating history and characterization sampling have identified the contaminant in the Hot Cell as Cs-137 with a DCGL of 28,000 dpm/100 cm^2. All Hot Cell surface measurements are within that guideline. All other surface activity beta measurements were within the adjusted gross DCGL of 6,320 dpm/100 cm^2.

With few exceptions, removable beta contamination was less than the detection sensitivity of 28 dpm/100 cm^2. Those exceptions were survey units 17 (maximum of 29 dpm/100 cm^2), 34 (maximum of 36 dpm/100 cm^2), 40 (maximum of 29 dpm/100 cm^2), 54 (maximum of 29 dpm/100 cm^2), 55 (maximum of 139 dpm/100 cm^2) and 63 (maximum of 39 dpm/100 cm^2). All levels were below the removable criteria of 10% of the activity DCGL's.

Table 4-14 Summary of Beta Activity Measurements for UVAR Building Interior Surfaces

Survey Unit	Room or Area	# of Meas.	Beta Activity (dpm/100 cm^2)			
			Minimum	Maximum	Mean	Std Dev.
1	131 Reactor room, West	21	510	1522	987	298
2	131 Reactor Room, East	21	15	1413	638	349
3	131 Reactor Room	21	-167	772	22	232

Survey Unit	Room or Area	# of Meas.	Beta Activity (dpm/ 100 cm²)			
			Minimum	Maximum	Mean	Std Dev.
4	Reactor Pool North	15	-146	1187	774	320
5	Reactor Pool South	15	-116	1704	854	438
6	M005/M005A	24	-549	2198	651	830
7	M008	24	-244	25495	4524	8402
8	M019	19	-73	1529	700	505
9	M020	16	-116	1442	565	509
10	M021/M021A	16	313	1296	661	217
11	Bio Shield Surfaces	21	-277	1471	531	467
12	G005	16	-204	1689	497	585
13	G007/G007A	26	-400	2643	705	789
14	G018	21	-146	1056	436	351
15	G020,West	16	-29	1165	477	355
16	G020, Center	18	138	2876	1004	627
17	G020, East	18	-102	1405	698	365
18	G022	17	-109	2796	1060	905
19	G024	19	182	1879	782	417
20	G025/G026/G027	23	-245	8804	1051	1751
34	131 Reactor Room	144	-218	1667	362	321
35	127/128/130	28	-175	1558	796	527
36	107/124/124A/124B	44	-648	881	100	242
37	M005/M005A	18	12	3455	1576	494
38	M008	18	-342	34982	3673	7629
39	M019	17	-116	1930	746	136
40	M020	17	-44	1500	706	513
41	M006/M014/M015/M030/M031	29	-459	1172	220	454
42	MCS (crawl space)	16	735	3262	1654	689
43	G004/G005A	16	-204	1689	497	585
44	G006	20	175	1646	926	506
45	G007B/G008/G008A/G016/G017/G019	26	-58	2548	657	496
45A	G007B/G008/G008A/G016/G017/G019	20	-248	1602	642	503
46	Stairwell 1	20	-111	1231	0	362
47	Stairwell 2	19	-82	1875	536	243
54	G007/G007A	15	277	2629	1471	720
55	G020	17	-334	1179	588	387
56	107/124/124A/124B	44	-648	882	100	247
57	M006/M014/M015/M030/M031	19	-189	1835	677	587
58	G004/G005A	17	313	3386	1250	903
59	G006	15	160	1580	818	492
60	G007B/G008/G008A/G016/G017/G019	38	182	3551	886	604
63	G002	15	-74	4020	1438	1090
64	Elevator	25	-237	1713	770	625
65	Mezzanine Offices	25	-128	393	87	131
66	First Floor Offices	34	-274	1105	110	269
66A	First Floor Offices	15	-245	438	68	145

Because all surface activity measurements were below the applicable guideline levels for the contaminants present, the established project criteria is satisfied; statistical testing to demonstrate compliance is not necessary.

The minimum relative shift, based on the actual survey data is 4.48 (survey unit 63); this is greater than the design basis relative shift of 3 and the number of data points obtained for each survey unit is therefore adequate for demonstrating compliance.

4.5.4 Conclusion

Surveys demonstrate that residual contamination of license origin on interior building surfaces satisfies established project decommissioning criteria.

4.6 Exterior Soils and Paved Areas

4.6.1 Description

The UVAR Facility includes UVAR building, a small pond, and asphalt paved road, parking areas, and equipment/materials storage pads, situated on a land area of approximately 9390 m^2 (see Figure 4-12). The site terrain generally slopes from north to south. The east and south portions of the site are wooded; the northern portion of the site surface is dominated by rock outcroppings. A low (~1 m high) fence encompasses the site.

During facility operation, several small spills of contaminated liquids occurred in the vicinity of the waste collection systems. Equipment, materials, and wastes with a potential for low-level contamination were stored on surfaces south of the building during facility operations and in connection with the facility remediation. In addition, several liquid discharge points from the building to the pond terminate on the hillside north of the pond.

Waste tanks have been excavated and the pond has been drained; final surveys of soils and sediments in those areas were performed and are described in Sections 4.2 and 4.4. Potentially contaminated wastes have also been removed from storage pads outside the building.

Initial characterization by GTS Duratek and follow-on monitoring during the decommissioning actions has identified Co-60 and Cs-137 as the dominant contaminants from facility operations. Significant levels of other site-related radionuclides were not identified by this monitoring; adequate activity levels were not available to enable meaningful determination of a radionuclide mixture for the balance of exterior rocks and paved areas.

Decommissioning project criteria are the NRC default screening guidelines. The default screening guideline levels for soil for Cs-137 and Co-60 are 11 pCi/g and 3.8 pCi/g, respectively. Default screening surface activity guidelines are 28,000 dpm/100 cm^2 for Cs-137 and 7,100 dpm/100 cm^2 for Co-60.

To demonstrate compliance with project criteria, final status soil samples were analyzed for specific gamma emitting contaminants of license origin and contaminant concentrations compared with respective screening default guideline levels; sum-of-ratios must satisfy the Unity Rule. The restrictive beta $DCGL_{adjusted\ gross}$ of 6,320 dpm/100 cm^2, used for other facility surfaces (refer to FSSP Addendum 002 in Appendix A), was the guideline for comparison with direct measurements on paved surfaces.

4.6.2 Survey Activities

A 10-meter grid was established over the entire site and referenced to the federal planar coordinate system. Figure 4-13 indicates the reference grid system. Further grid identification (e.g., northing and easting from a southwest origin point) was assigned to each node to facilitate location of sampling/measurement points.

For survey design purposes the planning area of the total site (excluding the pond and building footprint) is 6860 m^2. The site is thus comprised of two survey units; one is the paved surfaces of approximately 2500 m^2, and the other is the soil surfaces of approximately 4360 m^2.

Based on the facility use history and characterization and remediation control monitoring, the exterior soil and paved surfaces sediments were designated Class 3 for FSS planning and implementation purposes.

Two survey units were identified; they are:

Survey Unit	Description	Area (m^2)
50	Paved Surface	2500
52	Soil Area	4360

Gamma walkover surface scans were performed using a 2"x2" NaI detector (Ludlum Model 4-10) coupled within 5-10 cm of the surface and moved from side to side in a serpentine pattern while noting any indication of audible elevated count rate, which might indicate the presence of radioactive contamination. Results (count rate) were documented on survey area maps. Locations of elevated response were noted for further investigation. Gamma scanning coverage was a minimum of 50% of the soil and paved surfaces.

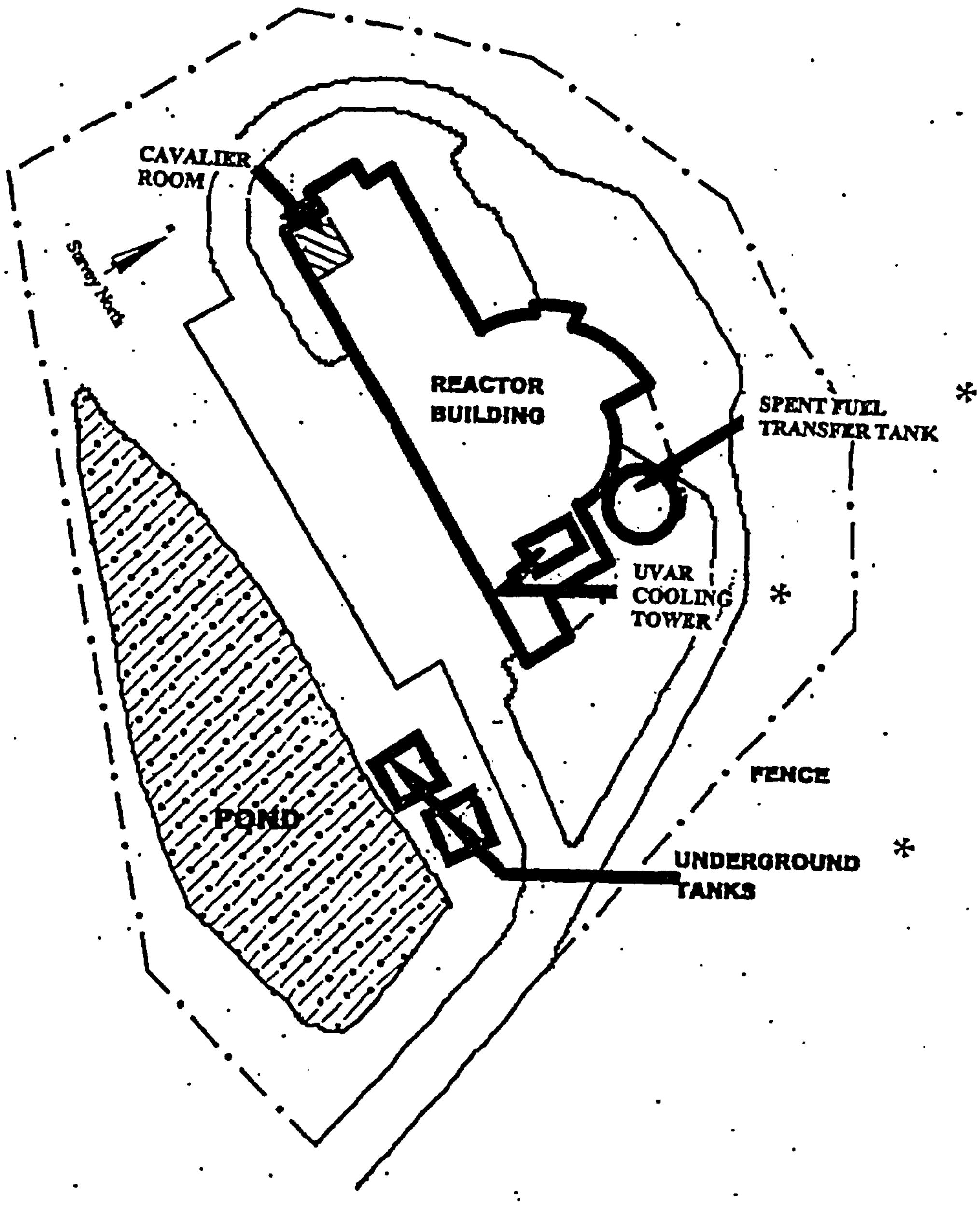
Beta scans of paved surfaces were performed using a large area (~580 cm^2) gas proportional detector (Ludlum Model 43-37) coupled with a Ludlum Model 2221 ratemeter/scaler and advancing the detector at a rate of approximately one detector width per second. Audible response was monitored for indication of elevate count rate. Results (count rate) were documented on survey maps. Locations of elevated response were noted for further investigation. Beta scanning coverage was a minimum of 50% of the paved surfaces.

The scans identified an area of elevated activity on the asphalt pad outside the Reactor Containment Room. Further investigation indicated an impacted area about 4m x 4m in size. Remediation was performed and the pad was designated survey unit 62A, reclassified as Class I, and rescanned at 100% coverage.

The number of data points required for the Sign Test was determined to be 15 for soil areas and 14 for paved surfaces (refer to FSSP Addendum 005 in Appendix A). Systematic soil sampling and direct measurement locations are indicated on Figure 4-13. Surface (0 to 15 cm) soil samples of approximately 500 g were collected at the systematic sampling locations for the soil area (17 samples were obtained). Soil samples were analyzed by an off-site commercial laboratory for gamma emitters. Results of these gamma analyses are the basis for demonstrating compliance with the NRC screening DCGL release criteria.

Because these were no areas of significant soil contamination noted during characterization of this survey unit, the radionuclide mixture for potential contamination was based on a limited number of characterization samples from other survey areas. Many of the analyses for hard-to-detect (10 CFR Part 61) radionuclides in these samples resulted in concentrations that contributed a very small fraction of the total potential dose and/or were less than the measurement sensitivities of the analytical procedures. Consistency in the ratios of hard-to-detect radionuclides could therefore not be demonstrated; however, there was not sufficient indication of the presence of these radionuclides to warrant costly analyses of a large number of the final status survey samples for the complete suite of hard-to-detects. It was therefore decided that, if the individual analyses for gamma emitters demonstrated compliance with release criteria, a composite sample, consisting of 20 grams from each of the individual systematic samples, would be prepared and analyzed by the off-site laboratory for hard-to-detect radionuclides for supplemental information only. Absence of positive or otherwise significant levels of non-gamma emitting radionuclides in the composite provides an increased level of confidence in the approach of using the surrogate gamma-emitter to demonstrate compliance. The number of samples in the composite is not limited, as would be appropriate, if the data were intended for use in demonstrating compliance.

Figure 4-12 University of Virginia Reactor Facility and Environs



*Removed during decommissioning

Surface activity measurements were performed at the systematic sampling locations for the paved areas. One-minute static measurements were conducted using a Ludlum Model 43-68 gas proportional detector coupled with a Ludlum Model 2221 ratemeter/scaler.

Because the radionuclides identified as potential contaminants are not present in background at concentrations, which are significant fractions of the release guidelines, correction of FSS sample data for background levels are not required. Adjustment of direct measurement results for background was through use of unshielded/shielded measurements at each data point.

4.6.3 Survey Results

Detailed survey results are provided in field data forms in Appendix B.

Surveys of exterior soil and paved surfaces are:

Survey Unit	Survey Number	Description
50	UVA-FS-45	Paved surfaces other than those in 62A
52	UVA-FS-36	Soil
62A	UVA-FS-80	Asphalt Pad

Gamma scans of the soil ranged from 11,500 cpm to 60,000 cpm. Elevated gamma scan readings were associated with rock outcroppings along the north parking lot area, the west roadway fill area and the east side of the facility. These outcroppings contain concentrations of potassium, natural thorium, and natural uranium that are higher than typical site surface soils. Increased gamma levels were also noted at the southeast corner of the building where sealed sources were stored inside the Hot Cell. Gamma scans did not identify soil area which might potentially be contaminated with radionuclides of license origin.

Results of gamma analyses of systematic soil samples are summarized in Table 4-15. Only Cs-137 was identified in the samples at detectable concentrations; the maximum level measured was 1.09 pCi/g.

Analyses of a composite of systematic samples for non-gamma emitting radionuclides of potential facility origin are summarized in Table 4-16. Only three radionuclides were identified at concentrations above the method detection sensitivities; they are Pu-238, Pu-239, and Sr-90. While the concentrations of Pu-238 and Pu-239 in this composite were a small fraction (less than 4%) of their screening DCGL values, and the maximum concentrations possible in an individual sample were 1.53 pCi/g (17 X 0.09 pCi/g) of Pu-238, 0.68 pCi/g (17 X 0.04 pCi/g) of Pu-239. These maximum levels are below the Pu-238 and Pu-239 screening DCGLs of 2.5 pCi/g, and 2.3 pCi/g, respectively. The Sr-90 concentration of 0.72 pCi/g was approximately 42% of the Sr-90 screening DCGL of 1.7 pCi/g. This indicated that one of the 17 individual samples in the composite could contain a Sr-90 concentration as high as 12.2 pCi/g (17 X 0.72 pCi/g). Each of the individual systematic final status survey samples was therefore analyzed for Sr-90. Results of these analyses (see Table 4-15) identified a maximum Sr-90 concentration of 0.66 pCi/g in sample 16, with 13 of the 17 samples having concentrations below the detection sensitivity of the procedure. The sum of fractions for the combined gamma emitters and Sr-90 range from

0.345 to 0.478; all are well below the Unity Rule criterion of 1.0. These results demonstrate compliance with the decommissioning criteria. The average and standard deviation of the sum of fractions are 0.385 and 0.40, respectively. The retrospective relative shift of 12.5 is much greater than the design value, thus indicating that adequate data points were obtained for this evaluation.

Gamma scans of paved surfaces ranged from 10,000 to 42,000 cpm. As with scans of soil surfaces, gamma levels were generally elevated in the vicinity of rock outcroppings and portions of the building where radioactive sources are being stored (e.g., Hot Cell). Gamma scans did not identify any areas of paved surfaces which might be contaminated as a result of licensed operations.

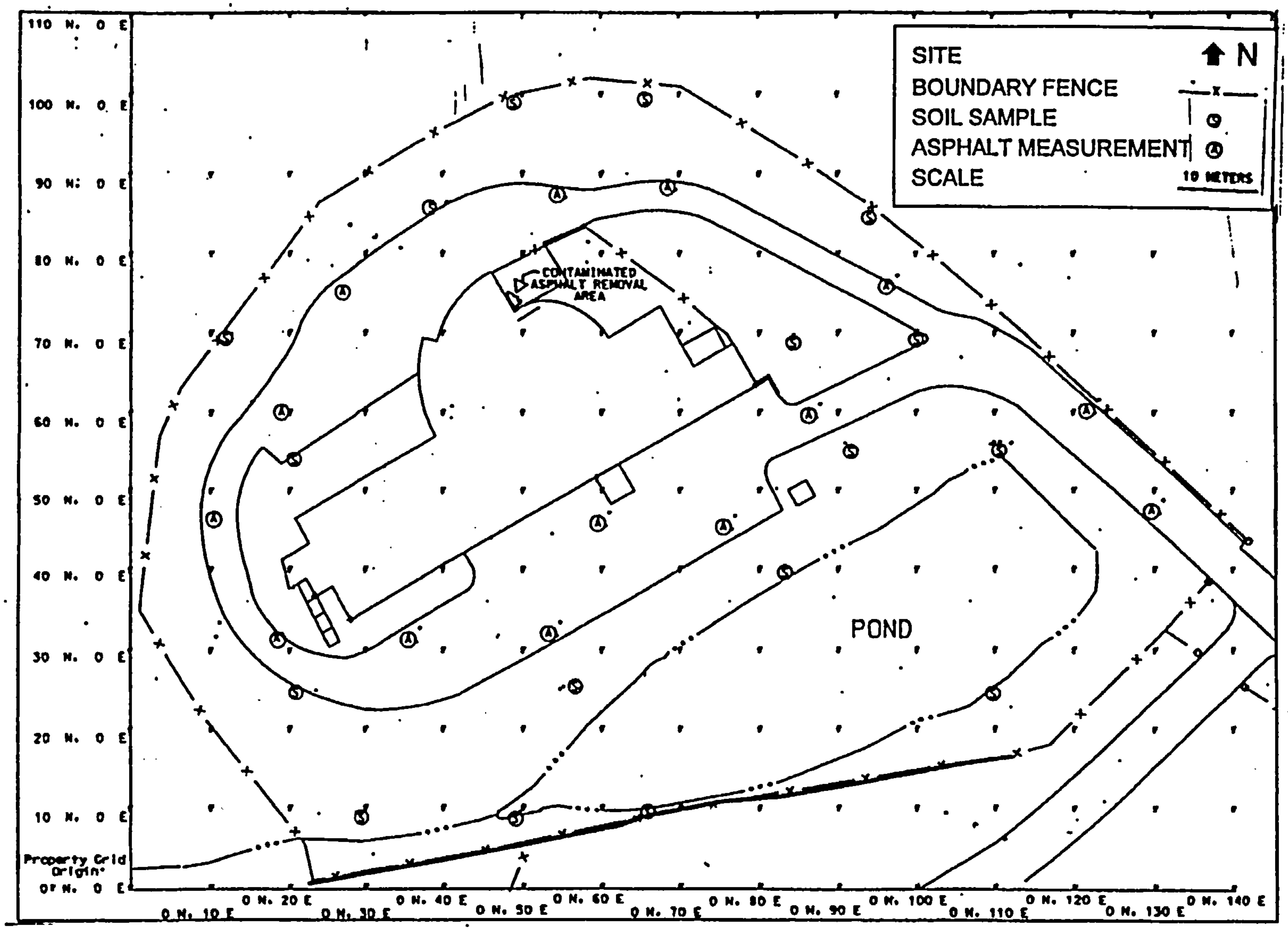


Figure 4-13 Plot of Site, Indicating Reference Grid System, and Measurement/Sampling Locations.

