Plum Brook Reactor Facility

Final Status Survey Report

Attachment 8

Revision 1

Hot Laboratory
(Building 1112)

FINAL STATUS SURVEY REPORT
ROUTING AND APPROVAL SHEET

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Revision 1: Table 12 was revised in response to an NRC comment/question on the table. The comment requested that the final resolution or outcome of all investigative measurements be clearly identified in the column headed "Comments/Results". This was done – an entry was made in each row of the table; if no further action was required, it is so stated. If the measurement is >DCGL and EMC/EMT are required, the notation "see Table 14" is added.

A new appendix, Appendix D, was added. This appendix evaluates the effects of the revised radionuclide mixtures and DCGLs in the new PBRF Technical Basis Document, TBD-11-002, which was issued in January 2012, subsequent to the submittal of Rev. 0 of this report. The text in this report was edited in several places to point to Appendix D as appropriate.

The second sentence in the first paragraph of Section 5.3 was edited to clarify the convention for identification (labeling) of investigative measurements.

The sentence beginning in line 4 of the first paragraph on page 42 (the second paragraph in Section 5.5) was corrected. The corrected sentence states: "Each case in which the original and QC replicate measurement pairs did not meet the 20% RPD acceptance criterion was investigated, resolved and determined to be acceptable."

Also several typographical errors were corrected. These are:

- In the List of Acronyms and Symbols, corrections are made to the definitions of the entries for ALARA and $DCGL_W$.
- The Acronym LBGR was misspelled several places in the text – these are corrected.
- Typographical errors are corrected in Table 6. The entry for Design 24A, LBGR was corrected from 32,796 to 32,976 and the entry for σ was corrected from 748 to 763. A mis-matched type font in the first column Title was corrected.
- Table 12; in the fourth row from the end of the table, the Measurement ID is corrected to change "ENA-2" to "EMA-2".
- Several blank character spaces were removed from the text.

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LIST OF ACRONYMS & SYMBOLS

α	Alpha; denotes alpha radiation, also type I error probability in hypothesis testing
AEC	Atomic Energy Commission
ALARA	As Low as Reasonably Achievable
AF	Area Factor
β	Beta; denotes beta radiation, also type II error probability in hypothesis testing
b_i	background counts in observation interval
B_R	Background count rate
BPL	Byproduct License
cm	centimeters
c/m	counts per minute
cm^2	square Centimeters
cpm	counts per Minute
Δ	delta, $DCGL_W$ – LBGR
d'	scan surveyor sensitivity index
DCGL	Derived Concentration Guideline Level
$DCGL_{EMC}$	DCGL for small areas of elevated activity, used with the Elevated Measurement Comparison test (EMC)
$DCGL_W$	DCGL for average concentrations over a survey unit, used with statistical tests. (the "W" suffix denotes "Wilcoxon")
d/m	disintegrations per minute
dpm	disintegrations per minute
E_i	Detector or instrument efficiency
E_s	Surface efficiency
E_t	Total efficiency
EMA	An area of elevated activity where more than one investigative measurement is recorded.
EMC	Elevated Measurement Comparison
EMT	Elevated Measurement Test
EPA	US Environmental Protection Agency
FH	Fan House, Building 1132
FSS	Final Status Survey
FSSP	Final Status Survey Plan
FSSR	Final Status Survey Report
γ	gamma, denotes gamma radiation
g	gram
HDS	Hot Dry Storage
HTD	Hard To Detect
HL	Hot Laboratory, Building 1112. Also abbreviated as Hot Lab, mostly in Tables.
HPT	Hot Pipe Tunnel
IM	Lead characters for identification of investigative measurements
i	observation counting interval during scan surveys
in.	inch
kW	kilowatt
LMI	Ludlum Measurements, Inc.
LBGR	Lower Bound of the Gray Region

LIST OF ACRONYMS & SYMBOLS, Continued

m^2	square meters
mR/hr	milliRoentgens per hour
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
MDC	Minimum Detectable Concentration
MDC_{scan}	Minimum Detectable Concentration for scanning surveys
MDC_{static}	Minimum Detectable Concentration for static surface activity measurements
MDCR	Minimum Detectable Count Rate
MOU	Memorandum of Understanding
mrem	millirem
MW	Megawatt
MWD	Megawatt Days
NASA	National Aeronautics and Space Administration
N	Number of FSS measurements or samples established in a survey design
N/A	Not Applicable
NRC	US Nuclear Regulatory Commission
PBRF	Plum Brook Reactor Facility
PNL	Pacific Northwest Laboratory
Φ	Standard normal distribution function
p	surveyor efficiency for scan surveys
pCi/g	picocuries per gram
%	percent
QC	Quality Control
RAL	Remedial Action Level
RESRAD	RESidual RADioactive – a pathway analysis computer code developed by Argonne National Laboratory for assessment of radiation doses. It is used to derive cleanup guideline values for soils contaminated with radioactive materials
RESRAD-BUILD	A companion code to RESRAD for evaluating indoor building contamination and developing site-specific DCGLs
RPD	Relative Percent Difference
s	seconds
σ	generic symbol for standard deviation of a population
SAIC	Science Applications International Corporation
SM	Lead characters for identification of systematic measurements
SNL	Sandia National Laboratory
SR	Survey Request
t_b	background count time
t_s	sample count time
TBD	Technical Basis Document
μ	Mean activity concentration
UCM	Unusual Condition Measurement
UL	Upper limit of the confidence interval about the mean
VSP	Visual Sample Plan
$Z_{1-\alpha}$	proportion of standard normal distribution values less than $1-\alpha$
$Z_{1-\beta}$	proportion of standard normal distribution values less than $1-\beta$
∞	mathematical symbol for infinity

1.0 Introduction

This report presents the results of the final status radiological survey of the Plum Brook Reactor Facility (PBRF) Hot Laboratory (HL, Building 1112). It is Attachment 8 of the PBRF Final Status Survey Report (FSSR) [1]. This attachment describes the HL, its operational history and final condition for the final status survey (FSS). It describes the methods used in the FSS and presents the results.

As stated in the PBRF Final Status Survey Plan (FSSP) [NASA 2007], the goal of the decommissioning project is to release the facility for unrestricted use in compliance with the requirements of US NRC 10CFR20 Subpart E. The principal requirement is that the dose to future site occupants will be less than 25 mrem/y. Subpart E also requires that residual contamination be reduced to levels as low as reasonably achievable (ALARA). Derived Concentration Guideline Levels (DCGLs) for residual surface contamination on structures have been established for the HL.[2]

The FSS of the HL comprises mostly structure survey units. However, two survey units were established for soil that was exposed as a result of HL remediation. Single radionuclide Derived Concentration Guideline Levels (DCGLs) have been established for PBRF site soils in the FSSP. The principal soil radionuclides of PBRF origin are Cs-137, Co-60 and Sr-90. Their respective DCGLs are: 14.7, 3.8 and 5.4 pCi/g. The soil DCGLs are applied to surface and subsurface soils and to excavated and backfill materials.

The survey measurement results and supporting information presented herein demonstrate that residual contamination levels in each survey unit of the HL are well below the applicable DCGLs. Additionally, it is shown that residual contamination has been reduced to levels that are consistent with the ALARA requirement. Therefore, the HL meets the criteria for unrestricted release.

Section 2.0 of the report provides a description of the HL. This includes the building layout, its relation to other PBRF buildings and facilities, design and materials of construction, building contents and use, systems and services, building modifications, final configuration and scope of the FSS for this building.

A brief history of operations is presented in Section 3.0. A chronology of significant milestones is followed by history of operations with radioactive materials. Post shutdown and decommissioning activities are summarized. Results of radiological characterization surveys in support of decommissioning are presented.

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[1] The PBRF Final Status Survey Report comprises the report main body and several attachments. The attachments present survey results for individual buildings and open land areas. The entire final report will provide the basis for requesting termination of NRC Licenses TR-3 and R-93 in accordance with 10CFR50.82 (b) (6).

[2] As discussed in Section 4.0, several DCGLs have been established for FSS of Hot Laboratory structures in consideration of radionuclide mixtures established for various areas within the HL. The most restrictive of these is 30,960 dpm/100-cm^2 (with adjustments applied to account for the possible presence of insignificant radionuclides and embedded piping). Also it is noted that the structural DCGLs for the Hot Lab have been modified from the values originally used, to correct a calculation error in the Technical Basis Document, TBD-07-001 [PBRF 2007]. A new TBD has been issued to correct the errors in TBD-07-001, including revised radionuclide mixtures and revised DCGLs for the PBRF structures [PBRF 2012].

Section 4.0 presents the FSS design for the HL. This section includes applicable FSS Plan requirements, breakdown into survey units and assignment of MARSSIM classifications. The survey design approach, instrumentation and measurement sensitivities are described.
Survey results are presented in Section 5.0. This section includes a summary of the FSS measurements performed in the HL survey units, comparison to DCGLs, tests performed and an evaluation of residual contamination levels relative to the ALARA criterion.

Supporting information is contained in Appendices. Appendix A contains drawings and photos to supplement the text. Survey design maps, tables of coordinates and total surface beta measurement results for each survey unit are provided in Appendix B. Appendix C contains QC measurements. Appendix D presents an evaluation of the impacts of DCGLs that were revised to correct errors noted in the Technical Basis Document, PBRF-TBD-07-001 [PBRF 2007].

2.0 Hot Laboratory Description

The Hot Laboratory is a large (15,000 $ft.^2$ floor area), building located adjacent to the south side of the Reactor Building [NASA 2007]. The HL was designed to handle and analyze highly radioactive materials produced in the PBRF test reactor facility. Chemical, radiochemical and metallurgical analyses of irradiated experiment specimens such as moon rocks, various nuclear fuel materials and nuclear rocket components were performed in the HL. Activities conducted in the HL also included inspection, disassembly, and modification of reactor core components such as fuel elements, beryllium reflectors (sections and plates), the upper grid assembly and irradiated test materials. These activities involved the potential for significant radiological exposure to and contamination of personnel. Hot Laboratory activities were controlled by AEC/NRC licenses and PBRF operational and health safety procedures. The HL contained extensive concrete shielding (high density and standard concrete) in walls, floors and ceilings. Through-wall mechanical manipulators, periscopes, microscopes and other remotely controlled analytical equipment were also used to limit personnel exposures.

Most of the highly radioactive materials were transferred underwater from the Reactor Building to the Hot Laboratory. These were transferred from Canal F in the Reactor Building to Canal J in the HL. Canal J connected to Canal F via a water-tight lift door. From Canal J, materials could be transferred within the Hot Laboratory to the Hot Cells, stored in the Hot Dry Storage area, or stored underwater in adjacent Canal K. Also, some radioactive materials were transferred overland in shielded casks to HL work areas.

2.1 Building Layout and Construction

Figure 1, on page 4, a map of the main PBRF area, shows the HL, Reactor Building and other principal support buildings. Views of the HL building exterior are shown in Exhibit 1 of Appendix A. The main operating floor of the HL contained seven hot cells and support and work areas. These included a hot work area, a cold work area, equipment areas, a manipulator repair room and an equipment repair area. Support areas included an isolatable Hot Handling Room behind Hot Cells 1 and 2 and two dry storage areas - one with a hot sample storage cave located below grade. A decontamination room, change room and showers, hot and cold lavatories and an office were also located on the 0 ft. elevation. Figure 2, on page 5 shows a plan view of the main operating floor at the 0 ft. elevation. Exhibit 2 of Appendix A, a photo of a scale mockup, provides a three dimensional perspective view of the operating floor layout.