The paving near the door to the Reactor Contaminant Room was remediated and beta scans were repeated using 125 cm^2 detectors. Levels ranged from 320 to 1,100 cpm. Beta scans of other paved surfaces (using large-area floor monitor detectors) ranged from 960 cpm to 4,000 cpm. Elevated readings were noted in the vicinity of the Hot Cell facility and are attributed to direct radiation from sealed sources stored in this facility. Otherwise, no specific locations of elevated levels were identified by the beta scans.

Table 4-15 Summary of Analyses for Soil Samples from Site Open Land Areas

Sample	Grid Coords [a]		Radionuclide Concentration (pCi/g)				Sum of [b] Fractions
	N	E	Co-60	Cs-137	Other Gamma Emitters	Sr-90	
1	9	30	< 0.12	0.24 ± 0.15	None Detected	<0.53	0.366
2	9	48	< 0.18	0.22 ± 0.24	None Detected	0.54 ± 0.31	0.385
3	9	66	< 0.11	0.10 ± 0.06	None Detected	<0.58	0.379
4	24	21	< 0.08	< 0.08	None Detected	<0.55	0.352
5	24	57	< 0.24	0.22 ± 0.15	None Detected	<0.45	0.348
6	24	111	< 0.12	0.60 ± 0.15	None Detected	<0.55	0.411
7	39	84	< 0.14	0.86 ± 0.20	None Detected	<0.58	0.356
8	54	111	< 0.10	0.71 ± 0.25	None Detected	<0.58	0.432
9	54	93	< 0.09	< 0.09	None Detected	<0.56	0.361
10	54	21	< 0.14	< 0.09	None Detected	<0.51	0.345

11	69	12	< 0.08	0.50 ± 0.13	None Detected	<0.51	0.367
12	85	39	< 0.11	0.35 ± 0.09	None Detected	<0.50	0.355
13	99	48	< 0.12	1.09 ± 0.21	None Detected	<0.59	0.478
14	99	66	< 0.18	< 0.12	None Detected	0.64 ± 0.29	0.442
15	84	93	< 0.12	0.27 ± 0.14	None Detected	0.51 ± 0.31	0.357
16	.69	84	< 0.09	0.31 ± 0.13	None Detected	0.66 ± 0.31	0.440
17	69	101	< 0.16	0.43 ± 0.13	None Detected	<0.50	0.375

[a] refer to Figure 4-13
[b] DCGL for Cs-137 = 11 pCi/g
DCGL for Co-60 = 3.8 pCi/g
DCGL for Sr-90 = 1.7 pCi/g

Table 4-16 Concentrations of Radionuclides in Composite of Systematic Soil Samples

Radionuclide	Concentration (pCi/g)	DCGL (pCi/g)
Am-241	< 0.09	2.1
Fe-55	< 1.46	10,000
H-3	< 6.66	110
I-129	< 0.34	0.5
Ni-63	< 3.62	2100
Pu-238	0.09 ± 0.07	2.5
Pu-239	0.04 ± 0.05	2.3
Pu-241	< 3.60	72
Sr-90	0.72 ± 0.37	1.7
Tc-99	< 0.21	19

Exterior paved surfaces beta activity measurements are summarized in Table 4-17. Levels ranged from 459 to 4631 dpm/100 cm^2 with the maximum activity on the pad outside the Reactor Containment Room roll-up door. All systematic measurements were below the guideline of 6,320 dpm/100 cm^2 and statistical testing is therefore not necessary to demonstrate compliance with the guideline. The averages for survey units 50 and 62A are 1,459 and 2,722 dpm/100 cm^2, respectively. Standard deviations are 714 and 701 dpm/100 cm^2; relative shifts for these levels are approximately 10, which are much greater than the design value, thus indicating adequate data points were obtained for evaluation.

Table 4-17 Summary of Beta Surface Activity Measurements on Exterior Paved Surfaces

Survey Unit	Description	No. of Meas.	Beta Activity (dpm/100 cm^2)			
			Minimum	Maximum	Mean	Std. Dev.
50	Bulk of paved surfaces	17	459	2614	1459	714
62A	Pad outside containment	15	1456	4631	2722	701

4.6.4 Conclusion

Exterior soil surfaces did not contain contaminants of license origin in excess of project decommissioning guidelines. One small area of pavement, adjacent to a door to the Reactor Containment Room, was identified as having surface Cs-137 contamination. This area was remediated, reclassified, and resurveyed. Final surveys of paved areas indicated beta surface activity is within the conservative $DCGL_{adjusted\ gross}$ of 6,320 dpm/100 cm^2. These results demonstrate that the exterior paved surfaces and soil areas at the UVAR site satisfy the established project decommissioning criteria.

4.7 Exterior Structure Surfaces

4.7.1 Description

Figure 4-14 is a plot plan of the UVAR building. The UVAR building is of concrete block construction with brick veneer. Floors are concrete slab. There is approximately 1190 m^2 of roof area, at two elevations; one covers the Reactor Confinement structure – a surface area of approximately 175 m^2, and the other (approximately 1,015 m^2) covers the remainder of the structure. During operation there was a cooling tower on the roof to the southeast of the Reactor Room; this structure was removed during decommissioning. Roofs are of tar-and-gravel composition. The roofs are essentially clear of obstructions such as items of HVAC equipment. There are multiple sewer line vents and rainwater drains on the roofs.

Other exterior building surfaces of concern include discharge grills and stacks servicing small laboratory exhaust ventilation systems; some of these, e.g., those from rooms M005 and M008, were known to have at one time been internally contaminated. Doors at exits from areas handling radioactive and/or potentially contaminated materials were also surfaces of interest. These exterior locations are identified on Figures 4-15 to 4-17.

The Decommissioning Plan established the criteria for residual radioactive material contamination on UVAR facility surfaces. UVAR facility criteria, also referred to as derived concentration guideline levels (DCGLs), are selected from the table of NRC default screening values. Exterior structure surfaces did not have sufficient activity levels to enable a meaningful determination of the facility contaminant mixture – particularly with respect to hard-to-detect radionuclides. Therefore, the contaminant mixture for facility drain systems was assumed for the exterior surfaces (refer to Final Status Survey Plan (FSSP) Addenda 001 and 002, in Appendix A). The principal radionuclides in this mixture are Co-60 and H-3, resulting in an beta $DCGL_{adjusted\ gross}$ of 6,320 dpm/100cm^2 as the basis for evaluating the final radiological status of the exterior structure surfaces. The guideline for removable surface contamination is 10% of the total surface activity guideline, i.e., 632 dpm/100cm^2. Use of these guidelines assures a conservative approach for satisfying the NRC dose-based criteria for future facility use.

4.7.2 Survey Activities

Reference grids (1 m) were established on the roof surfaces to identify survey locations. Other exterior structure surfaces were not gridded, due to their limited surface areas of ≤10 m^2; instead, survey locations were referenced to pertinent building features.

Two survey units were established for exterior structure surfaces. They were:

Survey Unit	Description
48	Reactor Containment Roof
49	Main Building Roof

Impacted structure surfaces of ≤ 10 m^2 were not designated as survey units. Instead, from 1 to 4 measurements were obtained from such areas, based on judgment and surface area, for comparison individually with the DCGLs. Such surfaces include exterior surfaces of vents, stacks, and exit doors, from areas of former radioactive materials use and facilities that required remedial action during this decommissioning project.

The roofs were designated MARSSIM Class 2 surfaces; other exterior surfaces were designated Class 3. Facility history (including the Historic Site Assessment) and radiological monitoring conducted during characterization and remedial activities were the bases for these classifications.

Gamma surface scans were performed using a 2"X 2" NaI detector (Ludlum Model 4-10) coupled with a Ludlum Model 2221 ratemeter/scaler. The detector was maintained within 5 to 10 cm of the surface and moved from side to side in a serpentine pattern while noting any indication of audible elevated count rate. Scans included the area out to 1 m beyond doors and vents. Results (count rate) were documented on survey area maps. Gamma scanning coverage was a minimum of 25% for Class 2 and 10% for Class 3 surfaces.

Beta scans of roof surfaces and exterior structure surfaces were performed using a Ludlum Model 43-68 gas proportional detector coupled with Ludlum Model 2221 ratemeter/scaler. The detector was maintained within ~1 cm of the surface while advancing the detector at a rate of approximately one detector width per second. Scans included the area out to 1 m beyond doors and vents. Scan speed was adjusted, as necessary, to assure detection sensitivities were less than 50% of the release criteria. Audible response was monitored for indication of elevated count rate. Results (count rate) were documented on survey area maps. Beta scanning coverage for roof and wall surfaces was a minimum of 25% for Class 2 and 10% for Class 3 surfaces.

Due to the variability in background levels, resulting from construction materials and radioactive sources stored within the facility, it was not practical to establish meaningful reference areas. Instead, unshielded and shielded measurements were performed at each surface activity data point location, and the Sign Test was used for evaluating direct measurements, relative to the established criteria. The Null Hypothesis is that activity levels in the survey unit exceed the criteria. Rejection of the Null Hypothesis is required to demonstrate that the release criteria are satisfied. Decision errors are 0.05 (Type 1 and Type 2).

The number of systematic data points required for the Sign test evaluation was determined to be 14 for a relative shift of 3 (refer to Section 4.6 of FSSP Addendum 006). To provide a high degree of coverage, data points on the roof surfaces were obtained at a spacing of 2 to 2.5 m, resulting in a number of data points significantly larger than the required number. Random start points were determined for establishing measurement patterns.

Surface beta activity measurements were performed at the systematic and judgmental locations. One-minute static measurements were conducted using a Ludlum Model 43-68 gas proportional detector coupled with a Ludlum Model 2221 ratemeter/scaler. Both shielded and unshielded measurements were performed at each location.

Smears for removable activity were performed at locations of direct activity measurements.

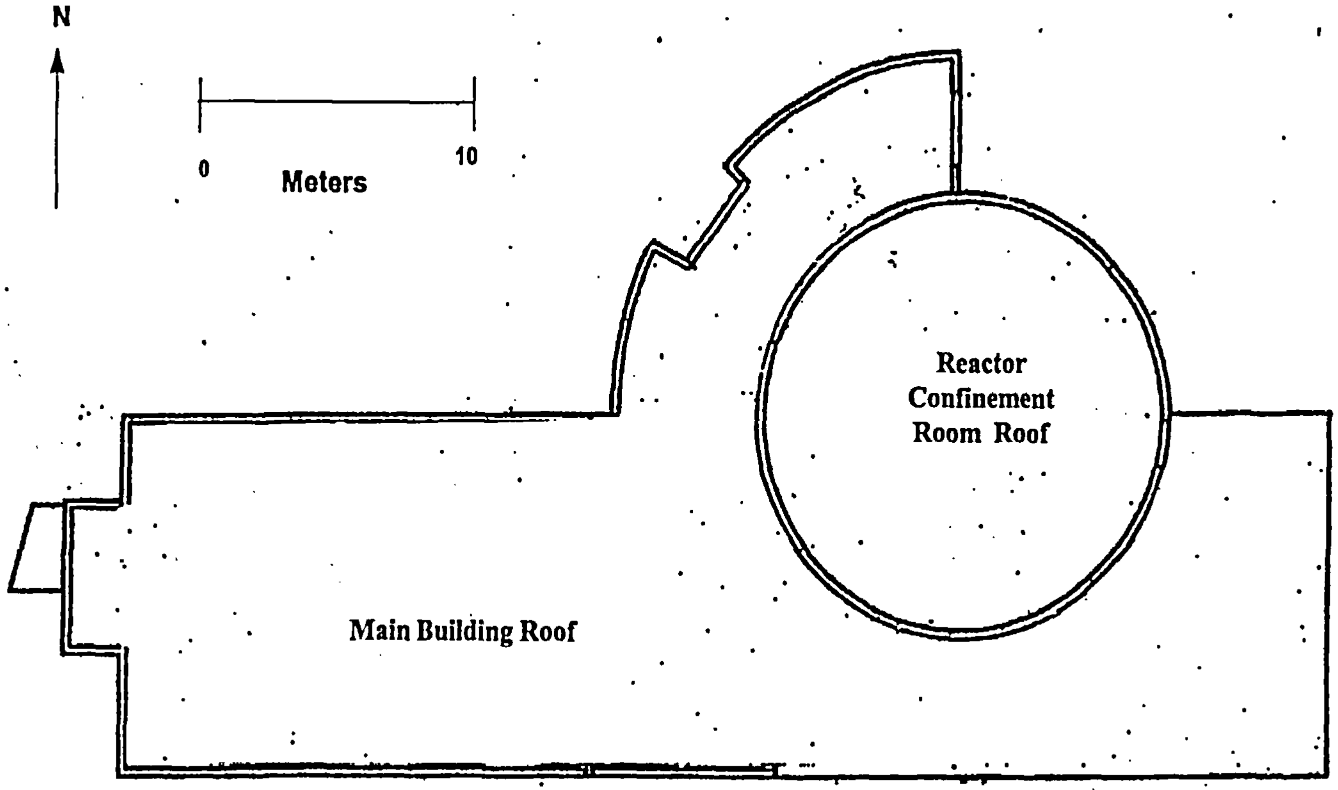
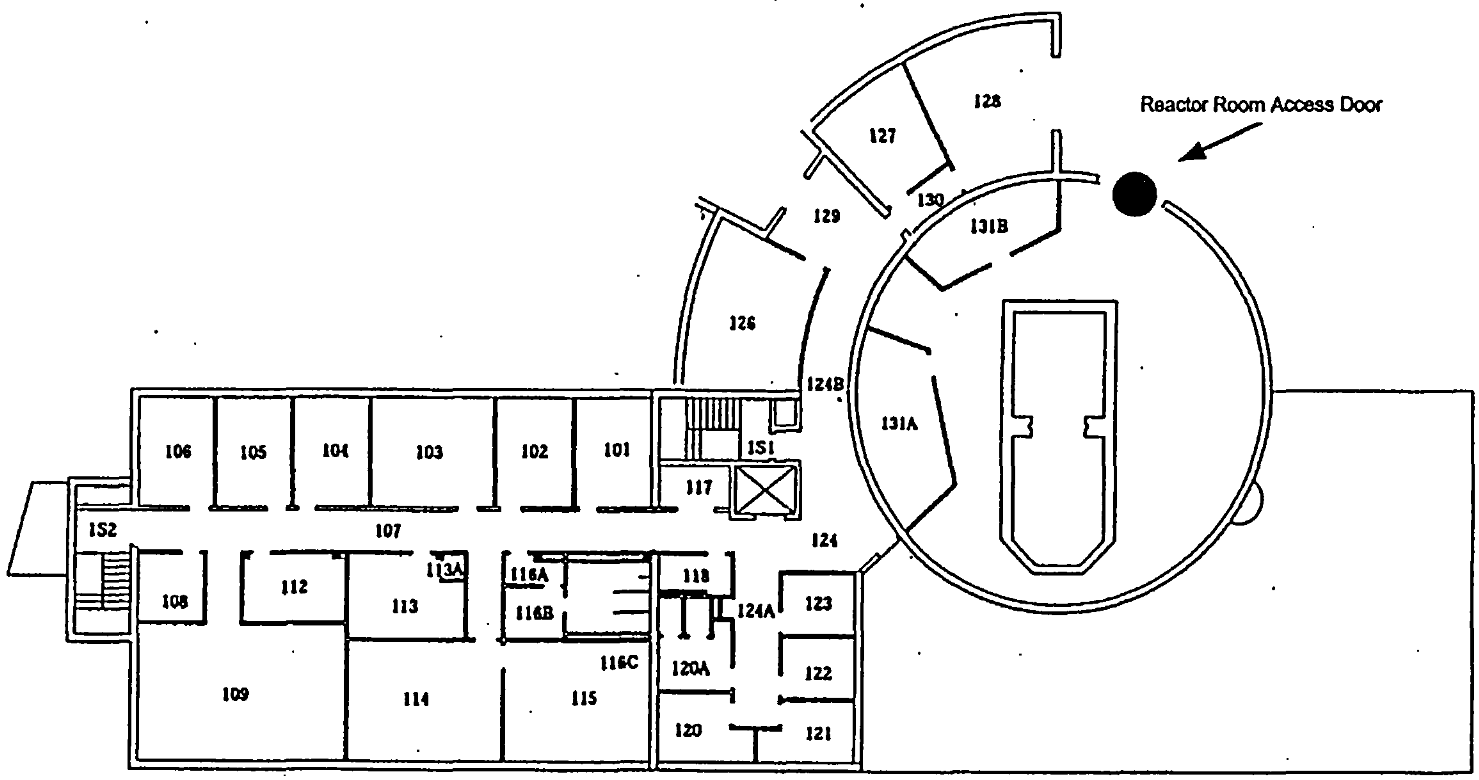


Figure 4-14 UVA Reactor Floor Plan View Indicating Roof Areas.



Figures 4-15 UVA Reactor First Floor Plan View Indicating Survey Locations on Exterior Building Surfaces.

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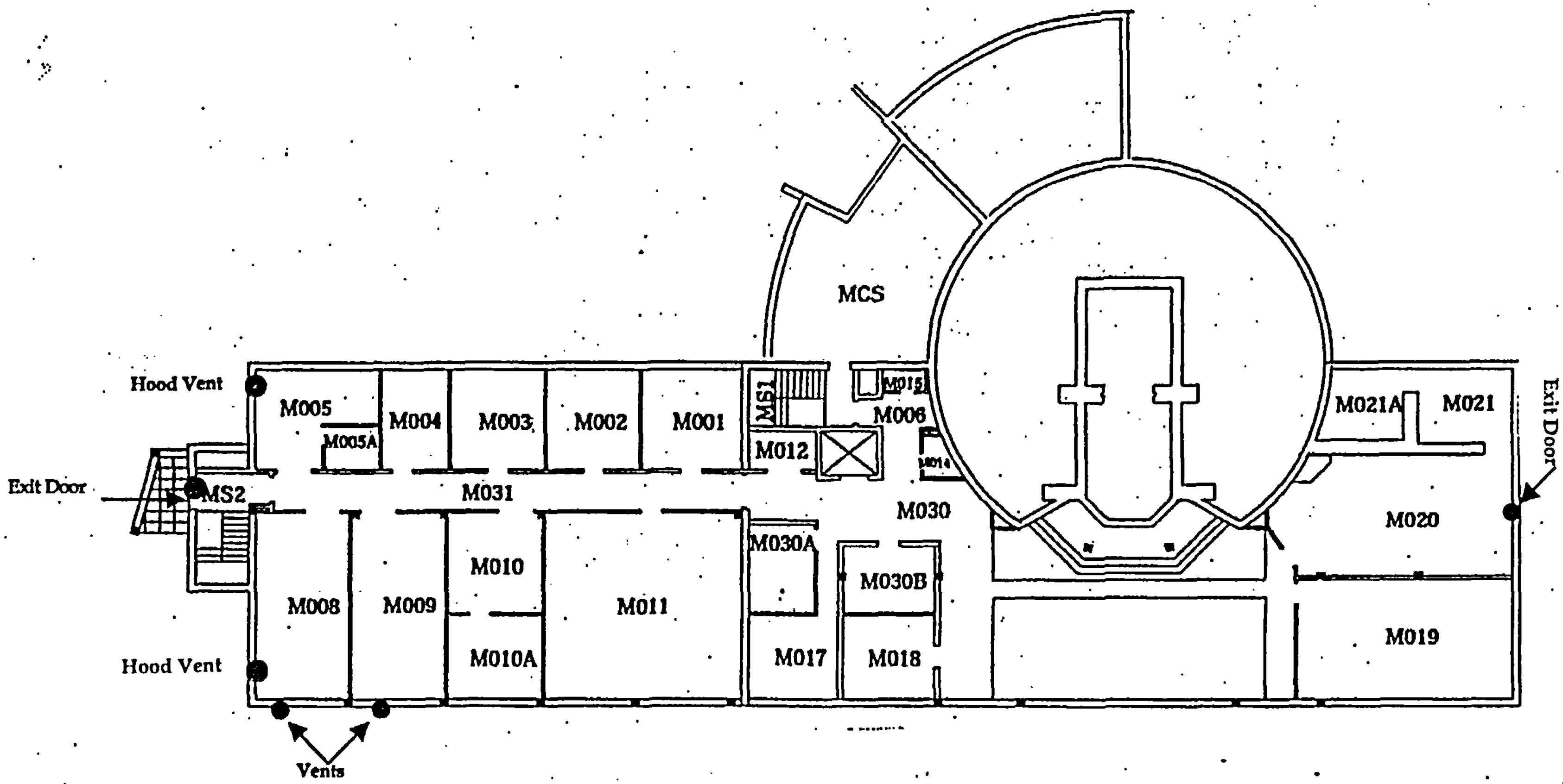

Figure 4-16 UVA Mezzanine Floor Plan View Indicating Survey Locations on Exterior Building Surfaces.

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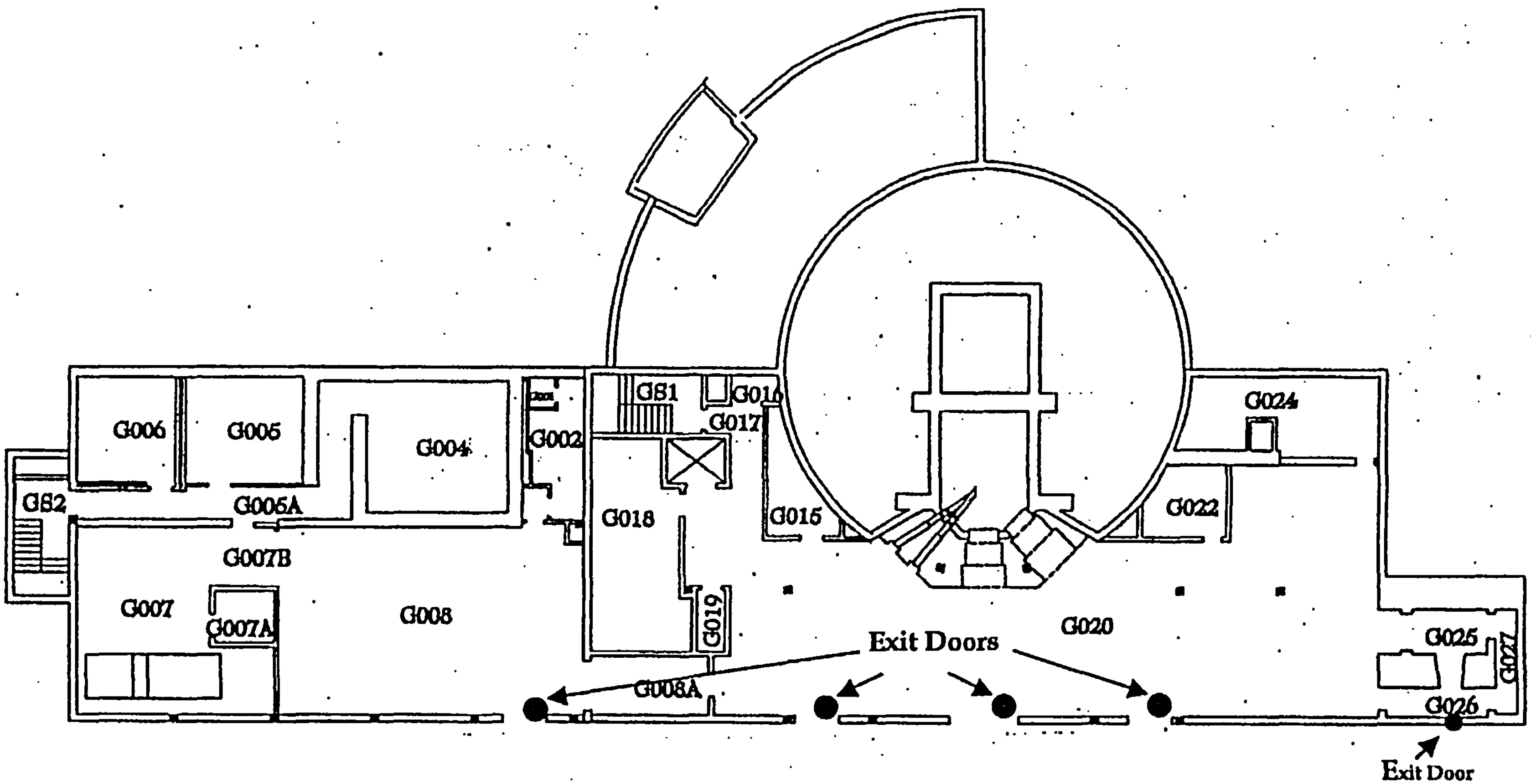

Figure 4-17 UVA Reactor Ground Floor Plan View Indicating Survey Locations on Exterior Building Surfaces.

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4.7.3 Survey Results

Detailed survey results are provided in field data forms in Appendix B. Surveys of exterior structure are:

Description	Survey Number	Survey Unit
Reactor Containment Roof	UVA-FS-52	48
Main Building Roof	UVA-FS-53	49
Exterior Doors and Vents	UVA-FS-59	N/A

Gamma scans of the Reactor Containment Roof ranged from 8,700 cpm to 10,500 cpm. Gamma Scans of the Main Building Roof ranged from 9,500 cpm to 15,000 cpm. No locations of elevated activity were noted on the roof surfaces. Gamma scans of exterior doors and exhaust vents ranged from 8,700 cpm to 88,000 cpm. Elevated gamma levels were noted in the vicinity of the Hot Cell area in the southeast corner of the building. These elevated levels were due to Co-60 and PuBe sealed sources stored in the Hot Cell. No other elevated locations were noted.

Beta scans of the Reactor Containment Roof ranged from 250 cpm to 800 cpm, and beta scans of the Main Building Roof area ranged from 250 cpm to 675 cpm. No locations of elevated beta activity were noted on the roof surfaces. Beta scans of the building exterior doors and vents ranged from 160 cpm to 14,000 cpm. As with the gamma scans, beta scans were elevated in the vicinity of the Hot Cell, due to the sources stored inside this area. No other locations of elevated beta activity were noted on building exterior surfaces.

Surface beta activity measurements are summarized in Table 4-18. The maximum measurement was 3494 dpm/100cm^2. All measurements were below the guideline value of 6320 dpm/100cm^2 and thus demonstrated the established criteria are satisfied without need of statistical testing. Reassessment of the relative shift, using actual survey data yielded values greater than 6. The data point requirements, based on a relative shift of 3 were thus adequate.

Table 4-18 Exterior Structure Surfaces Beta Activity Summary

Survey Unit	Description	Number of Measurements	Beta Activity (dpm/100 cm^2)			
			Minimum	Maximum	Mean	Std Dev
48	Reactor Containment Roof	57	200	3353	1905	695
49	Main Building Roof	207	-7	3494	1337	588
N/A	Exterior Doors and Vents	19	-96	2018	427	678

All smears contained less than the detectable level of removable beta activity (<28dpm/100cm^2).

4.7.4 Conclusion

Survey results demonstrate that exterior building surfaces do not contain radioactive material contamination of license origin in excess of established project guidelines.

4.8 Special Soils Areas

4.8.1 Description

Several soils areas inside the UVAR building have had a potential for radioactive contamination, based on the operating history of the facility. One of these is a small crawl space adjacent to the Reactor Confinement Room. This space, located between the first and Mezzanine levels, is accessed from the stairwell between these two floors. The crawl space is of masonry construction with a dirt (soil) floor, covering an area of approximately 50 m^2. This crawl space was used for storage of equipment, materials, and supplies, including some radioactive sources and potentially contaminated components and miscellaneous materials. Characterization surveys of this crawl space identified slightly elevated direct radiation levels, due to the masonry construction and the presence of elevated radon progeny, which is believed to originate from naturally occurring radionuclides in the soil floor and which accumulate in this unventilated space.

The soil surrounding the reactor pool is another area of potential soil contamination. The reactor pool is approximately 10 m x 3.6 m and extends approximately 7.5 m below the reactor room floor level. The reactor pool is located inside the circular Reactor Confinement structure, which has a diameter of approximately 16 m. The space between the outer pool walls and the Confinement structure contains soil fill. Since the base of the Confinement structure does not incorporate a floor, the pool therefore is underlain with soil and bedrock. During reactor operations, losses of pool water were a common occurrence. Specific locations of any pool leakage have not been identified; however, such leakage potentially could have resulted in contamination of soils around and beneath the pool. Breaks in piping beneath the Reactor Room floor were identified during facility remediation. Leakage of contaminated liquids from floor, sink, and pool overflow drains could have contaminated surface soils in the vicinity of these breaks. Characterization of surface and subsurface soils beneath the Reactor Room floor identified small, localized areas of contaminated surface soil; these areas were remediated. Characterization of the fill around the pool and in the soil, bedrock, and groundwater beneath the pool did not identify contamination of these media requiring remediation.

Figures 4-18 to 4-20 indicate the locations of these soil areas inside the UVAR building.

In preparation for implementing the Final Status Surveys, materials and equipment were removed from the crawl space and piping and other potentially contaminated items and components were removed from the fill area beneath the Reactor Room floor and around the reactor pool. Soils in the vicinity of piping leaks and pool water leaks, identified by scoping and characterization efforts as containing elevated activity were excavated. Areas of particular note that required soil excavation were around a section of piping near the Demineralization Room (M021A) wall on the east side of the Reactor Containment structure (Figure 4-21) and at piping leaks beneath the Reactor Room floor at core locations "M" and "B" (Figure 4-22).

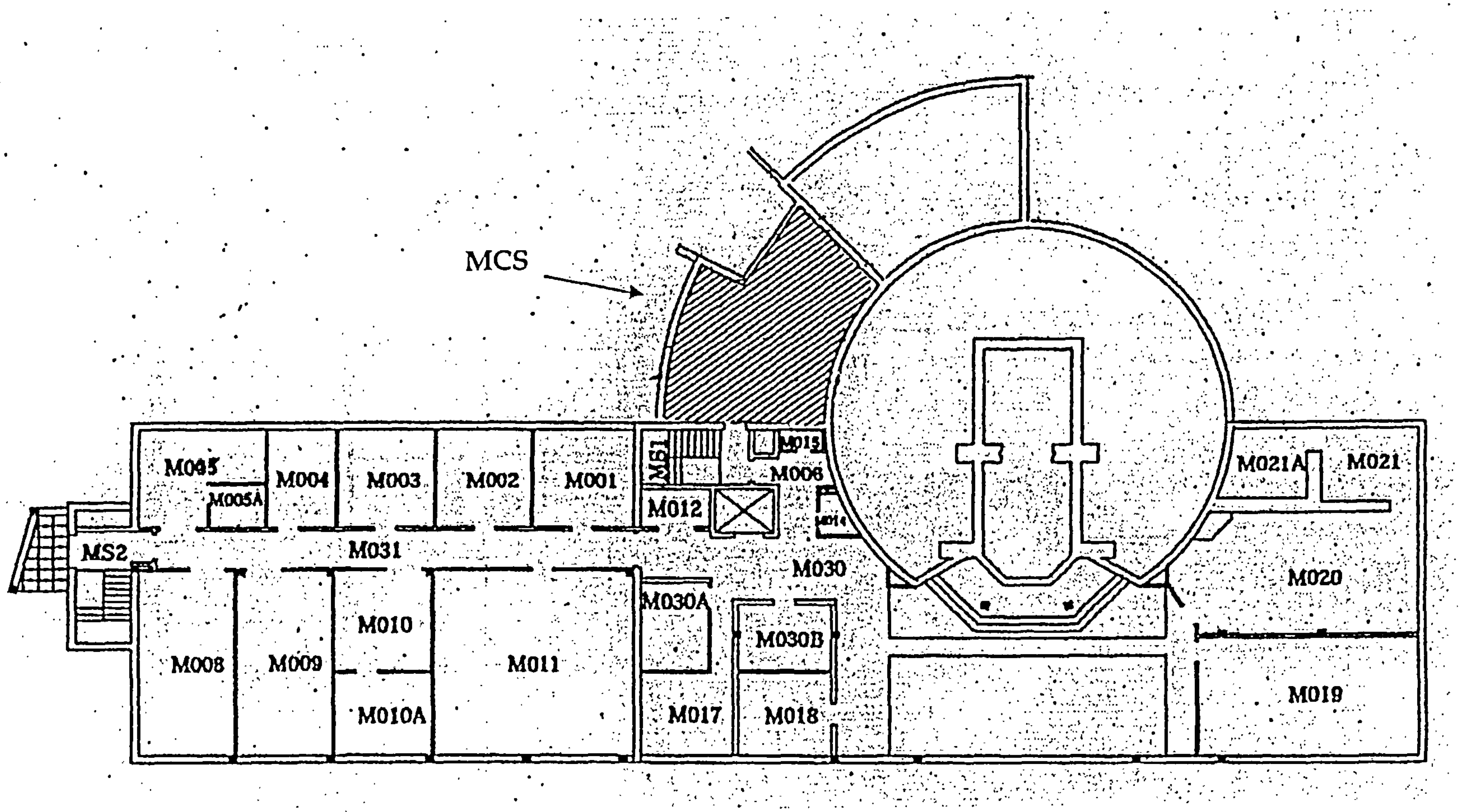

Figure 4-18 UVA Mezzanine Floor Plan View Indicating the Location of the Mezzanine Crawl Space.

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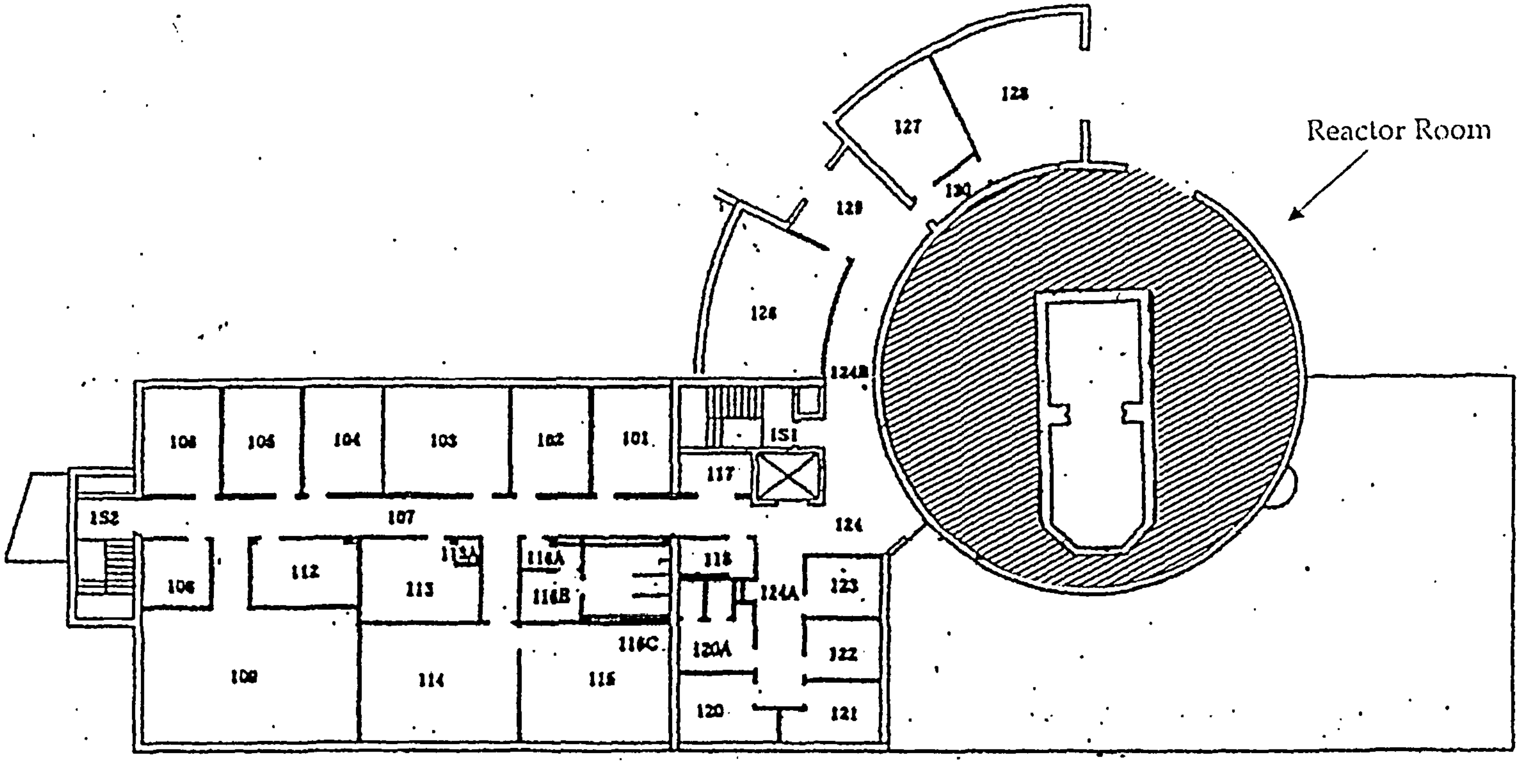

Figure 4-19 UVA Reactor First Floor Plan View Indicating the Location of Soil Fill Around Reactor Pool.

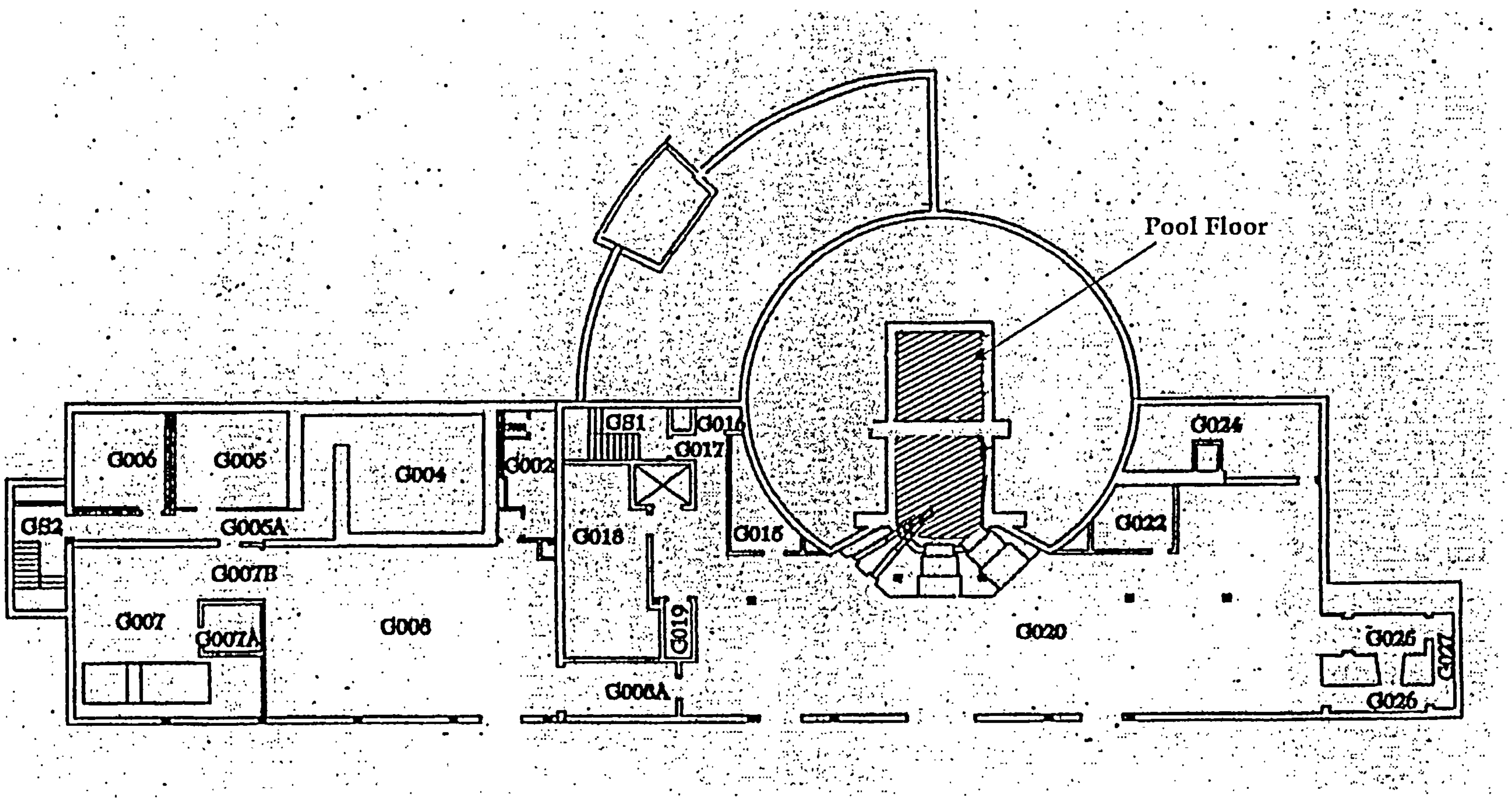

Figure 4-20 UVA Reactor Ground Floor Plan View Indicating the Location of the Soils Beneath the Reactor Pool.