Hot Cells 1 and 2 are located west of Canal J and the Hot Dry Storage area. Hot Cells 3 through 7 are South of Hot Cells 1 and 2 and are accessed through the Hot Work Area, Room 16. The primary purpose of each Hot Cell was as follows:

Hot Cell 1 - hot cutting and dismantling,
Hot Cell 2 - machining,
Hot Cell 3 - physical testing,
Hot Cell 4 - metallographic preparation,
Hot Cell 5 - metallographic examinations,
Hot Cell 6 - chemical analysis and
Hot Cell 7 – other analytical measurements.

Hot cell operations were controlled from the area identified as Room 8, also indentified as the Cold Work Area and the Viewing Gallery. Photos of this area are shown in Exhibit 3 of Appendix A. The hot cell front walls were constructed of four-foot thick high-density concrete, side walls of three-foot thick high-density concrete and rear walls of four foot thick standard concrete. As seen in Exhibit 3 of Appendix A, the hot cell front walls contain numerous penetrations for manipulators, leaded glass viewing windows, periscopes, analytical instruments and conduit. Motor-driven barrier doors between Hot Cells 1 and 2 and 3 through 7 and a transfer drawer between Cells 2 and 3 provided a means to transfer materials between cells. As shown in Exhibit 10 of Appendix A, the hot cell rear walls had removable four-foot thick shield doors and other penetrations, including an 18 inch diameter cut-off port in the rear wall of Hot Cell No. 1. Access to the hot cells could also be gained from above through two- foot thick removable roof slabs at the 17.5 ft. elevation. Cells 1 through 7 each had one 19-inch circular access plug in the roof slab and Cell 7 had two additional 16-inch roof plugs.

Canals J and K, Hot Dry Storage and the Off-Gas Cleanup Room were 25 ft. deep structures. Canals J and K extended below grade from the 0 ft. elevation and the latter two areas extended below grade from the 6.5 ft. elevation. A valve pit was located at the - 28-foot level (this valve pit was originally accessible from the reactor building -25 foot level). These areas totaled about 2500 square feet of floor space.

The Hot Pipe Tunnel (HPT) and its extension (a 6 ft. diameter corrugated metal pipe) to the Reactor Office and Laboratory Building (ROLB) are located at the -12 ft. elevation. The HPT entered the northwest corner of the HL from the Reactor Building. It exited the east side of the HL and entered the Fan House (FH) below grade at the west side. A large number of various sized process pipes ran through the HPT. These included contaminated and clean water piping systems (quadrant and canal water, primary cooling water, de-ionized and process water and radioactive waste water) and radioactively contaminated ventilation systems which serviced the hot cells, Reactor Tank vent, Containment Vessel ventilation and Off-Gas Cleanup system. The – 12 ft. layout is shown in Exhibit 4 of Appendix A. Exhibit 5 of Appendix A, a section view, shows the vertical arrangement of the Hot Pipe Tunnel, Canal J and the Hot Dry Storage Area.

Thick standard concrete walls and a roof surrounded the Hot Handling Room, in which Hot Cells 1 and 2, the Hot Dry Storage and Off-gas Cleanup System areas were located. The latter two areas were covered by removable 2.5 ft. thick concrete shield-slabs at the 6.5 ft elevation. The concrete over the Hot Handling Room (at the 35.5 ft. elevation) was covered by a conventional built-up 4 ply bitumen and gravel roof. The high roof over Room 16 was also a conventional 4 ply bitumen and gravel built-up roof over 1½-inch metal decking. The lower west side roof area, at the 19 ft. elevation, was of concrete slab construction, covered by 4-ply bitumen and gravel. The lower east side roof area covering was constructed of 1½ inch metal decking covered by 4-ply bitumen and gravel. Roof drains were installed in all roof areas and a fresh air intake housing structure was located on the east side lower roof. A 12x18 inch fresh air louvered intake was located on the south end of the west metal sided area. The exterior walls of the HL were constructed of concrete, except for fluted metal siding on the east, west and south walls above the 20-foot elevation.

Ground floor access to the HL was provided through two double door airlocks, one from the reactor building on the northwest side and one from the southwest side of the cold work area. A personnel door and a roll-up truck door were located on the east side of the building at ground level. Ground level access to Canals J and K was also available from the operating floor behind the hot cells. Locked access gates to the Hot Pipe Tunnel were located at the –12 ft. elevation in the FH and at the -15 ft. elevation in the ROLB.

Figure 1, PBRF NW Area Showing Hot Laboratory, Reactor Building, and Support Buildings