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The initial characterization by GTS Duratek showed that radiological contamination was generally low level and was limited to a small portion of the structure interior. Major structural contamination was generally limited to surfaces exposed to or in contact with reactor coolant, reactor neutron fields, and materials containing high levels of activity (e.g., the Hot Cell). Depending on the mechanism of contamination and the medium, radionuclides and their relative ratios varied. The overall predominant radionuclides were Co-60 and Cs-137; smaller activities of some other gamma emitters and hard-to-detect radionuclides were identified in samples from certain facility locations and media.

Continuing characterization by CH2M HILL identified small localized areas of elevated direct gamma radiation on the surface of the soil fill beneath the Reactor Room floor and the south end of the reactor pool. This contamination was at locations of piping breaks and leaks. Remediation of these areas of elevated activity appeared to eliminate contamination of the fill soil. Characterization did not identify any contamination of the Mezzanine crawl space by radionuclides of license origin.

Addendum 007 to the Final Status Survey Plan (available in Appendix A) describes the contaminants and guidelines for these soil areas. The relatively low activity levels in the surface soil beneath the Reactor Room and pool floor did not enable a meaningful determination of the complete mix; particularly of hard-to-detect radionuclides. Therefore, because of the dominance of Co-60 in the surface samples and because the source of the contamination was liquids from the reactor facility, the same contaminant mixture is assumed for the surface of the fill soil as used for the waste tank remediation and reactor facility piping FSSP. A Co-60 $DCGL_{surrogate}$ of 3.4 pCi/g is thus used for these soils.

Compliance with decommissioning requirements will be demonstrated by comparing the results of final status survey sample analyses with the Co-60 $DCGL_{surrogate}$ of 3.4 pCi/g and by furthermore demonstrating that hard-to-detect radionuclides are not present in significant concentrations. Subsurface soils surrounding and beneath the reactor pool will be evaluated over 1-meter thick intervals. Because the radionuclides identified as potential contaminants are not present in background samples at concentrations, which are significant fractions of the release guidelines, correction of FSS sample data for background levels will not be required.

4.8.2 Survey Activities

A 1-meter interval grid system was established on surfaces to provide a means for referencing measurement and sampling locations.

Based on facility operating history, characterization survey results, and findings during remediation, the crawl space was designated MARSSIM Class 2 contamination potential, and the soil areas around and beneath the reactor pool were designated Class 1 for survey planning purposes.

Demineralizer Room Wall Core

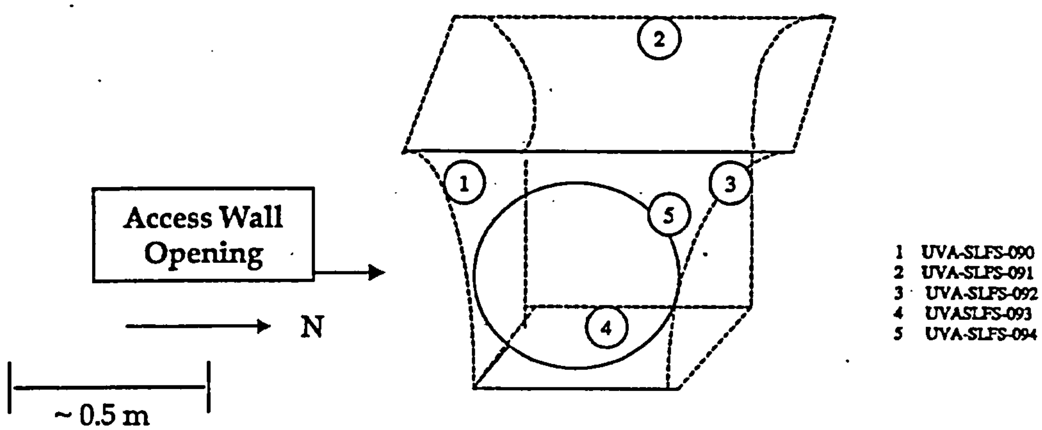

Figure 4-21 Excavation of Pool Fill at Demineralizer Room Wall (numbers indicated final sampling locations)

For final evaluation, interior soils are divided into the following five groupings:

1) Mezzanine crawl space
2) Surface soil at piping excavations beneath the reactor room floor
3) Surface soil at demineralizer excavation
4) Surface/subsurface fill around pool
5) Surface/subsurface fill beneath pool

Because of their small surface areas and location (inside the building), and inclusion of subsurface material, these soils were not evaluated as survey units. Although the FSS differed slightly from traditional MARSSIM approaches, the survey frequency, survey methods, and data evaluation were consistent with the intent of MARSSIM (refer to Addendum 007 in Appendix A for further information).

Gamma scans of accessible surfaces were performed using a 2" X 2" NaI detector (Ludlum Model 44-10) coupled with a Ludlum Model 2221 ratemeter/scaler. The detector was maintained within 5 to 10 cm of the surface and moved slowly across the surface while noting any indication of audible elevated count rate, which might indicate the presence of radioactive contamination. Results (count rate) were documented on survey area maps. Locations of elevated response were noted for further investigation. Gamma scanning coverage was

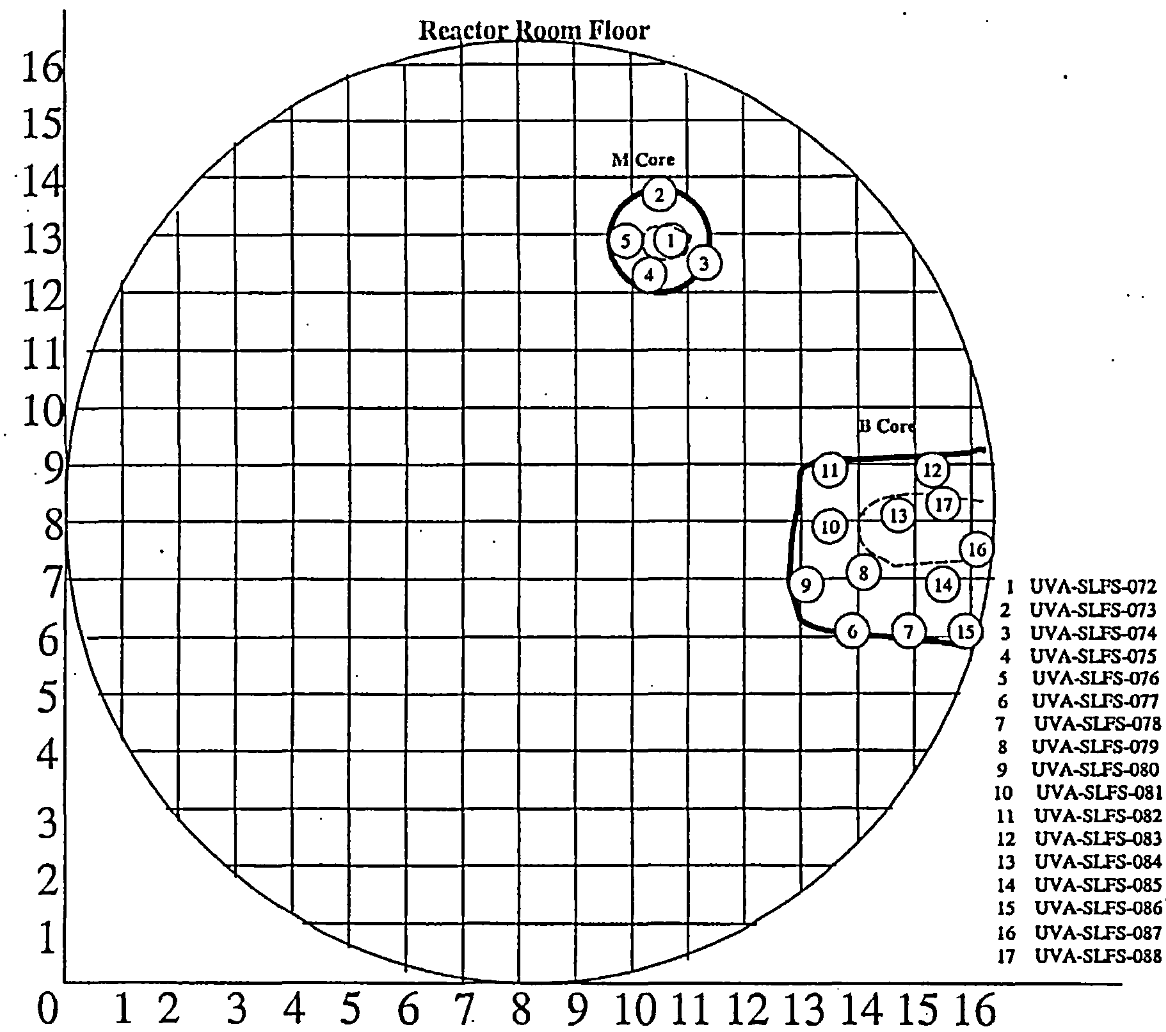

Figure 4-22 Excavation of Sub-floor Fill at "M" and "B" Core Locations of Pipe Leaks (numbers indicate final sampling locations)

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100% of accessible surface soils surfaces. Gamma logs of boreholes for subsurface sampling were conducted using the NaI detector (Ludlum Model 44-10 or Ludlum Model 44-2) coupled with a Ludlum Model 2221 ratemeter/scaler. Gamma levels (c/1 min) at 1-m depth intervals were obtained throughout the length of the borehole. Audible response was monitored during detector movement for indication of elevated count rate, which might indicate the presence of radioactive contamination. Gamma scan and logging results were documented on survey maps. Locations of elevated response were noted for further investigation.

Sampling/measurements were performed at uniformly spaced intervals throughout the soil areas or volumes of interest. This spacing between data points was determined by the surface area or volume.

For the small Mezzanine crawl space area, samples of surface soil were obtained on the same pattern and at the same intervals (about 3.5 m) as the surface activity measurement data points on the non-soil surfaces of this area. Thus 5 samples were obtained from this soils area. Five samples were also collected from the small excavation adjacent to the Demineralizer Room; sample locations were biased by professional judgment to locations of remediation. Figures 4-23 and 4-21, respectively indicate these sampling locations.

Due to their larger area/volume, the number of samples from the remaining areas of reactor pool fill were based on the MARSSIM guidance for Sign Test evaluation, which yielded a minimum sample requirement of 15.

Seventeen samples were obtained from surface soil at the locations beneath the Reactor Room floor of the "M" and "B" cores. Sample locations were based on professional judgment and biased to surfaces where remediation was performed. Figure 4-22 indicates these sampling locations.

Soil beneath the reactor pool was sampled at 12 locations, spaced to provide coverage across the pool floor area and to address locations where characterization identified contamination and/or remediation was performed. At each location, surface soil beneath the pool floor was sampled. At 4 locations, boreholes were drilled to the undisturbed soil surface or refusal, whichever was encountered first, using a 2" hand-auger; depth of boreholes ranged from 1.05 to 3.15 m; samples were obtained at 4 depths in each of these boreholes. This resulted in a total of 24 samples from this soil region. Because of groundwater infiltration, gamma logging of these boreholes could not be performed. Samples representing the upper 1 m soil layer were also collected at three locations at the extreme south end of the pool, where water leakage was suspected to allow for averaging contamination over a 1-m soil thickness, as described in NUREG-1727 (Ref. 11). Sampling locations are indicated on Figures 4-24 and 4-25.

For the remainder of the fill around the sides of the reactor pool, borings were performed at 16 access locations. Sampling was biased by professional judgment to those locations were corings through the floor had been performed to enable access for remediation of piping and adjacent contaminated soil. Additional corings were performed at non-remediated locations to achieve more uniform coverage and provide the minimum of 15 data points. Borings and sampling were performed with a 2" hand-auger. Depths of borings ranged from 1 m to 6.7 m. A total of 14 surface and 16 subsurface samples were obtained from the fill around the reactor pool. Gamma scans and static counts inside the bore holes were performed by using a 1" NaI detector to identify potential locations of residual concentration. Figures 4-26 and 4-27 indicate the locations of surface and subsurface sampling, respectively.

Soil samples of approximately 500 g each were collected at sampling locations. Surface samples were obtained from the upper 15 cm soil layer, using trowels or bucket augers. Subsurface samples were obtained using bucket augers, split spoon samplers, or other methods consistent with the drilling technique and equipment, and homogenized over a depth interval of 1 meter.

All individual samples were analyzed by gamma spectrometry. Results of these gamma analyses are the basis for demonstrating compliance with the NRC screening DCGL release criteria.

The radionuclide mixtures for potential contamination of these survey units were based on a limited number of characterization samples and many of the analyses for hard-to-detect (10 CFR Part 61) radionuclides in these samples resulted in concentrations that contributed a very small fraction of the total potential dose and/or were less than the measurement sensitivities of the analytical procedures. Consistency in the ratios of hard-to-detect radionuclides could therefore not be demonstrated; however, there was not sufficient indication of the presence of these radionuclides to warrant costly analyses of a large number of the final status survey samples for the complete suite of hard-to-detects. It was therefore decided that, if the individual analyses for gamma emitters demonstrated compliance with release criteria, composite samples consisting of 20 grams from each of the individual systematic samples from Mezzanine Crawl Space surface soil, surface soil beneath the Reactor Room Floor, subsurface soil from beneath the Reactor Room Floor, and all soil beneath the Reactor Pool, would be prepared and analyzed by the off-site laboratory for hard-to-detect radionuclides. Absence of positive or otherwise significant levels of non-gamma emitting radionuclides in the composites provides an increased level of confidence in the approach of using the gamma-emitters to demonstrate compliance. Analyses of the composites are for supplemental information only, and therefore the numbers of samples in the composites are not limited, as would be appropriate, if the data were intended for use in demonstrating compliance.

4.8.3 Survey Results

Detailed survey results are provided in field data forms in Appendix B. Surveys of interior soil are:

Survey Number	Description
UVA-FS-039	Soil beneath reactor room floor
UVA-FS-079	Soil beneath pool
UVA-FS-057	Demineralization Excavation
UVA-FS-056	Sub-floor cores "M" and "B"
UVA-FS-042 & 011	Mezzanine Crawl Space

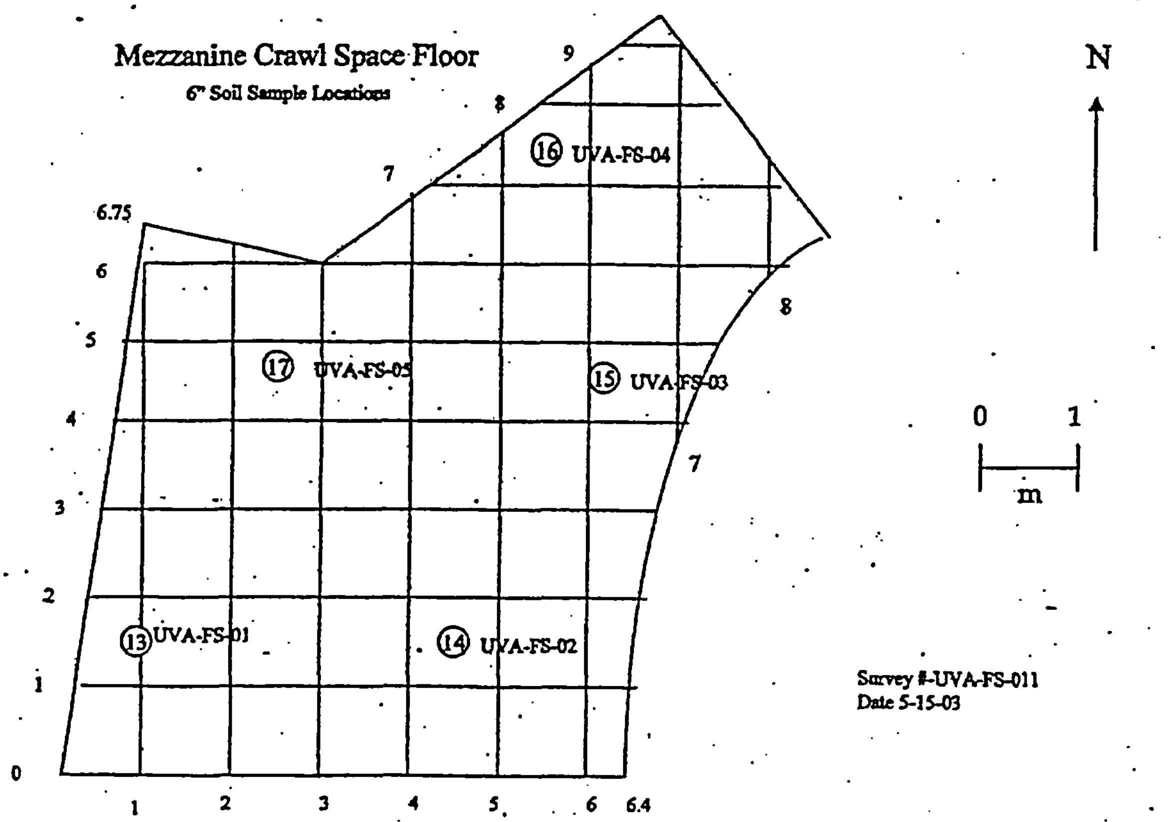

Figure 4-23 Mezzanine Crawl Space Floor, Indicating Soil Sampling Locations

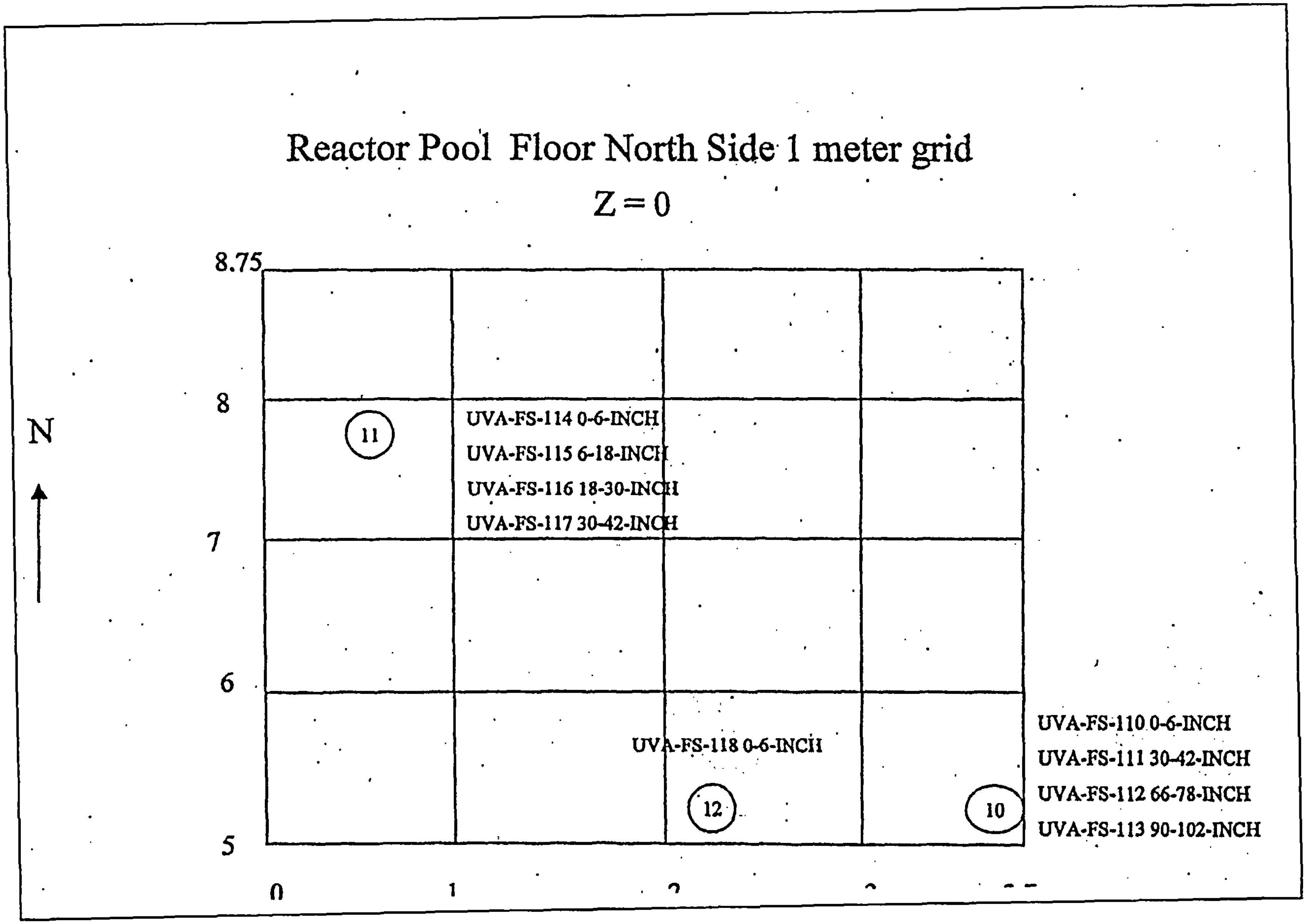

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Figure 4-24 Soil Sampling Locations Beneath the North End of the Reactor Pool.

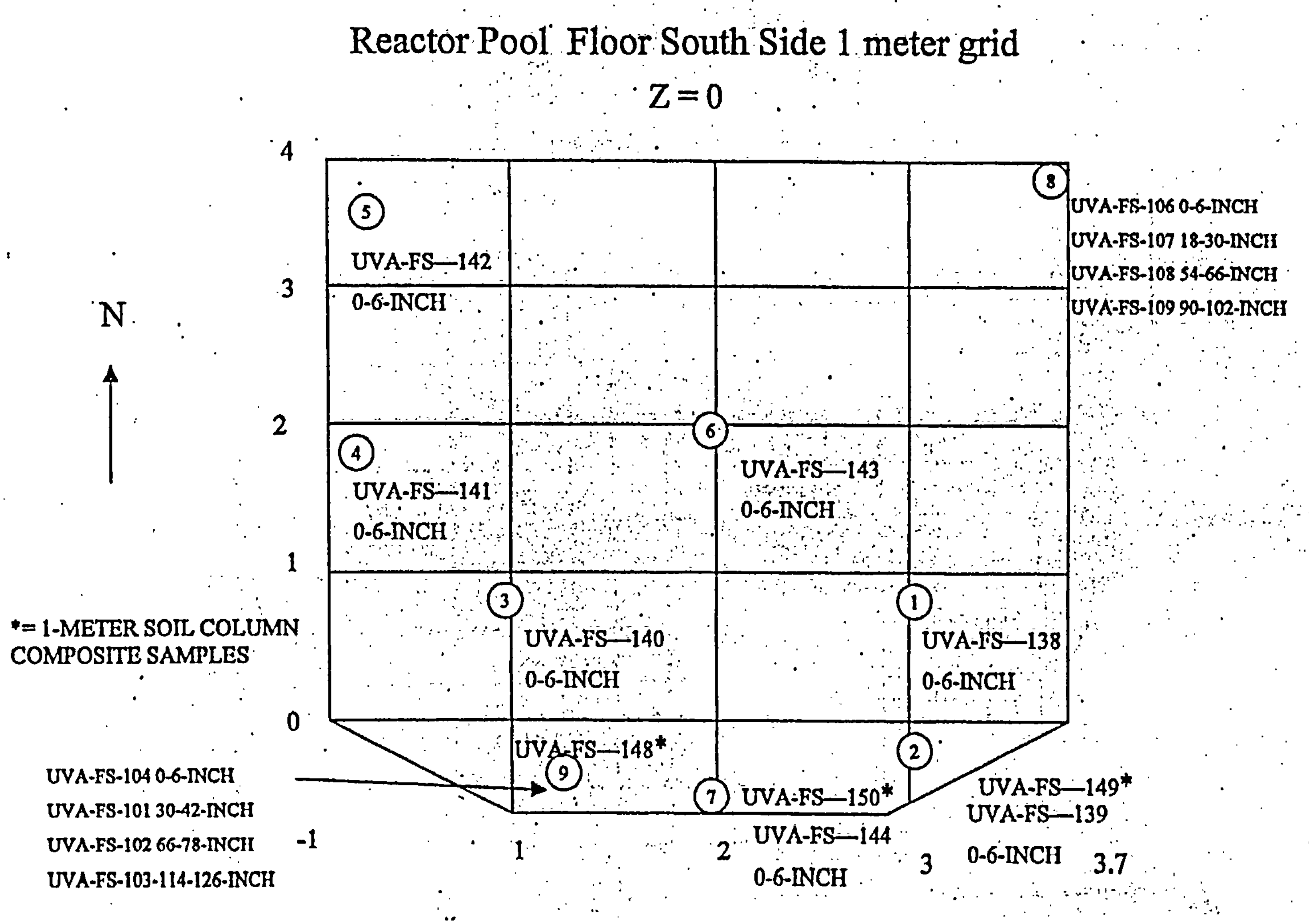

Figure 4-25 Soil Sampling Locations Beneath the South End of the Reactor Pool.

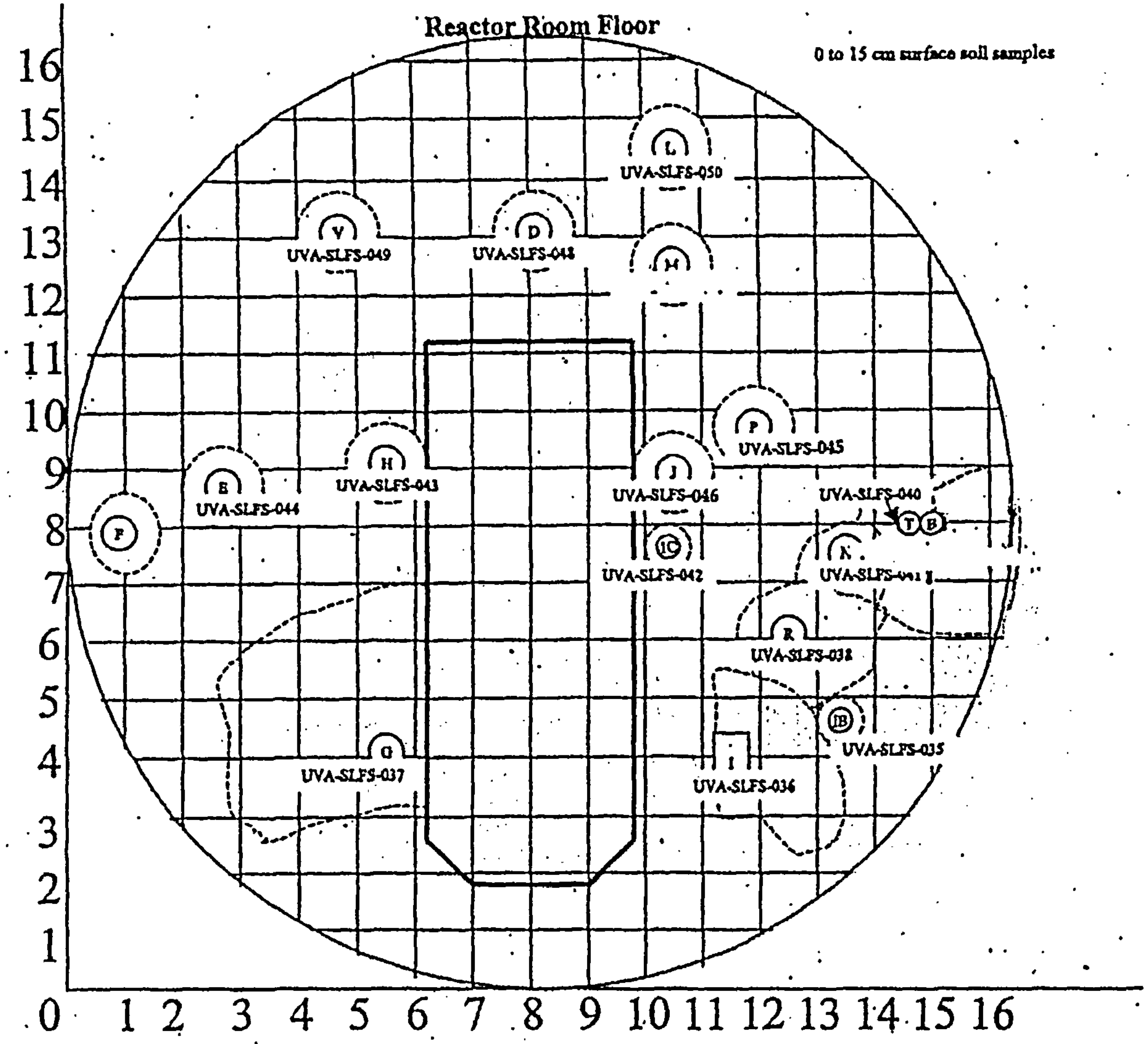

Figure 4-26 Locations of Surface Sampling of Fill Soil Beneath Reactor Room Floor

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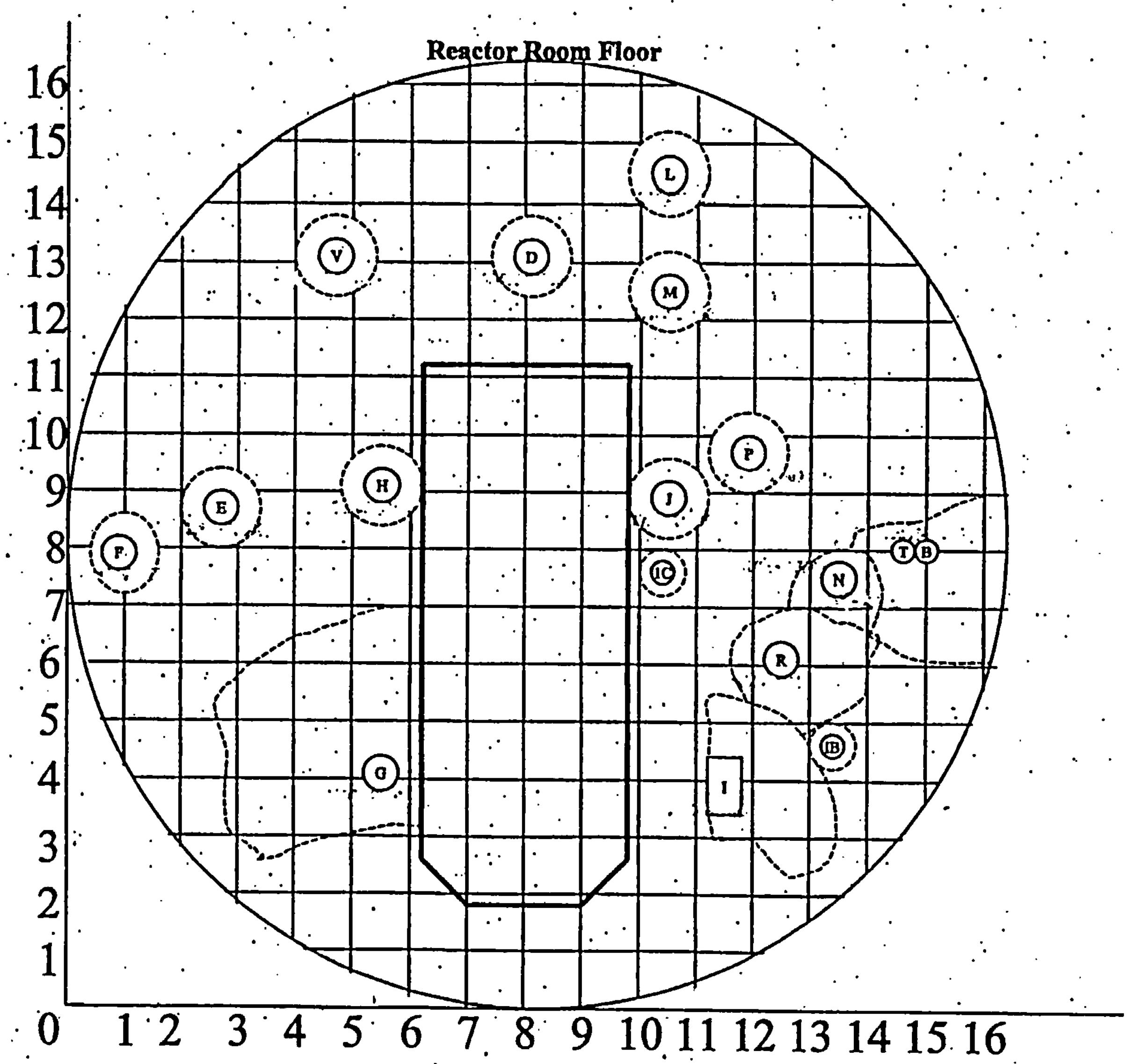

Figure 4-27 Locations of Sub-Surface Samples from Fill Beneath Reactor Room

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Gross gamma levels, noted by gamma scans, were generally higher for all interior soil surfaces than for exterior soil areas and structure surfaces. Ranges of these levels are summarized in Table 4-19. Such gamma levels are the result of elevated concentrations of naturally occurring K-40 and uranium and thorium decay series radionuclides in site soils and the enhanced geometry of the detector with soils and structural concrete. The gamma scans did not identify specific locations of significantly elevated levels, which would be suggestive of residual contamination.

Table 4-19 Range of Gamma Scan Levels on Surfaces of Interior Soil

Area	Gross Gamma Levels (c/m)	
	Minimum	Maximum
Pool fill soil	14100	30000
Soil beneath pool	13456	40495
Demineralizer excavation	19637	24700
Soil at Cores "M" and "B"	19749	30397
Mezzanine Crawl Space	18000	23000

The nature of the "special soil" areas and the elevated ambient gamma levels necessitated a reevaluation of scanning sensitivities for the 2" x 2" NaI detector. Other than the Mezzanine floor, the exposed surfaces of the "special soil" were sub-floor and were small in area. In most locations, accessible soil surfaces were less than 1 m^2 and scans were performed by either holding the detector in the hand and passing it over the surface or "dangling" the detector through a hole in the concrete surface and moving it slowly over the soil surface below. Because of these restrictions, scan speeds were slower than the "walkover" scan of open land surfaces, which typically leads to a dwell time of 1 second or less. The dwell time for these surface scans in the vicinity of a hypothetical 28 cm diameter area of contamination was therefore at least several seconds. If a conservatively low dwell time of 2 seconds is assumed, the following scan sensitivities are obtained:

Ambient level (cpm)	Cs-137 MDC (pCi/g)	Co-60 MDC (pCi/g)
10,000	4.5	2.3
20,000	6.4	3.3
30,000	7.9	4.0
40,000	9.1	4.6

The sensitivity of the scan for Cs-137 is adequate to detect screening DCGL levels of Cs-137 contamination (11 pCi/g) in surface soil in the presence of ambient radiation levels present in the special soils areas. However, as can be noted from this table, the scan cannot detect the DCGL level of Co-60 (3.8 pCi/g) at ambient background levels above approximately 26,000 cpm. Because the scan surveys were performed in July 2003, levels of Co-60 detectable at that time would be reduced by decay to approximately 0.85 times the above values, effective at the time this report was prepared (i.e., early November 2004). Thus a scan sensitivity below 4.5 pCi/g at the time of the survey would now satisfy the 3.8 pCi/g Co-60 screening criteria. Only one sampling location from beneath the reactor pool had an ambient gamma level (40495 cpm) such that the scan sensitivity at the time of survey would not currently satisfy the 3.8 pCi/g Co-60 concentration; approximately 3 additional months of decay will assure that this concentration was satisfied. In addition, the scan sensitivity estimate utilized a conservative dwell time. Also, the soils beneath the reactor room floor and the reactor pool are not surface soils, and any residual activity on their surface would undergo dilution by mixing with the other fill soil, which this report has demonstrated to contain residual activity well below the screening DCGLs. Results of the scan are thus considered adequate to demonstrate absence of small elevated areas of contamination in excess of project decommissioning criteria.

Results of gamma analyses of Mezzanine Crawl Space soil samples are summarized in Table 4-20. These samples contained maximum Co-60 and Cs-137 concentrations of 0.34 Ci/g and 0.18 pCi/g, respectively, but no other detectable radionuclides of license origin. Comparing these results with the Co-60 $DCGL_{surrogate}$ of 3.4 pCi/g indicates that residual activity is well below the guidance level. Gamma spectrometry of samples from this and several other "special soil" areas identified some samples containing positive concentrations of Cs-137 without corresponding elevated Co-60 concentrations, which would have been expected based on the choice of Co-60 as the surrogate radionuclide for demonstrating compliance. Therefore, to provide added confidence that project decommissioning criteria have been satisfied, the sum of fractions was determined for all gamma-emitting radionuclides of potential license origin, identified in the final status survey samples from "special soil" areas. The sum of fractions (maximum 0.107) was less than the Unity Rule criterion of 1.0.

Gamma analysis results for the Demineralizer Room wall excavation contained a maximum Co-60 level of 0.39 pCi/g and no other detectable concentrations of gamma emitters (see Table 4-21). All samples thus satisfied the Co-60 $DCGL_{surrogate}$ value of 3.4 pCi/g and the sum of fractions (maximum of 0.114) was less than the Unity Rule criterion of 1.0.

Table 4-20 Results of Gamma Spectrometry of Mezzanine Crawl Space Soil Samples

Sample [a] Location	Depth (cm)	Radionuclide Concentration (pCi/g)			Sum of [b] Fractions
		Co-60	Cs-137	Other	
13	0-15	<0.13	<0.13	None Detected	0.041
14	0-15	0.34 ± 0.13	<0.19	None Detected	0.107
15	0-15	<0.09	<0.08	None Detected	0.041
16	0-15	<0.19	<0.22	None Detected	0.077

17	0-15	<0.11	0.18 ± 0.09	None Detected	0.045

[a]Refer to Figure 4-23
[b] Co-60 DCGL = 3.8 pCi/g
Cs-137 = 11 pCi/g

Table 4-21 Results of Gamma Spectrometry of Demineralizer Wall Excavation Soil Samples

Sample [a] Location	Depth (cm)	Radionuclide Concentration (pCi/g)			Sum of [b] Fractions
		Co-60	Cs-137	Other	
1	0-15	<0.13	<0.12	None Detected	0.045
2	0-15	<0.23	<0.19	None Detected	0.078
3	0-15	0.39 ± 0.12	<0.12	None Detected	0.114
4	0-15	<0.11	<0.12	None Detected	0.040
5	0-15	<0.20	<0.16	None Detected	0.068

[a] Refer to Figure 4-21
[b] Co-60 DCGL = 3.8 pCi/g
Cs-137 DCGL = 11 pCi/g

Table 4-22 summarizes gamma spectrometry of surface soil samples from the remediated areas beneath the Reactor Room floor, near "M" and "B" cores. The maximum Co-60 level was 2.0 pCi/g in the sample from location 17. The maximum Cs-137 level was 7.10 pCi/g at sample location 3. No other gamma emitting radionuclides of license origin were detected. Based on the presence of Cs-137 without correspondingly elevated levels of Co-60, use of Co-60 is a surrogate to demonstrate compliance for these soils is not considered applicable. The sum of fractions (maximum 0.675) was less than the Unity Rule criterion of 1.0, thus demonstrating compliance.