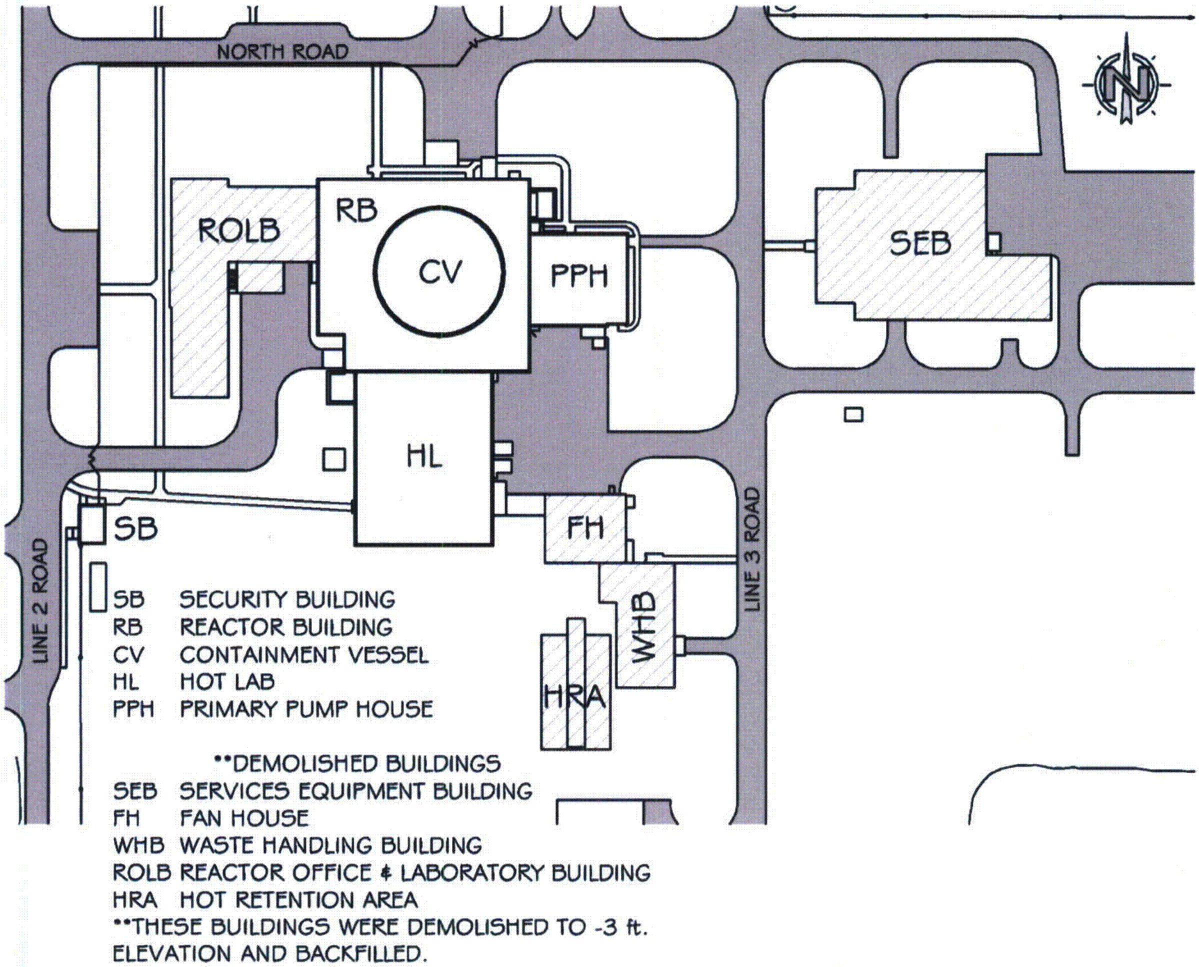
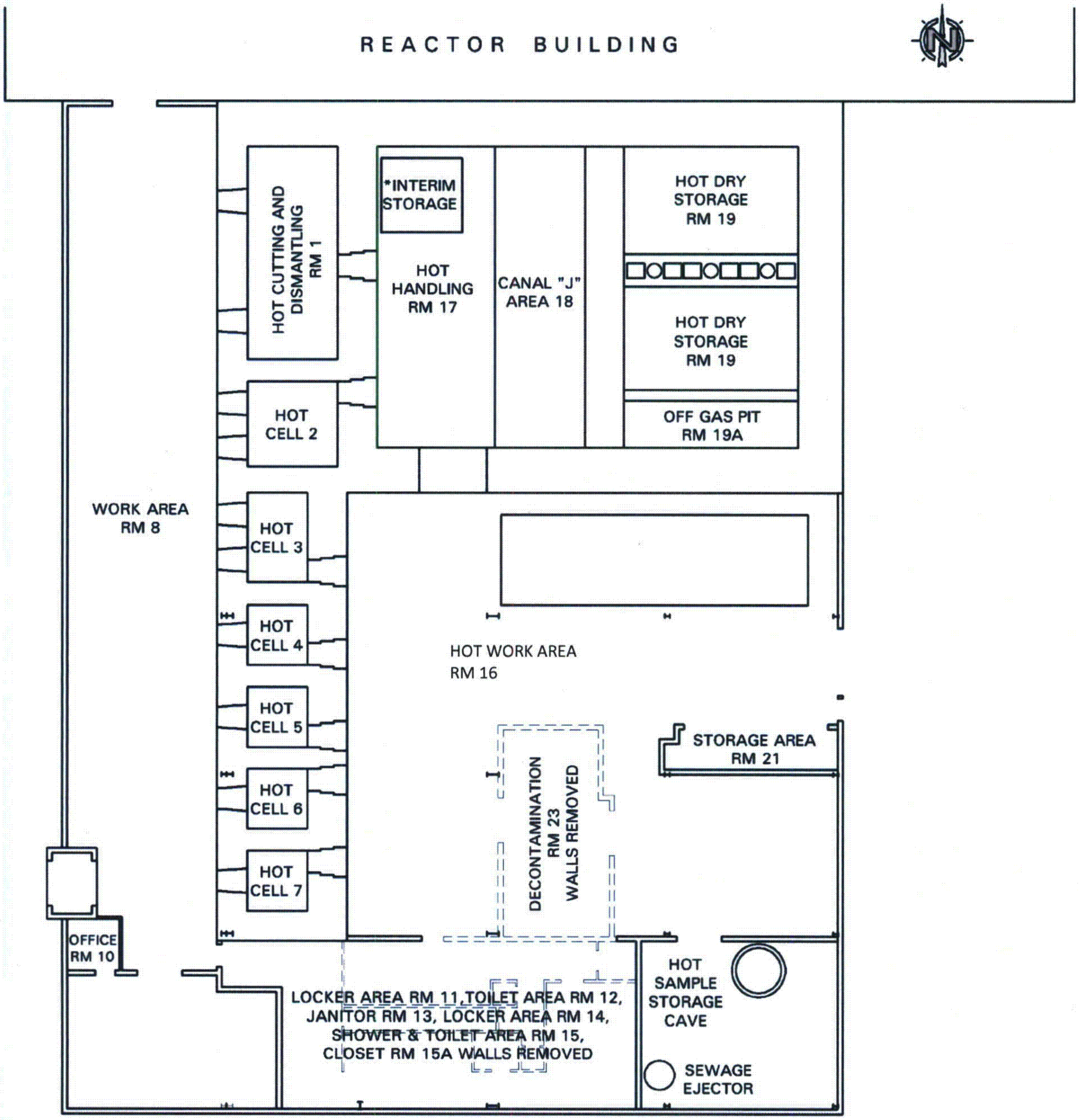