Gamma spectrometry results for samples from beneath the reactor pool are summarized in Table 4-23. Samples from the 0-15 cm depths at locations 2 and 9 contained 4.23 pCi/g of Co-60 and 4.99 pCi/g of Co-60, respectively. Both of these concentrations exceed the Co-60 $DCGL_{surrogate}$ of 3.4 pCi/g. However, when averaged over an interval of 1 m, the resulting Co-60 concentrations are 1.09 pCi/g and 0.32 pCi/g, respectively. Both of these values and all other Co-60 concentrations in samples from below the pool are below the 3.4 pCi/g $DCGL_{surrogate}$ value. The maximum Cs-137 concentration in these samples was 0.38 pCi/g; Co-57 was identified in 3 samples at a maximum level of 0.15 pCi/g. No other gamma emitting radionuclides of license origin were identified. The sum of fractions for 0-15 cm depths (maximum 1.333) was greater than the Unity Rule criterion of 1.0, but when averaged over the 1-m interval the maximum sum of fractions value was 0.306.

Concentrations of gamma emitters in soil samples from the surface of fill beneath the Reactor Room floor are summarized in Table 4-24. The maximum Co-60 concentration in these samples was 0.40 pCi/g; all samples were therefore well below the Co-60 surrogate DCGL of 3.4 pCi/g. No detectable levels of Cs-137 or other radionuclides of license origin were identified. The sum of fractions (maximum 0.117) was less than the Unity Rule criterion of 1.0.

Table 4-22 Results of Gamma Spectrometry of Soil Samples From "M" and "B" Areas

Sample [a] Location	Depth (cm)	Radionuclide Concentration (pCi/g)			Sum of [b] Fractions
		Co-60	Cs-137	Other	
1	0-15	<0.14	0.25 ± 0.13	None Detected	0.060
2	0-15	<0.14	0.19 ± 0.10	None Detected	0.054
3	0-15	<0.11	7.10 ± 1.05	None Detected	0.675
4	0-15	<0.22	0.30 ± 0.15	None Detected	0.085
5	0-15	<0.13	<0.14	None Detected	0.047
6	0-15	<0.21	<0.21	None Detected	0.074
7	0-15	<0.10	0.24 ± 0.10	None Detected	0.048
8	0-15	<0.14	<0.12	None Detected	0.048
9	0-15	<0.12	<0.12	None Detected	0.043
10	0-15	0.19 ± 0.15	<0.15	None Detected	0.064
11	0-15	<0.13	<0.11	None Detected	0.044
12	0-15	<0.14	<0.14	None Detected	0.050
13	0-15	<0.23	1.94 ± 0.35	None Detected	0.137
14	0-15	<0.11	0.11 ± 0.05	None Detected	0.039
15	0-15	0.29 ± 0.10	<0.16	None Detected	0.091
16	0-15	0.65 ± 0.11	<0.11	None Detected	0.181
17	0-15	2.00 ± 0.26	<0.24	None Detected	0.548

[a] Refer to Figure 4-22
[b] Co-60 DCGL = 3.8 pCi/g
Cs-137 DCGL = 11 pCi/g

Table 4-23 Results of Gamma Spectrometry of Soil Samples from Beneath Reactor Pool

Sample [a] Location	Depth (cm)	Radionuclide Concentration (pCi/g)			Sum of [b] Fractions
		Co-60	Cs-137	Other	
1	0-15	<0.18	0.24 ± 0.14	Co-57 (0.10 ± 0.08)	0.070
2	0-15	4.23 ± 0.37	<0.23	None Detected	1.134
2	0-100	1.09 ± 0.21	<0.21	None Detected	0.306
3	0-15	0.18 ± 0.09	0.38 ± 0.11	Co-57 (0.14 ± 0.08)	0.083
4	0-15	<0.19	<0.14	None Detected	0.063
5	0-15	<0.20	<0.15	None Detected	0.067
6	0-15	<0.17	<0.12	None Detected	0.056
7	0-15	0.97 ± 0.17	<0.18	None Detected	0.271
7	0-100	0.67 ± 0.16	<0.18	None Detected	0.192
8	0-15	<0.22	<0.18	None Detected	0.074
8	45-75	<0.19	<0.23	None Detected	0.071
8	135-165	<0.21	<0.22	None Detected	0.075
8	225-255	<0.21	<0.26	None Detected	0.079
9	0-15	4.99 ± 0.43	<0.22	None Detected	1.333

9	75-105	0.24 ± 0.13	<0.21	None Detected	0.082
9	165-195	<0.23	<0.17	None Detected	0.076
9	285-315	<0.25	<0.20	None Detected	0.084
9	0-100	0.32 ± 0.13	<0.18	Co-57 (0.15 ± 0.10)	0.101
10	0-15	<0.23	<0.25	None Detected	0.084
10	75-105	<0.22	<0.22	None Detected	0.078
10	165-195	<0.17	<0.15	None Detected	0.059
10	225-255	<0.21	<0.18	None Detected	0.071
11	0-15	<0.19	<0.15	None Detected	0.064
11	15-45	<0.25	<0.22	None Detected	0.086
11	45-75	<0.21	<0.17	None Detected	0.70
11	75-105	<0.22	<0.21	None Detected	0.077
12	0-15	0.75 ± 0.17	<0.21	None Detected	0.216

[a] Refer to Figures 4-24 and 4-25
[b] Co-60 DCGL = 3.8 pCi/g
Cs-137 DCGL = 11 pCi/g
Co-57 DCGL = 150 pCi/g

Table 4-24 Results of Gamma Spectrometry of Surface Soil Samples From Beneath Reactor Room Floor.

		Radionuclide Concentration (pCi/g)			
		Co-60	Cs-137	Other	Sum of [b] Fractions
D	0-15	<0.11	<0.10	None Detected	0.038
E	0-15	<0.14	<0.11	None Detected	0.047
G	0-15	<0.16	<0.14	None Detected	0.055
H	0-15	<0.08	<0.07	None Detected	0.027
I	0-15	<0.10	<0.11	None Detected	0.036
IB	0-15	<0.09	<0.08	None Detected	0.031
IC	0-15	<0.09	<0.09	None Detected	0.032

		Radionuclide Concentration (pCi/g)			
J	0-15	<0.12	<0.10	None Detected	0.041
L	0-15	<0.11	<0.14	None Detected	0.042
N	0-15	<0.20	<0.14	None Detected	0.066
P	0-15	<0.10	<0.07	None Detected	0.032
R	0-15	<0.08	<0.07	None Detected	0.027
T	0-15	0.40 ± 0.11	<0.13	None Detected	0.117
V	0-15	<0.09	<0.12	None Detected	0.035

[a] Refer to Figure 4-25.
[b] Co-60 DCGL = 3.8 pCi/g
Cs-137 DCGL = 11 pCi/g

Results of gamma spectrometry analyses on samples representing 1-m intervals in fill beneath the Reactor Room floor are summarized in Table 4-25. No radionuclides of license origin were detected in these samples; maximum Co-60 was <0.27 pCi/g and maximum Cs-137 was <0.20 pCi/g. These results are well below the Co-60 surrogate DCGL of 3.4 pCi/g. The sum of fractions (maximum 0.087) was less than the Unity Rule criterion of 1.0.

Table 4-25 Results of Gamma Spectrometry of Soil Samples Representing 1-m Fill Intervals Beneath Reactor Room Floor

Sample [a] Location	Depth (cm)	Radionuclide Concentration (pCi/g)			Sum of [b] Fractions
		Co-60	Cs-137	Other	
B	460-560	<0.27	<0.18	None Detected	0.087
D	30-130	<0.17	<0.15	None Detected	0.059
E	0-100	<0.13	<0.11	None Detected	0.044
F	190-290	<0.23	<0.18	None Detected	0.077
G	210-310	<0.16	<0.16	None Detected	0.057
H	250-350	<0.23	<0.18	None Detected	0.077
I	0-100	<0.24	<0.19	None Detected	0.079
IB	570-670	<0.23	<0.18	None Detected	0.077
IC	130-230	<0.16	<0.16	None Detected	0.057
J	290-390	<0.13	<0.12	None Detected	0.045
L	310-410	<0.17	<0.15	None Detected	0.059
M	30-130	<0.18	<0.14	None Detected	0.060
N	380-480	<0.18	<0.15	None Detected	0.061
P	300-400	<0.24	<0.20	None Detected	0.081
R	110-210	<0.12	<0.12	None Detected	0.043
T	0-100	<0.13	<0.11	None Detected	0.044

[a] Refer to Figure 4-27
[b] Co-60 DCGL = 3.8 pCi/g
Cs-137 DCGL = 11 pCi/g

Table 4-26 summarizes the results of analyses for hard-to-detect radionuclides, performed on composite samples from the interior soil areas for supplemental information purposes. Samples of surface and subsurface soil from beneath the Reactor Room floor did not contain detectable concentrations of radionuclides of license origin. The sample of soil from beneath the reactor pool had detectable concentrations of Pu-238 and Pu-241 at 0.08 pCi/g and 2.43 pCi/g, respectively. The composite of Mezzanine Crawl Space samples contained detectable concentrations of H-3 and Tc-99 at 7.48 pCi/g and 0.22 pCi/g, respectively. Because the presence of Cs-137 raised concerns regarding the applicability of Co-60 as a surrogate to demonstrate compliance and assumptions that the characterization sample from the waste tank was representative of these interior "special soils," the positive concentrations of hard-to-detect radionuclides in the composites were individually evaluated. Theoretical maximum concentrations of these hard-to-detect radionuclides in individual samples are 1.60 pCi/g (20 x 0.08) of Pu-238, 48.6 pCi/g (20 x 2.43) of Pu-241, 37.4 pCi/g (5 x 7.48) of H-3, and 1.10 pCi/g (5 x 0.22) of Tc-99. These concentrations are below their respective screening DCGL values of 2.5 pCi/g, 72 pCi/g, 110 pCi/g, and 19 pCi/g. Absence of positive or otherwise significant levels of non-gamma emitting radionuclides in the composites provides an increased level of confidence in the approach of using gamma-emitters to demonstrate compliance. Analyses of the composites for supplemental information only, and therefore the numbers of samples in the composites are not limited, as would be appropriate, if the data were intended for use in demonstrating compliance.

Table 4-26 Analyses of Composite Samples from Interior Soil Areas

Radionuclide	Concentration (pCi/g)			
	Sample A*	Sample B*	Sample C*	Sample D*
Am-241	<0.13	<0.05	<0.13	<0.06
Fe-55	<1.03	<1.47	<1.36	<1.04
H-3	<5.48	<4.99	<7.38	7.48 ± 2.66
I-129	<0.23	<0.29	<0.24	<0.22
Ni-63	<9.61	<3.37	<4.95	<10.6
Pu-238	<0.13	<0.01	0.08 ± 0.05	<0.12
Pu-239	<0.12	<0.02	<0.06	<0.10
Pu-241	<7.96	<1.14	2.43 ± 1.42	<5.42
Sr-90	<1.23	<0.57	<0.87	<0.58
Tc-99	<0.30	<0.20	<0.31	0.22 ± 0.13

*Sample A: Surface soil beneath Reactor Room Floor (14 individual locations)
Sample B: Subsurface soil beneath Reactor Room Floor (16 individual locations)
Sample C: Soil beneath reactor pool (20 individual locations)
Sample D: Soil from Mezzanine Crawl Space (5 individual locations)

4.8.4 Conclusion

Several individual 0-15 cm samples from areas of piping leaks beneath the reactor pool contained Co-60 concentrations slightly above the $DCGL_{surrogate}$. However, when averaged over 1-m soil intervals, the concentrations were well within the DCGL value. Other interior soils areas did not contain levels of Co-60 or other gamma-emitting radionuclides above their DCGL values. Because some samples contained Cs-137 concentrations without correspondingly elevated levels of Co-60, use of Co-60 as a surrogate for demonstrating compliance was questionable. Sum of fractions for each sample was therefore calculated and all values were below the Unity Rule criterion of 1.0. Composite samples confirmed the absence of significant hard-to-detect radionuclides of license origin. Based on these findings, the interior soils satisfy established project decommissioning criteria.

4.9 Facility Ventilation

4.9.1 Description

Several systems provided ventilation for facilities having a potential for airborne radioactivity. The systems/components remaining after decommissioning, which were potentially radiologically impacted, are:

- Exhaust for fume hood in Room M005.
- Exhaust for fume hood in Room M008.
- Blower for fume hoods (2) in Room M019.
- Exhaust for source storage Room G022.
- Hot Cell exhaust.
- Reactor Room recirculation and exhaust.

Because the exhaust ventilation systems in laboratories M005 and M008 had become contaminated with Tc-99 and Ni-63, respectively, during research projects in those facilities, new fume hoods and ductwork between the hoods and the exhaust fans were installed in these rooms a short time before the reactor decommissioning activities began. The blower assembly was removed from Room M-008 during D&D operations; the original squirrel-cage blower for the M005 exhaust system remains, along with the ductwork downstream of both fan units. During facility operation, these systems exhausted through the outside laboratory walls and into vertical ducts on the building exterior; the vertical ducts discharged above the roof level through rain-cap covered stacks. The remaining exhaust ventilation systems in laboratories M005 and M008 are potentially impacted and were included in this survey. Because the new hoods and ductwork were never used for contaminated operations, the potential for contamination of those surfaces is considered negligible.

Fume hoods in Room M019 became contaminated with Tc-99. Hood baffles were removed and cleaned. Ductwork from the rear of the hood was removed up to and including the HEPA filter and housing. A short section of ductwork, which connected the exhausts from this facility to the former exhaust ventilation from the Hot Cell, remains. The Hot Cell exhaust duct from inside the Hot Cell to the blower in Room M020, remains; the HEPA filter box has been removed from the point where the ductwork joins the blower. The combined Hot Cell and M019 fume hood exhausts pass through a duct inside the Reactor Stack and discharge into the plenum of the Reactor Room exhaust fan.

Reactor Room air is exhausted through a duct near the ceiling of the Reactor Room into the suction plenum of the Reactor Room exhaust fan at the top of the Reactor Stack. At this location the duct from the Hot Cell/M019 hood and the Reactor Room are combined and exhausted through the plenum vertically on the roof of the Reactor Room.

There was a small exhaust from the source storage room (Room G022). The blower has been removed, but the ductwork which discharges at the Mezzanine level on the east end of the building remains.

Reactor Room air is conditioned by a recirculating system. This system draws make-up fresh air through the Reactor Room doorways and combines the fresh air with room air. This air stream is heated or cooled as needed and then discharged back into the Reactor Room through 12 vents, located at the base of the Reactor Room wall.

Figures 4-28 to 4-30 indicate the locations of the remaining potentially impacted ventilation system surfaces. Except for portions of the recirculating air vents, which are encased in concrete, there is access to interior surfaces of components of these ventilation systems to conduct surface activity scans and measurements. That access was adequate to demonstrate that radiological conditions satisfy decommissioning criteria.

The GTS Duratek initial characterization and continuing characterization by the CH2M HILL team showed that radiological contamination was generally low level and was limited to a small portion of the structure interior. The overall predominate radionuclides were Co-60 and Cs-137. Contamination of Hot Cell surfaces is primarily Cs-137. Ni-63 was present on facility surfaces from research projects in lab M008, and Tc-99 was present on facility surfaces in lab M005, respectively. Sufficient activity levels were not present on facility surfaces to enable a meaningful determination of the contaminant mixture – particularly for hard-to-detect radionuclides. Therefore an adjusted gross beta DCGL of 6320 dpm/100 cm^2 was developed for surfaces, based on the contaminant mix resulting from reactor effluents. With exception of the systems in labs M008 and M005, this adjusted gross DCGL is the basis for evaluating the final radiological status of ventilation system surfaces. For the systems in M008 and M005, the default screening value of 1.3E+6 dpm/100 cm^2 for Ni-63 is applicable (this is more restrictive than the value of 1.3E+6 dpm/100 cm^2 for Tc-99 and is used for simplicity in total surface activity.

4.9.2 Survey Activities

The following 5 survey units were established for remaining ventilation systems:

Survey Unit	Description
24	Reactor Stack
25	Hot Cell Exhaust Ventilation/M019 Blower
26	Reactor Room Recirculation Ventilation
61	Rooms M005 & M008 Exhaust Ventilation
61A	Room G022 Exhaust Ventilation

All ventilation system surfaces were classified as Class 1 for final status survey design and implementation.

Ventilation surveys were performed in a similar manner as surveys of facility piping. The number of data points required for the Sign Test was determined to be 18 (FSSP Addendum 008 in Appendix A). Direct measurements were obtained at equally spaced intervals to assure a minimum of 18 data points. Although the relative shift would be higher and the number of data points required would be lower for Ni-63 and Tc-99 as the contaminates, for consistency the number of data points (i.e., 18) remained the same for all survey units.

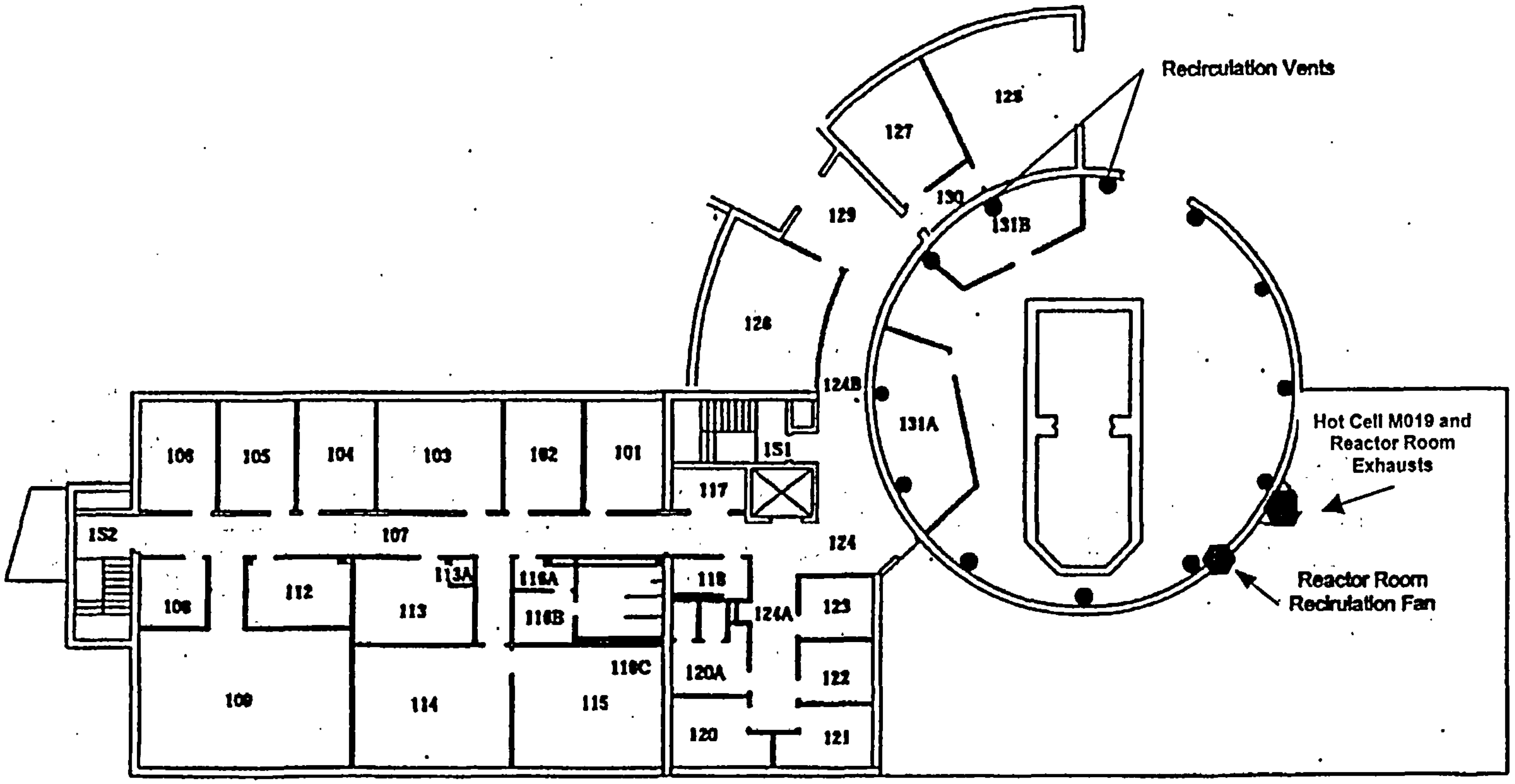

Figure 4-28 UVA Reactor First Floor Indicating Potentially Impacted Ventilation Systems.

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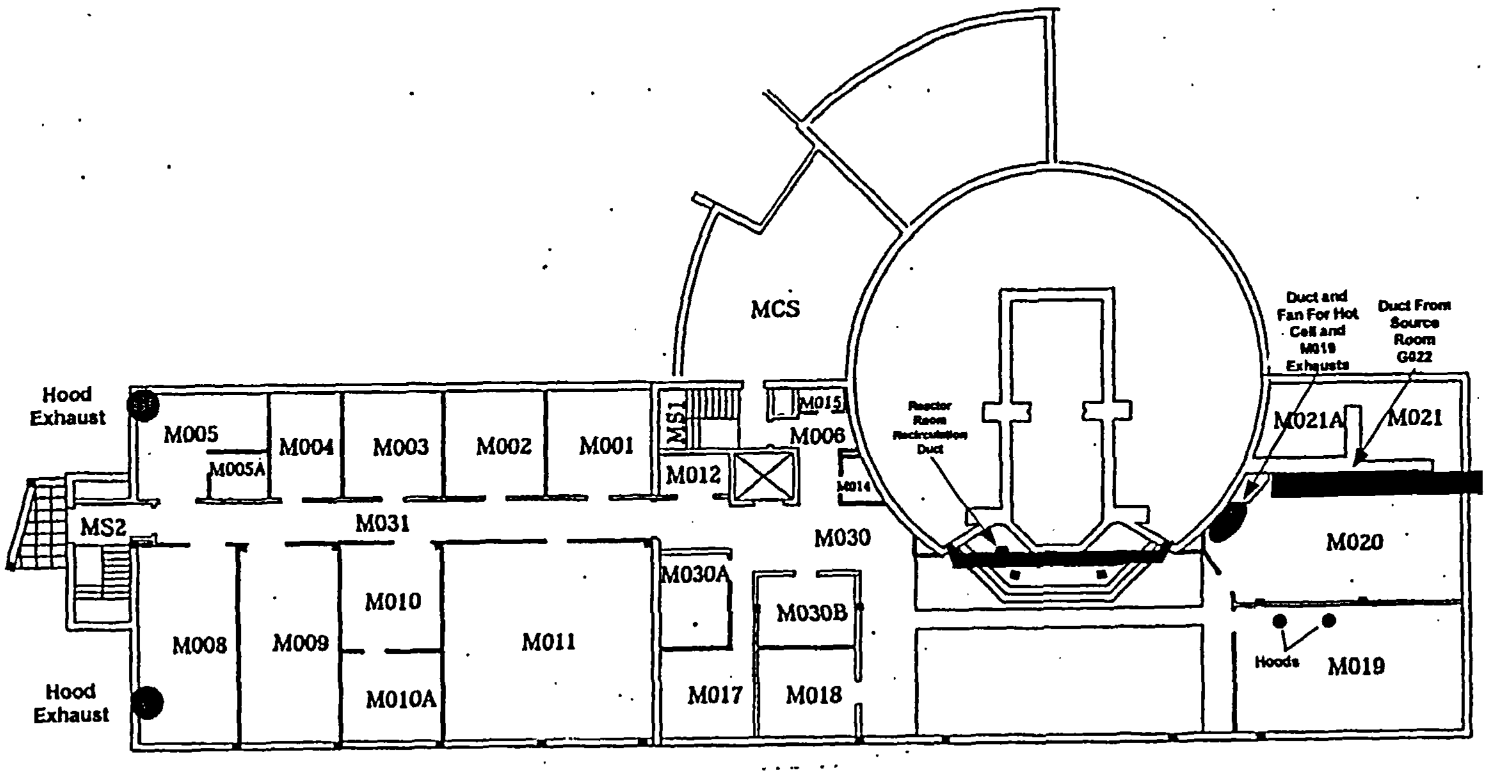

Figure 4-29 UVA Mezzanine Floor Indicating Potentially Impacted Ventilation Systems.

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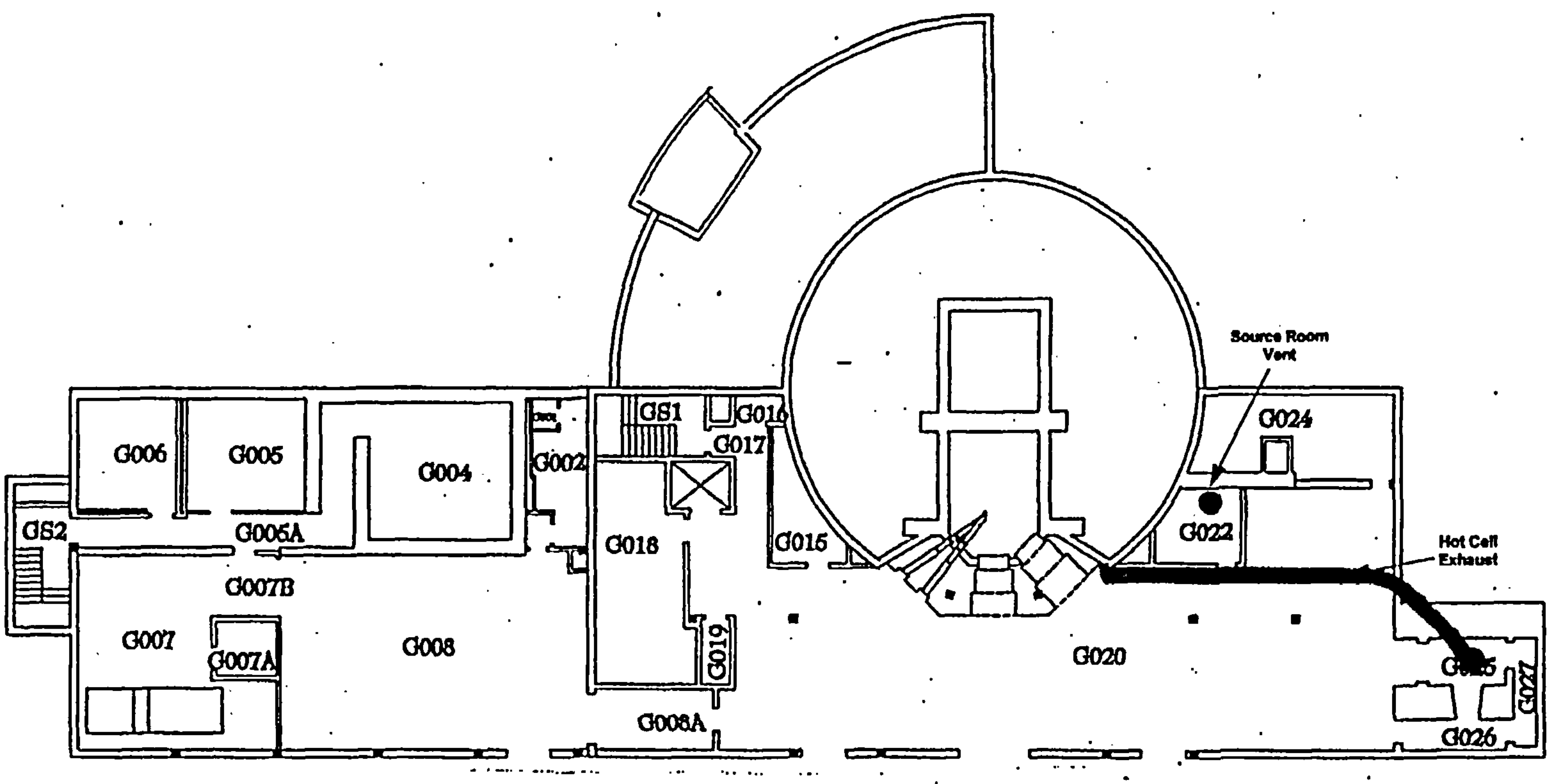

Figure 4-30 UVA Reactor Ground Floor Indicting Potentially Impacted Ventilation Systems.

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Gamma and beta scans of accessible Reactor Stack surfaces were performed inside the plenum on the roof, inside the air intake in the Reactor containment room, and at inlets to the stack plenum in the boiler room. Beta scans were performed on all other interior system surfaces.

Beta scans and surface activity measurements of interior surfaces of 6 in (or larger) ID ductwork were performed using a Model 43-68 gas proportional detector. Ductwork, which was not accessible with this detector, was surveyed using a Victoreen Model 491-30 GM detector (refer to FSSP Addendum 002 in Appendix A).

Interior duct surfaces were scanned by passing the detector through the duct. The rate of detector movement was approximately 1 detector width/sec for the gas proportional and pancake GM detectors and 2.5 to 3.0 cm/sec for the 491-30 GM detector. Model 2221 scaler/ratemeters used with the detectors were monitored for changes in audible signal and any indication of elevated count rate, suggesting possible presence of radioactive contamination, were noted for further investigation. Scan coverage was 100% of the accessible surfaces.

One minute static counts were performed at the designated systematic locations and at locations of elevated count rate identified by scans. Because of the variability in instrument background levels due to varying levels of naturally occurring radionuclides in building construction materials, appropriate reference areas were not applicable. Instead, unshielded and shielded measurements were performed at the same locations and difference compared to the contamination criteria. Smears and Masslinn swabs of duct surfaces were performed to identify the presence of removable activity.

Compliance with decommissioning requirements was demonstrated by comparing the beta activity measurements with the applicable guideline values, i.e., 1.3E+6 dpm/100 cm^2 for systems in Rooms M005 and M008 and 6320 dpm/100 cm^2 for all other ventilation system surfaces.

4.9.3 Survey Results

Detailed results of ventilation surveys are presented in Appendix B; the specific survey numbers are

Survey Unit	Survey ID Number	Description
24	UVA-FS-68	Reactor Stack
25	UVA-FS-69	Hot Cell Exhaust Ventilation/M019 Blower
26	UVA-FS-71	Reactor Room Recirculation Ventilation
61	UVA-FS-70	Rooms M005 & M008 Exhaust Ventilation
61A	UVA-FS-70	Room G022 Exhaust Ventilation

Gamma scans of the Reactor Stack ranged from 9,200 to 15,900 cpm; these levels are comparable to background gamma levels on masonry and brick materials. No locations of elevated direct radiation, which would suggest residual contamination, were identified.

Results of beta scans are summarized in Table 4-27.

Table 4-27 Beta Scans of Facility Ventilation

Survey Unit	Survey Unit	Location	Counts Per Minute		Instrument Set
			Minimum	Maximum	
UVA-FS-68	24	Reactor Stack	300	650	9 (b)
UVA-FS-69	25	Hot Cell Ventilation	170	390	9 (b)
UVA-FS-71	26	Reactor Rm Recirc Ventilation	190	460	9 (b)
UVA-FS-70	61	M005 & M008 Ventilation	200	500	9 (b)
UVA-FS-70	61A	Rm G022 Ventilation	10	26	15(a)
(a) 491-30 GM Detector					
(b) 43-68 Gas Proportional Detector					

Scans utilizing a Model 43-68 gas proportional detector ranged from 170 cpm to 650 cpm; those utilizing a Model 491-30 detector ranged from 10 cpm to 26 cpm. Higher ambient levels were observed in the stack of masonry/brick construction. No specific locations of elevated activity were identified.

Total activity measurement results are summarized in Table 4-28. The maximum activity level was 2,433 dpm/100cm^2 in the Reactor room recirculation ductwork. All systematic measurements were below the adjusted gross DCGL of 6320 dpm/100cm^2, (1.3 E+6 dpm/100 cm^2 for survey unit 61) thus statistical testing is not necessary to demonstrate compliance with the guidelines.

Table 4-28 Ventilation Beta Activity Measurement Summary

Survey Unit	Instrument Type	Number of Measurements	Beta Activity (dpm/100cm^2)			
			Minimum	Maximum	Mean	Std Dev
24	43-68	18	393	2351	1202	578
25	43-68	20	-326	1276	203	348
26	43-68	30	215	2433	595	542
61	43-68	18	-260	883	230	277
61A	491-30	19	-169	576	52	181

Smears obtained at the locations of direct measurements in ventilation systems contained a maximum level of 46 beta dpm/100 cm^2; all but a couple of these smears were below the detection sensitivity of 28 dpm/100 cm^2.

A Masslinn swab of the entire G022 duct had a positive beta activity of 990 dpm. This activity is representative of the entire system interior surface, estimated at between 3 and 4 m^2, and is therefore well within the guideline level of 632 dpm/100 cm^2. Smears at the inlet and outlet of this duct had <28 dpm/100 cm^2.

4.9.4 Conclusion

Surveys demonstrated that remaining potentially impacted ventilation systems do not contain residual contamination in excess of the applicable guideline levels and that the established project decommissioning criteria are satisfied.

5. Quality Assurance

Final status survey activities were performed by qualified and trained personnel, following documented procedures and using properly calibrated instrumentation. Activities were in accordance with the Master Final Status Survey Plan and the area/media-specific Addenda to that Plan. No deviations from plans or procedures that might adversely impact final status survey data quality or its evaluation were identified.

In addition, all activities were in accordance with the Quality Assurance Project Plan, developed specifically for this decommissioning project.

Instrumentation and other measuring devices were properly calibrated and data quality was assured through daily performance testing.

Measurements were duplicated at a frequency of 5% for quality control purposes. Table 5-1 summarizes comparisons of 30 duplicate measurements, from the initial FSS Survey Data Forms. Results are evaluated by Normalized Absolute Difference (NAD), where:

$$\text{NAD} = \frac{\left| Measurement^1 - Measurement^2 \right|}{\sqrt{(\sigma_1)^2 + (\sigma_2)^2}}$$

NAD should be <1.96. All of the QC measurement pairs satisfied this criterion.

Sampling was in accordance with documented plans. Equipment was decontaminated and monitored, where appropriate, to prevent cross contamination. Samples were controlled under chain-of-custody until transferred to a commercial laboratory that utilized industry-recognized analytical methods. With several minor exceptions, prescribed measurement sensitivities were met. The laboratory followed appropriate internal QA/QC procedures to assure data accuracy and defensibility.

Table 5-1 Normalized Absolute Difference for Duplicate Measurements

Survey ID UVA-FS-	Initial Measurement		Duplicate Measurement		NAD	NAD <1.96 ?
	Unshield	Shield	Unshield	Shield		
005	328	262	339	250	0.67	Y
010	544	754	551	356	0.12	Y
011	425	289	466	321	0.11	Y
013	439	391	469	364	1.40	Y
014	434	271	426	281	0.22	Y
015	346	259	354	277	0.28	Y
016	2429	346	2463	375	0.07	Y
017	413	401	410	337	1.54	Y
019	408	373	402	348	0.49	Y
021	442	322	410	310	0.52	Y
022	488	397	433	368	0.58	Y
023	496	337	466	360	1.30	Y
024	530	423	507	367	0.77	Y
025	419	297	432	329	0.49	Y
026	307	294	322	291	0.52	Y
027	301	291	279	326	1.65	Y
028	371	305	388	300	0.54	Y
029	335	285	326	287	0.04	Y
029	325	306	320	294	0.19	Y
030	296	314	301	327	0.23	Y
032	322	306	375	300	1.63	Y
033	122	128	127	127	0.27	Y
034	409	333	406	364	0.26	Y
035	302	258	316	71	0.03	Y
040	508	333	502	401	1.77	Y
041	396	288	387	270	0.25	Y
041	342	313	356	320	0.19	Y
042	182	180	180	180	0.07	Y
043	340	264	341	275	0.14	Y
044	727	348	701	313	0.20	Y

6. Summary

Final status surveys were conducted on building surfaces and soils, potentially impacted by licensed activities of the University of Virginia pool-type 2 Megawatt research reactor. These surveys were designed, implemented, and evaluated, following the guidance of MARSSIM and NRC supporting documents. Project decommissioning criteria were the conservative NRC default-screening values.

Monitoring before, during, and after remediation indicated that contamination was primarily low-level and was limited to a small portion of the facility. Contaminants were primarily Co-60 and Cs-137; a small number of samples also contained some hard-to-detect radionuclides, but levels were low relative to guidelines and occurrence was spotty.

Results of the FSS identified one small area of paving, requiring remediation and resurvey. Otherwise, the FSS demonstrated that remedial contamination of license origin is well below the default-screening guideline levels and that the facility satisfies project decommissioning objectives and criteria and qualifies for termination of NRC License No. R-66.

7. Works Cited

1. Characterization Survey Report for the University of Virginia Reactor Facility, GTS Duratek, March 2000.
2. University of Virginia Reactor Decommissioning Plan, GTS Duratek, February 2000.
3. Evaluation of Radiological Characterization Results Relative to Termination of NRC License R-123, University of Virginia, Charlottesville, Virginia, Safety and Ecology Corporation, January 2003.
4. University of Virginia Reactor Decommissioning Plan Summary, CH2M HILL, April 2004.
5. Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM), NUREG-1575, June 2001.
6. Consolidated NMSS Decommissioning Guidance, NUREG-1757, September 2002.
7. Residual Radioactive Contamination from Decommissioning, NUREG/CR-5512, Vol. 3, Parameter Analysis, October 1999 (Draft).
8. Evaluation of Surface Contamination -Part 1: Beta Emitters) and Alpha Emitters, ISO-7503-1, First Edition 1988-08-01.
9. Minimum Detectable Concentrations with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions, NUREG-1507, December 1997.
10. Approval of Final Status Survey Plan Coverage Change for License No. R-66-University of Virginia (TAC No. MA3737), Letter from D. E. Hughes (U.S. Nuclear Regulatory Commission) to P. Benneche (University of Virginia), March 31, 2004.
11. NMSS Decommissioning Standard Review Plan, NUREG-1727, September 2000.

Attachment 5

Instrument Set 11

Revision 1

Incorporates 3 calibration data sheets

Clarifying the use of Tc-99 and Ni-63
Calibration sources.