Figure 2, Hot Laboratory Operating Level Plan View



*INTERIM STORAGE AREA ADDED DURING DECOMMISSIONING

2.2 Building Systems and Services

Radioactive materials were transferred into and out of the Hot Laboratory in several ways. Reactor components and experiment hardware were routinely transferred underwater to the Hot Handling Room through the system of 25-foot deep water-filled quadrants and canals using transfer carts. Then, items destined for the hot cells were remotely removed from underwater to the rear of Hot Cell 1, placed on a tray attached to the Hot Cell 1 door front, and then the door was closed remotely to move the item into the cell. Further remote handling was conducted from the Cold Work area, or viewing area located at front side of the hot cells. Other items were transferred at grade level to the rear of the hot cells. For example, the large irradiated Lockheed cryogenic test loop was transferred overland from the Reactor Building experimental air lock via special trailer into the Hot Laboratory through the rear truck door. Items such as rabbit capsules and other small irradiated experiment specimens were transferred in small casks to hot cells via opened rear shield doors. Irradiated materials and experiment specimens were transferred between hot cells through a pneumatic transfer system and through the motor-driven barrier doors.

Floor drains in the Cold Work Area, the Manipulator Repair Area, the Cold Rest Room Area, and the Mezzanine drained directly to the outside storm sewer system. The remainder of the HL floor drains on the first floor (hot cells, hot work areas, hot change rest rooms, etc.) and in the HPT went to the HL hot sump at the - 12 ft. level. Floor drains from the Off-gas System and Hot Dry Storage went to the Process Piping Pump Room hot sump in the Reactor Building.

The HL atmosphere was maintained at a negative pressure such that any air leakage was into the building. The HL air ventilation systems were exhausted from the building through the HPT to the Fan House. Since there was potential for release of airborne radioactive contamination and radioactive gases within the HL, the vent systems exhaust was filtered, monitored, and then released through the 100 foot high Fan House stack.

The HL contained five permanently mounted cranes. A 15-ton crane serviced the Hot Work Area (Room 16) behind Hot Cells 3-7. A combined 20-ton and 5-ton crane in the Hot Handling Room (Room 17), was located above and behind Hot Cells 1 and 2. A 5-ton crane on a monorail operated along Canal K to the east truck door. A smaller crane, with about one ton capacity, was located inside the Hot Dry Storage area and was operated remotely from the Reactor Building south wall area. A one-ton rail crane ran the length of the Hot Cell Operating Galley (Room 8) above the master-slave manipulators. A traveling bridge and ladder over Canal J provided access to Hot Dry Storage and the Off-gas Cleanup areas at six and one-half feet above grade level. These areas were covered with two and one-half foot thick removable concrete slabs

2.3 Building Modifications

The Hot Laboratory was operated as designed and built, with only minor modifications during the PBRF operating period. Stainless steel liners were installed in the hot cells, circa 1962, to facilitate decontamination. In the 1980s and 1990s, the roofing material was removed from the HL and a layer of foamed material added to limit water leakage into the building.

2.4 Final Configuration and Scope

The scope of FSS reported in this attachment includes remaining building interior surfaces and exterior concrete surfaces. All hot cell manipulators, viewing windows, movable shields and associated mechanical and electrical equipment have been removed from the HL (see Section 3.5 for a discussion of equipment and materials removed during HL decommissioning). Most of the building interior partition walls on the 0 ft. elevation (except fixed shielding walls) have also been removed. The FSS covers remaining surface attachments, temporary safety covers and small embedded fixtures that remain such as "unistruts", pipe and conduit stubs. It does not include piping embedded in Hot Laboratory building concrete or piping buried beneath or adjacent to the building. These results are reported in separate attachments to the FSS Report.[3] Exhibits 6 through 24 of Appendix A show the condition of the principal HL areas at the time of the FSS (2009-2011).

3.0 History of Operations

A chronology of major milestones is given below. This is followed by a discussion of building operations, post-shutdown and decommissioning activities. Emphasis is on operations with radioactive materials that could affect the final building condition and final status survey.[4]

3.1 Chronology

Major PBRF and Hot Laboratory milestones are listed below:

1956 – September, groundbreaking for PBRF.

1961 – June, 60 MW Test Reactor critical.

1961- 1964 HL testing.

1963 – Full Power 60 MW Test Reactor operations begin.

1964 - HL operational.

1973 - January 5th, Reactor shutdown.

[3] The FSS of embedded piping is reported in Attachment 9 of the FSS Report. The FSS of buried and miscellaneous piping is reported in Attachment 17 of the FSS Report.

[4] Information sources for the history and pre-decommissioning period include, construction photos, construction drawings, PBRF Operating Cycle Reports, Radiochemistry periodic reports, PBRF Annual Reports, Unusual Occurrence Files, memoranda and other historical files maintained by PBRF Document Control.

1973 – June 30, PBRF facilities placed in "standby" condition.

1985 – Initial radiological characterization, Teledyne Isotopes Inc.

2002 – Decommissioning Plan approved.