Replace existing 7 pages with these 10 pages

UVAP
DAILY FIELD SOURCE CHECK LOG - FIELD INSTRUMENT

Source Type. Tc-99/98TC4700730 Source Activity: 35800 DPM

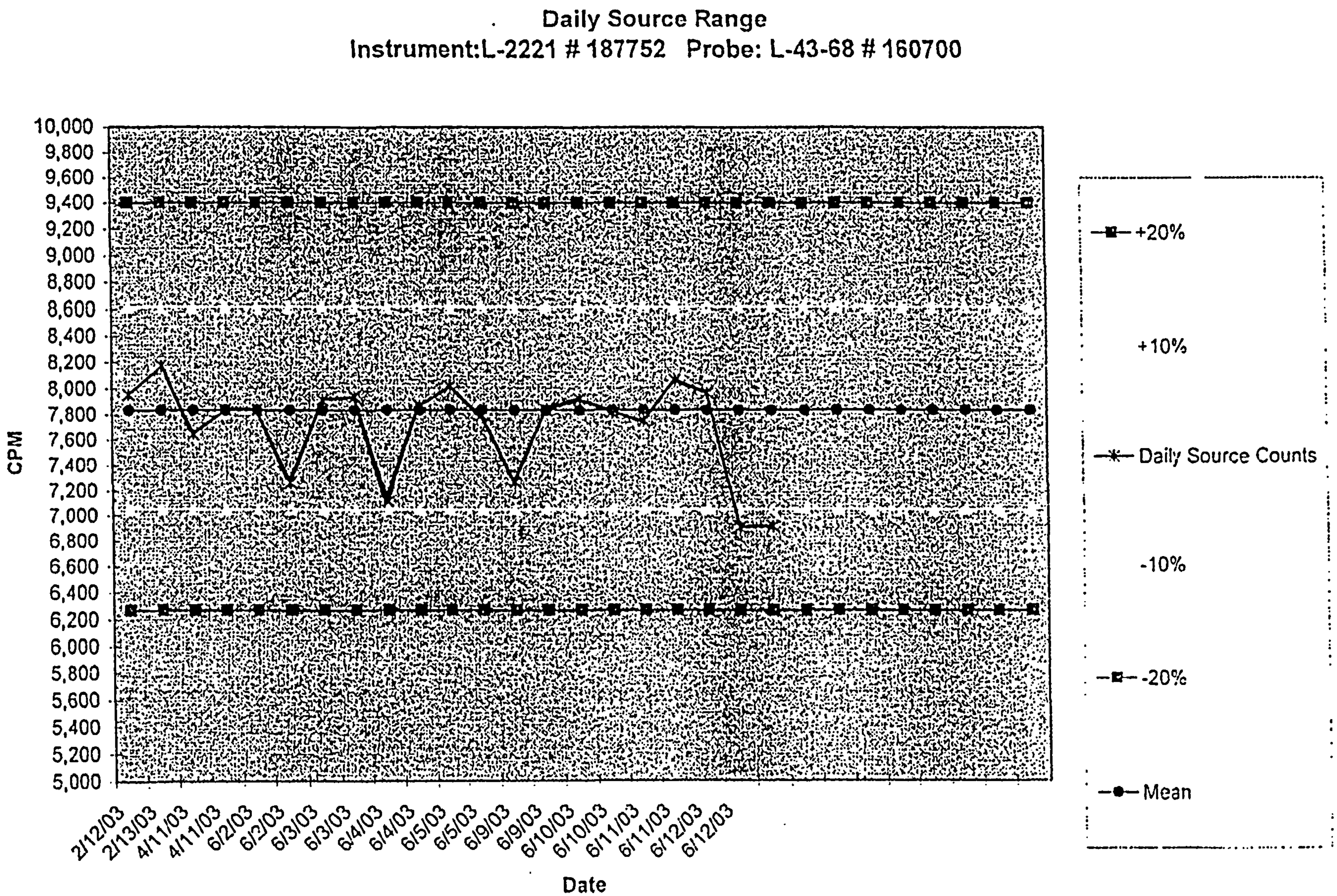
Instrument: L 2221 S/N: 187752 Voltage: 1700 Cal. Due: 1/16/04

ector: L43-68 S/N: 160700 Threshold: 100 Cal. Due: 1/16/04

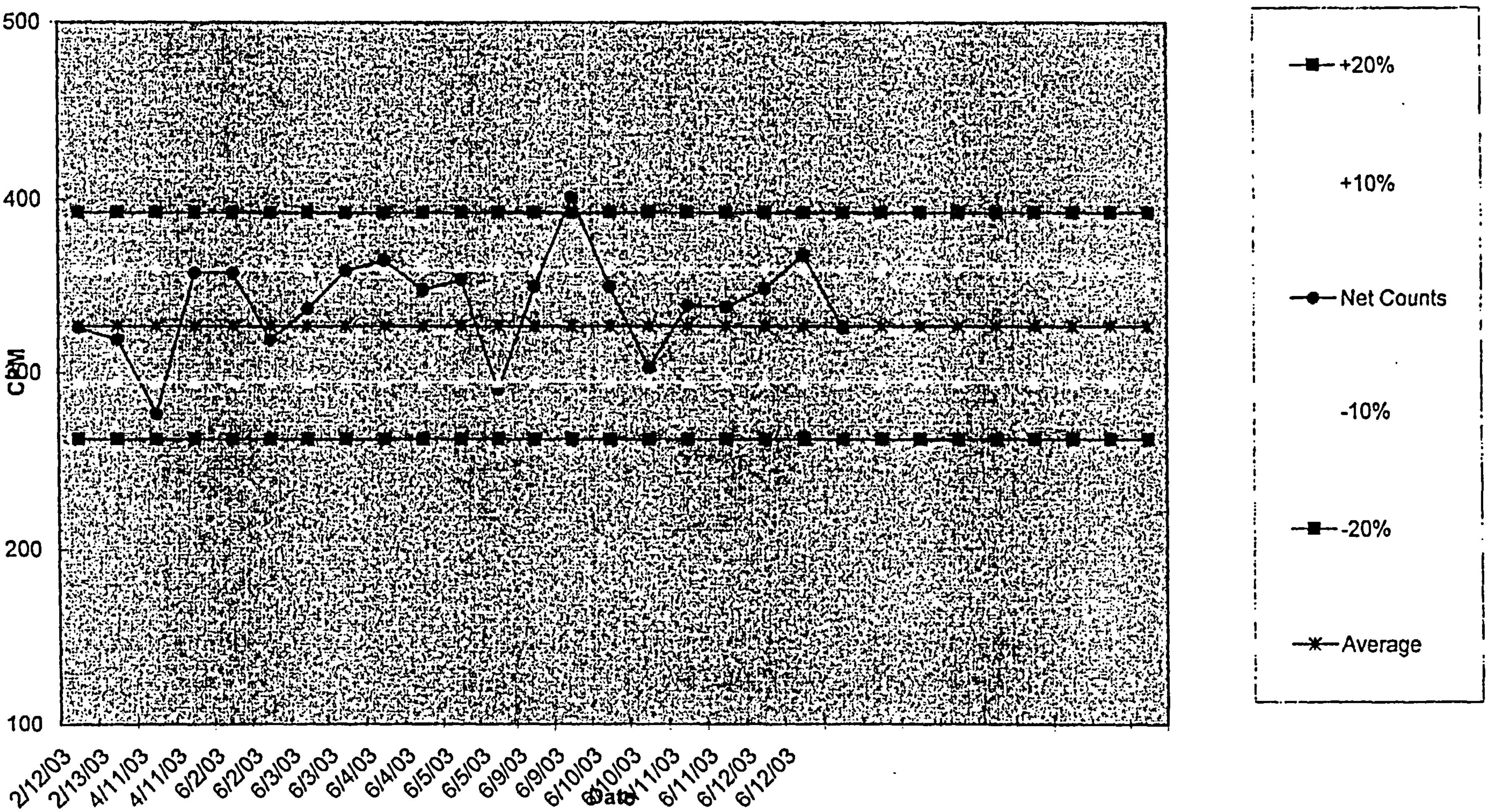
Date	Time	Source Check Gross CPM (A)	Bkg. cpm (B)	Net Counts	Eff. 2 Pi	HV	Batt.	Spkr.	Phys.	By
2/12/03	11:00	8278	326	7952		1700	6.3	ok	ok	BM
2/13/03	8:25	5,494	319	8175		1702	6.2	ok	ok	JS
4/11/03	11:05	7,920	276	7644		1700	6.1	ok	ok	JS
4/11/03	11:35	8,196	358	7838		1700	6.1	ok	ok	JS
6/2/03	10:14	7,580	319	7261		1700	5.9	ok	ok	BL
6/2/03	17:00	8,248	337	7911		1700	5.8	ok	ok	BL
6/3/03	7:30	8,297	359	7938		1699	5.9	ok	ok	BL
6/3/03	17:15	7,479	365	7114		1700	5.8	ok	ok	BL
6/4/03	7:55	8,216	348	7868		1700	5.8	ok	ok	JS
6/4/03	17:25	8,369	354	8015		1701	5.8	ok	ok	JS
6/5/03	7:48	8,080	290	7790		1700	5.8	ok	ok	BL
6/5/03	17:15	7,617	350	7267		1701	5.7	ok	ok	BL
6/9/03	7:39	8,233	401	7832		1700	5.8	ok	ok	BL
6/9/03	17:15	8,266	350	7916		1700	5.7	ok	ok	BL
6/10/03	7:22	8,115	303	7812		1700	5.7	ok	ok	BL
6/10/03	11:17	8,087	339	7748		1700	5.7	ok	ok	BL
6/11/03	8:30	8,400	338	8062		1700	5.7	ok	ok	JS
'/11/03	8:50	8,314	349	7965		1700	5.7	ok	ok	BL
6/12/03	8:56	7,274	368	6906		1700	5.7	ok	ok	BL
'2/03	9:40	7,241	326	6915		1700	5.7	ok	ok	BL

Remarks

+20% 9,401 (A) - (B) = (D) (Daily Calculated Efficiency)
-20% 6,267 Activity


Daily Source Range
Instrument:L-2221 # 187752 Probe: L-43-68 # 160700
10,000
9,800
9,600
9,400
9,200
9,000
8,800
8,600
8,400
8,200
8,000
7,800
7,600
7,400
7,200
7,000
6,800
6,600
6,400
6,200
6,000
5,800
5,600
5,400
5,200
5,000
CPM
2/12/03
2/13/03
4/11/03
4/11/03
6/2/03
6/2/03
6/3/03
6/3/03
6/4/03
6/4/03
6/5/03
6/5/03
6/9/03
6/9/03
6/10/03
6/10/03
6/11/03
6/11/03
6/12/03
6/12/03
Date
+20%
+10%
Daily Source Counts
-10%
-20%
Mean

Daily Background Range
Instrument:L-2221 # 187752 Probe: L-43-68 # 160700



Designer and Manufacturer of Scientific and Industrial Instruments

CERTIFICATE OF CALIBRATION

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

CUSTOMER SAFETY & ECOLOGY CORP ORDER NO. 291067 / 269336

Mfg. Ludlum Measurements, Inc. Model 2221 Serial No. 187752

Mfg. Ludlum Measurements, Inc. Model 43-68 Serial No. PR160702

Cal. Date 16-Jan-03 Cal Due Date 16-Jan-04 Cal. Interval 1 Year Meterface 202-159

Check mark ☑ applies to applicable instr. and/or detector IAW mfg. spec. T. 71 °F RH 20 % Alt 712.8 mm Hg

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

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

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

Instrument Volt Set Comments V Input Sens. Comment mV Det. Oper. Comments V at Comment mV Threshold Dial Ratio 100 = 4 mV

☑ HV Readout (2 points) Ref./Inst. 500 / 500 V Ref./Inst. 1992 / 2000 V

COMMENTS:

HV Alpha Voltage: 1250v
HV Beta Voltage: 1700v
Threshold: 4mv

Tc-99 Eff: 61%, Source Serial: 635183, Source Size: 14300cpm, Source Count: 9176cpm, Background: 325cpm (2π)
Ni-63 Eff: 26%, Source Serial: 4017, Source Size: 148575cpm, Source Count: 40612cpm, Background: 325cpm (2π)

FIRMWARE: 26 1010
Calibrated with 39" Cable

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

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

*Uncertainty within ± 10% C.F. within ± 20%

ALL Range(s) Calibrated Electronically

Digital Readout

REFERENCE CAL. POINT	INSTRUMENT RECEIVED	INSTRUMENT METER READING*
400 K cpm	40008 (S)	39888 (S)
40 K cpm	4001	3989
4 K cpm	400	399
400 cpm	40	40
40 cpm	4	4

Log Scale

REFERENCE CAL. POINT	INSTRUMENT RECEIVED	INSTRUMENT METER READING*
500 K cpm	500k	500k
50 K cpm	50k	50k
5 K cpm	5k	5k
500 cpm	500	500
50 cpm	50	50

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

Reference Instruments and/or Sources:

Cs-137 Gamma S/N ☐ 1162 ☐ G112 ☐ M565 ☐ 5105 ☐ T1008 ☐ T879 ☐ E552 ☐ E551 ☐ Neutron Am-241 Be S/N T-304

☐ Alpha S/N ☐ Beta S/N ☐ Other

500 S/N 189509 ☐ Oscilloscope S/N ☑ Multimeter S/N 80820360

Calibrated By: [signature] Date 16 Jan 03

Reviewed By: [signature] Date 20 Jan 03

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Bench Test Data For Detector

Detector 43-68 Serial No. PR160700

Customer SAFETY & ECOLOGY CORP Order #. 291067 / 269336

Counter 2221 Serial No. 187752 Counter Input Sensitivity ~~Comments~~ var 4 mV

Count Time 1 minute Distance Source to Detector Surface

Other

High Voltage	Background	Isotope Pu239 Size 12600 cpm	Isotope Tc 99 Size 14300 cpm	Isotope Size	Isotope Size
1150	0	6364			
1200	0	6497			
Alpha O.V. 1250	0	6445			
1300	3	6488			
1350	4	6485			
1650	144		7213		
Beta O.V. 1700	325		9176		
1750	711		9441		

Signature [signature] Date 16 Jan 09

Designer and Manufacturer of Scientific and Industrial Instruments

Work Order: 291067

TAG #: 269336

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POST OFFICE BOX 810 PH: 915-235-5494
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Date Received: 01/10/2003 Received Via: FESON Condition Received: FAIR / NO CABLES, BAD faces

SHIP TO:
SAFETY & ECOLOGY CORP
% UNIV OF VIRGINIA
675 OLD RESERVIOR RD
CHARLOTTESVILLE VA 22903
NUC RES FACILITY

BILL TO:
SAFETY & ECOLOGY CORP
SEC BUSINESS CENTER
2800 SOLWAY ROAD
KNOXVILLE TN 37931

CUSTOMER #: 11997

red

Reason for Return: Repair/Calibration Cal Interval \ Special Instructions: 1 YR / NI-63 EFF JTC 99 – Need 1-17

Comments: Cal'd – BOTH DETECTOR RE-WINDOWED / PR116722 RE-STRINGED

LABOR 3 hrs

ITEM	QTY	PART #	DESCRIPTION	PRICE	COST	ITEM	QTY	PART #	DESCRIPTION	PRICE	COST
01	1.00 EA	2221	M 2221 FOR REPAIR/CAL *187752			4	48"	21-9227	48" string	.10	4.80
02	1.00 EA	2221	M 2221 FOR REPAIR/CAL *187762			1,2	8	21-9313	D Batteries	—	—
	1.00 EA	43-68	M 43-68 FOR REPAIR/CAL *PR160700								
04	1.00 EA	43-68	M 43-68 FOR REPAIR/CAL *PR116722								

Instrument Calibrated: 2 at 50.00 Total Parts Cost: 4.80 Sub Total Calibration, Parts, and Labor: 269.80

Secondary Detectors: ______ at ______ Total Calibration Charge: 100 Shipping Charges: ______

Extended Calibration: ______ at ______ Total Labor: 165.00 Total Charges: ______

Labor: 3 hour(s) at $ 55.00 per hour

Signed: [signature] Date: 16 JAN 03

Released: [signature] Date: 20 Jan 03

DO NOT PAY! INVOICE TO FOLLOW

Date: 1/20/03 Contacted: MIKE PARTEN OK By: ______

Designer and Manufacturer of Scientific and Industrial Instruments

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501 OAK STREET FAX NO. 915-235-4672
SWEETWATER, TEXAS 79556, U.S.A.

CERTIFICATE OF CALIBRATION

CUSTOMER SAFETY & ECOLOGY CORP ORDER NO. 291067 / 269336

i. Ludlum Measurements, Inc. Model 2221 Serial No. 187752

g. Ludlum Measurements, Inc. Model 43-68 Serial No. PR160700

Cal. Date 16-Jan-03 Cal Due Date 16-Jan-04 Cal. Interval 1 Year Meterface 202-159

Check mark ☑ applies to applicable instr. and/or detector IAW mfg. spec. T. 71 °F RH 20 % Alt 712.8 mm Hg

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

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

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

Instrument Volt Set Comments V Input Sens. Comment mV Det. Oper. Comments V at Comment mV Threshold Dial Ratio 100 = 4 mV

☑ HV Readout (2 points) Ref./Inst. 500 / 500 V Ref./Inst. 1992 / 2000 V

COMMENTS:

HV Alpha Voltage: 1250v
HV Beta Voltage: 1700v
Threshold: 4mv

Tc-99 Eff: 61%, Source Serial: 635183, Source Size: 14300cpm, Source Count: 9176cpm, Background: 325cpm (2π)
Ni-63 Eff: 26%, Source Serial: 4017, Source Size: 148575cpm, Source Count: 40612cpm, Background: 325cpm (2π)

FIRMWARE: 26 1010
Calibrated with 39" Cable

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

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

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

	REFERENCE CAL. POINT	INSTRUMENT RECEIVED	INSTRUMENT METER READING*		REFERENCE CAL. POINT	INSTRUMENT RECEIVED	INSTRUMENT METER READING*
Digital Readout	400 K cpm	400008 (G)	39868 (G)	Log Scale	500 K cpm	500k	500k
	40 K cpm	4001	3989		50 K cpm	50k	50k
	4 K cpm	400	399		5 K cpm	5k	5k
	400 cpm	40	40		500 cpm	500	500
	40 cpm	4	4		50 cpm	50	50

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

Reference Instruments and/or Sources:

Cs-137 Gamma S/N ☐ 1162 ☐ G112 ☐ M565 ☐ 5105 ☐ T1008 ☐ T879 ☐ E552 ☐ E551 ☐ Neutron Am-241 Be S/N T-304

☐ Alpha S/N ☐ Beta S/N ☐ Other

☑ m 500 S/N 189509 ☐ Oscilloscope S/N ☑ Multimeter S/N 80820360

Calibrated By: [signature] Date 16 Jan 03

Reviewed By: [signature] Date 20 Jan 03

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

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

Designer and Manufacturer of Scientific and Industrial Instruments

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501 OAK STREET FAX NO. 915-235-4672
SWEETWATER, TEXAS 79556, U.S.A.

Bench Test Data For Detector

Detector 43-68 Serial No. PR160700

Customer SAFETY & ECOLOGY CORP Order #. 291067 / 269336

Counter 2221 Serial No. 187752 Counter Input Sensitivity ~~Comments~~ 4 mV

Count Time 1 minute Distance Source to Detector Surface

Other

High Voltage	Background	Isotope Pu239 Size 12600 cpm	Isotope Tc 99 Size 14300 cpm	Isotope Size	Isotope Size
1150	0	6364			
1200	0	6497			
Alpha O.V. 1250	0	6445			
1300	3	6488			
1350	4	6485			
1650	144		7213		
Beta O.V. 1700	325		9176		
1750	711		9441		

Signature [signature] Date 16 Jan 09

FORM C4A 02/23/94

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PROCUREMENT REQUISITION

Requestor: J.DeGroodt PR Date: 1/9/2003	Date Required: ASAP	Date Ordered: PO No:	Mod No:
Ship To: SEC LAB	Project/Site Name: Lab	Buyer's Signature:	
Attention: J.DeGroodt	G/L Number:	Selected Vendor:	
Street: 2800 Solway Road	Project No: 30-9337	Street:	
City/St/Zip: Knoxville, TN 37931	Dept. Number: 30	City/St/Zip:	
Phone: (865) 251-2074	Task/WBS/WR No:	Vendor Contact:	Confirming: Yes/No
Requested Shipper:	Estimated PO Value: $300.00	Promised Delivery Date:	Ship Via:

1	2	ea	repair & cal	Replace mylar windows on 43-68s SN pr160700 and pr116722 with	$77.00	$ 154.00
2				single layer mylar windows (.4 mg) and then calibrate them to the 2221s		$ -
3				using Ni-63. Only need the one efficiency for Ni-63		$ -
4						$ -
5	2	ea	calibration	Calibrate 2221s SN 187762 and 187752 with the two 43-68s	$50.00	$ 100.00
6				Please drop ship completed items to: Nuclear Reactor Facility		$ -
7				Attn: Frank Myers (434)982-5440		$ -
8				University of Virginia		$ -
9				675 Old Reservior Road		$ -
10				Charlottesville VA. 22903		$ -
					PO Total	$254.00

Suggested Vendors:	Vendor Contact:	Phone/Fax:	Reason Needed:	RADCON INFORMATION:
1 Ludium			Requested by J. Berger	PR Number:
2				Sample Location:
3				Client Requestor:
4				Client Charge/WBS Code:

CHECK ONE CHOICE:	YES	NO	Sole Source Justification:	QA Approval (If Critical Items): Date:
Can items be rented?		X	Manufacturer	
Client reimbursable?	X			Finance Approval (If non-reimb. & value >$5,000): Date:
Accountable Property?	X			
Critical items need QA review?		X	Rental Period or Period of Performance:	Project/Department Manager's Approval:
PR value within budget?	X		From ________ to ________	Date:

Unshaded Areas are to be completed by Requestor and Approvers. Draft Rev. 2/1/02

All Requestor and Approvers' signatures must include the date.