2003-2004 - Equipment removal and initial building decontamination.

2006-2011 - Remediation of contaminated areas and preparation for FSS.

2011 – FSS measurements completed.

3.2 Startup and Operations

Hot Laboratory startup and testing occurred during 1961 to 1964 (full power, 60MW reactor operations began in 1963). Hot cell shielding, particularly the front walls, was tested in late 1963 using an 11 curie Co-60 source. No "leakage" was detected through shield walls or around windows. Streaming was noted around the manipulators and various penetrations; however. Additional shielding was installed to reduce the streaming. Subsequently in 1964, an irradiated reactor fuel element was used to confirm shielding adequacy in the hot cells and the Hot Dry Storage area. These tests showed that a fuel element source, producing a dose rate of 10^6 R/hr at one foot, could be handled in any of the hot cells and the Hot Dry Storage area without exceeding dose limits in the operating areas. The HL was then considered to be operational.

The HL was not manned continuously. Handling of reactor and test components within the HL, as well as analytical activities within the hot cells were mostly performed by day shift personnel. Roving shift personnel attended to back-shift activities such as material transfers in the canals and support equipment maintenance, repair and monitoring.

3.3 Radioactive Materials in the HL

The US Atomic Energy Commission (AEC) authorized operations and use of radioactive materials at the PBRF under several licenses.[5] License No.TR-3 (Docket 50-30) authorized the 60 MW test reactor. The 100 kW Mock-up Reactor was licensed under License No.R-93. A broad byproduct license (BPL) No. 34-06706-03, authorized possession and use of radioactive materials (byproduct material) produced by the Plum Brook 60MW and Mock-up reactors and other radioactive materials. Radioactive materials in the HL were those originating from PBRF tests and experiments [PBRF 2009].

Quantities of radionuclides handled in the Hot Laboratory included:

[5] Authority for the PBRF reactor and radioactive materials licenses was assumed by the US Nuclear Regulatory Commission in 1975.

- An estimated total of 384 grams of U-235 from various experiments, primarily fuel specimens were processed in the HL during the 1962-1973 period. About half was consumed in examination and about 10 per cent was lost in cutting and drilling. Of the cuttings and drillings (approximately 19 grams), at least half was vacuumed up, filtered out or processed as waste. Less than 10 grams of U-235 were calculated as lost down the drains. As the HL sump was cleaned several times over the operating period, only a small amount of U-235 remained in PBRF systems at shutdown.

- Activity of beryllium reflector pieces and associated steel fittings stored in the Hot Dry Storage Area was calculated on June 1, 1973. The assumed irradiation time was 46,000 Megawatt Days (MWD) of continuous exposure at 60MW. The calculated induced activity inventories were:

  - reflector plates: Zn-65, Fe-59, Ni-65 (680 Ci). H-3 (28,860 Ci), Sc-46 (224 Ci), Co-60 (213 Ci)
  - 304 stainless steel fittings: Fe-55 (1080 Ci), Co-60 (174 Ci), Cr-51 (36 Ci), Fe-59 (11 Ci).

- The calculated isotope inventory on the license governing by-product material operations on February 1, 1973 indicated: 22,200 Ci of Cr-51; 27,600 Ci of Fe-55; 34,600 Ci of Co-60; 1210 Ci of Mn-54; 6260 Ci of mixed fission products; 980 Ci of Kr-85; 123,000 Ci of Ta-182; 56 Ci of Xe-133; 10 Ci of Ra-226 and 19,500 Ci of tritium. A best estimate of the actual curie quantities present was one-half to one-third the calculated amounts [PBRF 2009].

Incidents reported in PBRF Operational Cycle reports that involved HL operations are summarized in Table 1. The list is not all-inclusive, but rather shows typical events that occurred during operations.

Table 1, HL Activities Covered in Unusual Incident Reports (1960-1973)

Report Cycle No.	Date	Description
30	12/24/64	An uncontrolled release of I-131 to the stack occurred when an Experiment 62-12 capsule containing a fuel pin was disassembled. I-131 levels of $9x10^{-9}$ µCi/cc were measured. The capsule was then sealed in a secondary container (Note – there were about 20 similar incidents reported through Cycle 93)
34	5/18/65	Contaminated water spilled in Hot Cell 6 leaked from the floor drain system into the HPT. An area of approximately10 ft^2 of the HPT floor below Hot Cell 6 was contaminated to $2x10^5$ dpm/100-cm^2. The area was decontaminated to 2000 dpm/100-cm^2.
39	10/13/65	An individual was exposed while repairing an experiment in the Hot Handling Room above dry storage. The estimated whole body exposure was 279 mrem and the extremity exposure was 324 mrem.
70	11/26/67	About one gallon of decontamination solution leaked from the Decontamination Room drain system onto the HPT floor. Contamination levels were greater than

Table 1, HL Activities Covered in Unusual Incident Reports (1960-1973)

Report Cycle No.	Date	Description
		50,000 dpm at one inch above the floor based on a GM survey meter measurement. The floor was decontaminated to within magenta-yellow zone limits. [6]
74	1/26/68	The HL hot sumps malfunctioned and caused contaminated water to backup through the floor drains onto the floors in the HPT and Fan House.
86	2/3/69	Between a pint and a quart of mercury was inadvertently dumped into a HL floor drain. About ½ pint was recovered.
125	4/22/71	While cutting parts of Experiment 69-01 in Hot Cell 1, filter monitors (33U02, 33U03, and 33U04) alarmed on high radiation. Monitor 33U03 read 100 mR/hr. The stack particulate filter showed gross beta-gamma activity of $2x10^{-11}$ μCi/ml. The major isotope identified was Ta-182.

3.4 Disposition of Materials in the Post-Shutdown Period

In the period between termination of reactor operations in January 1973 and June 30th of 1973, the Hot Laboratory Building was placed in standby status as was the entire PBRF. End condition statements were prepared which governed the status of each system for the protected safe shutdown mode.

Notification was received on January 5, 1973 that due to budget constraints, NASA was terminating all nuclear related research operations at PBRF. The Test Reactor, Mock-up Reactor, Hot Laboratory and all associated operations were to be shutdown and placed in a standby condition and the Reactor Staff terminated by June 30, 1973. Following notification, the 60MW test reactor was immediately shutdown. A Master Plan was developed to address activities associated with terminating the operating licenses for PBRF and placing the facility in standby status. Plum Brook Reactor Facility End Condition Statements for Protected Safe Storage Mode detailed the facility final condition status goals for mid-1973; including the Hot Laboratory.

During the shutdown period, the Hot Laboratory was utilized to disassemble and prepare HL and reactor components and experimental hardware for shipment. Near the end of the period, leaded glass windows, manipulators and analytical equipment in the hot cells were decontaminated and stored in place; tools were decontaminated and stored. The hot cell shield doors were closed and deactivated; cut-off port doors were closed and deactivated; Canals J and K were drained and isolated. The specimen storage device (Ferris Wheel) located in the Hot Cell 5 shield door plug, was emptied and placed in the closed position. The hot cells were decontaminated and the CO_2 fire suppression system removed. Highly radioactive materials, such as cadmium and stainless steel control rods and beryllium plugs, were inventoried and placed in Hot Dry Storage. Other radioactive materials were removed and shipped as radioactive waste.

[6] Control of contamination and radiation levels at PBRF were based on Radiological Control Zone Criteria published in Health and Safety procedures. For example, surface removable contamination Magenta-Yellow Zone limits were from 2 x background to 1000 d/m alpha and 2 x background to 1000 c/m beta-gamma.

During the period between 1973 and the start of decommissioning, activities at PBRF were controlled in accordance with the modified AEC and NRC licenses: TR-3, R-93 and BPL No. 34-06706-03. These licenses authorized possession only of the remaining radioactive materials on site, i.e., no facility operations were permitted. During this period, selected equipment, materials, and waste (both low-level radioactive and non-radioactive) were removed to other locations or discarded as the projected long-term goals for facility use changed from possible restart to standby to decommissioning. In 1982, the NRC terminated BPL 34-06706-03 based on NASA's request. A Decommissioning and Dismantling amendment to Licenses TR-3 and R-93 transferred any existing licensed radioactive materials to those licenses. For a brief history of the activities during this period see the NASA PBRF Decommissioning Plan, Section 1.2.1 Decommissioning Historical Overview [NASA 2007a].

The radiological status of the HL has been investigated during the period between July 1973 and start of decommissioning in 2002. The Hot Laboratory was included in an evaluation performed by Teledyne Isotopes, Inc. during 1984-86. The results were reported in a 1987 Report [TELE 1987]. The Teledyne Isotopes Report indicated that the majority of the radionuclide inventory in the HL was material stored in the Hot Dry Storage area. Significant contamination was present inside equipment, piping, drains and sumps. Hot Laboratory structures were extensively contaminated in areas where highly radioactive irradiated experiments and samples were handled (hot cells, Hot Handling Room, Decontamination Facility and Hot Dry Storage) and where process piping and equipment leaked. For example, Hot Pipe Tunnel survey results showed:

- contact dose rates of 6 to 2200 mR/hr were measured on piping,
- general area direct radiation measurements ranged from 2 to 85 mR/hr,
- removable surface beta-gamma contamination levels ranged from non detectable to 47,000 dpm/100 cm^2 (a hot spot from a line leak) and
- removable surface alpha contamination levels ranged from non detectable to 17 dpm/100 cm^2.

3.5 Decommissioning

It was recognized early-on in the decommissioning that contamination in the HL structure was widespread and significant remediation would be required. Extensive radiological surveys were performed to guide remediation efforts. A summary of survey results from the 2003-2004 time period is provided to illustrate contamination levels in the HL prior to remediation of the structure surfaces:

- Total surface beta contamination levels in the Hot Cells up to 1.2E+07 dpm/100-cm^2 and removable surface beta activity levels of up to 7.0E+03 dpm/100-cm^2 were measured. Total surface alpha activity of up to 900 dpm/100-cm^2 was measured in the hot cells.

- In the Hot Work Area, Decontamination Room and equipment repair areas, total surface beta activity levels of up to 1.7 E+06 dpm/100-cm^2 and removable activity of up to 2.5 E+03 dpm/100-cm^2 were measured.

- Surveys of the Locker Room, Lavatory and Manipulator Repair Area reported total surface beta activity levels of up to 7.8 E+04 dpm/100-cm^2 and removable surface beta activity of up to 2.5 E+03 dpm/100-cm^2. Direct surface alpha activity of up to 150 dpm/100-cm^2 was reported (in addition, 37 smears were collected in these areas and counted for alpha activity - all were < MDA). [7]

During 2004, the equipment, piping and pipe hangers, ventilation ductwork, and other interferences were removed from the Cold Work Area/Manipulator Repair Shop, making a larger portion of the floor, walls, and ceiling accessible to survey. During this time, the interior partition walls, piping and fixtures in the lavatory and locker room areas were also removed. Additional remediation was performed in these areas in 2006 through early 2008. Approximately ⅛ in. of the floor surface was removed using a floor shaver. The paint on the walls, ceiling, and steel beams was removed using a sponge blaster. Post remediation surveys were performed after the completion of these activities.[8]

The floor of the Hot Dry Storage Area at -25 ft. elevation was shaved to remove surface activity, and the top 6 ft. of the walls were shaved to remove the paint/mastic layer so that asbestos would not be a concern during building demolition. Trenches were cut in the floor concrete of the Interim Storage Pit and the Hot Dry Storage Area to remove volumetric contamination. Trenches were 100% scanned and static measurements taken. Cracks and boreholes were investigated and remediated as necessary. [9]

Contamination from leaking pipes and valves in the Hot Pipe Tunnel required an aggressive decontamination effort. All exposed surfaces were surface-cleaned and decontaminated. Floors and a small section of several lower wall areas were decontaminated by use of hydraulic hammers, concrete shavers and/or scabbing to a depth greater than 5 centimeters. The majority of the remaining wall and other surface areas were cleaned by sponge/grit blasting. A section of the main floor slab was removed and then re-poured after performing FSS of the exposed concrete edge and sub-floor surface soil. During 2006-2008, embedded piping and other wall and floor penetrations were surveyed and remediated to meet FSS criteria. Floor drains and other process lines that could not be remediated were removed. Remediated floor drains that were left in place and select other lines were grouted to meet FSS Plan requirements.[10]

In 2007 and 2008, the decommissioning contractor performed the following tasks in the Hot Cells:

- removed periscopes and manipulator arms, removed concrete blocks, screw gears and viewing windows,

[7] Contamination levels in the Hot Cells and support areas on the 0 ft. elevation prior to structure remediation are from the 2004 Supplemental Characterization Report, prepared by Montgomery Watson Harza [NASA 2004].

[8] Summary from Survey Design # 25.

[9] Summary from Survey Design # 40E.

[10] Summary from Survey Design # 24A.

- removed the crane in Hot Cells 1 and 2,
- removed highly radioactive material from the shielded storage container in Hot Cell 1,
- removed the hot cell door shield-plug rails,
- performed remediation, removal and release of the hot cell ceiling plugs,
- sponge blasted, scabbled and hammer drilled walls and floor,
- removed steel liners from hot cell walls and floor and
- performed spot remediation by scabbling areas above the Remediation Action Level (RAL).[11]

In 2010, the rolling assembly and hoist mechanism were removed from the overhead crane in the Hot Handling Room. See Exhibit 17 in Appendix A for before and after views of the crane disassembly.

4.0 Survey Design and Implementation for the HL

This section describes the method for determination of the number of fixed measurements and samples for the FSS of the HL. Applicable requirements of the FSS Plan are summarized. These include the $DCGL_W$[12], the gross activity DCGL, scan survey coverage and action-investigation levels, classification of areas and breakdown of the survey units. Radiological instrumentation and detection sensitivities are discussed.

4.1 FSS Plan Requirements

The DCGLs for individual radionuclides were obtained for PBRF structures considering exposure to future site occupants from two potential pathways. Single radionuclide DCGLs were calculated using RESRAD-BUILD Version 3.22 for a building reuse scenario. Single radionuclide volumetric DCGLs were calculated for subsurface structures using RESRAD Version 6.21 for a resident farmer scenario.[13] The volumetric DCGLs (in pCi/g) were converted to "effective surface" DCGLs (in dpm/100-cm^2) using surface-to-volume ratios for the assumed volume of contaminated subsurface concrete. The DCGL calculations are described in the FSSP, Attachment B. To obtain the DCGLs for PBRF structures, the smaller of the two DCGLs calculated for each of the radionuclides of concern were selected.

A gross activity DCGL is used for structural surfaces in the PBRF, where multiple radionuclides are potentially present in residual contamination. The gross activity DCGL accounts for the presence of multiple radionuclides, including beta-gamma and alpha emitters. The gross activity DCGL can also account for so-called hard-to-detect (HTD) radionuclides. The latter are not detected, or detected with very low efficiency, by the beta detectors selected for the FSS of structures.

[11] Remedial Action Levels were typically set at 50% of the applicable DCGL. Summary from Survey Design # 41B.

[12] The convention used in the MARSSIM is to identify the DCGL used as the benchmark for evaluating survey unit measurement results, as the $DCGL_W$. The "W" subscript denotes "Wilcoxon", regardless of the particular test used (Wilcoxon Rank Sum Test, or Sign Test).

[13] Potential exposure to future occupants from subsurface structures could occur from contaminated concrete rubble placed as fill and from contaminated intact structures such as the below-grade portion of the Reactor Bioshield.

The gross activity DCGL for the HL is calculated using equations in the FSSP for gross beta, gross alpha and surrogate DCGLs, based on the radionuclide mixture in residual contamination. Activity fractions and the gross activity DCGLs are shown in Table 2.

Table 2, Radionuclide Activity Fractions and Gross Activity DCGLs for HL Structures

Location	Radionuclides								$DCGL_W$ (dpm/100 $-cm^2$) (1) (2)
	H-3	Co-60	Sr-90	I-129	Cs-137	Eu-154	U-234	U-235	
	Activity Fractions Assigned to HL (1)								
Hot Cells	0.1045	0.0255	0.3302	0.0003	0.5379	0.0012	0.0004	0.00003	34,404
Hot Pipe Tunnel	0.0060	0.0203	0.3444	0	0.6240	0	0.0048	0.0005	35,781
All Other Areas	0	0.0058	0.1577	0	0.8347	0	0.0017	0.0001	38,647

Table 2 Notes:

1. Activity profiles and gross activity DCGLs for structures in this table are reported in the Technical Basis Document PBRF-TBD-07-001 [PBRF 2007]. As discussed in Appendix D, the gross activity DCGLs and radionuclide activity fractions for HL structures have been revised to correct errors discovered in TBD-07-001. However, the information in Table 2 was used in the design and evaluation of the Hot Lab FSS measurements and is reported here as such. The re-evaluation reported in Appendix D shows that the FSS Plan requirements remain satisfied, considering all the effects of the revised DCGLs, radionuclide mixtures and activity fractions.
2. In HL Survey Designs, the DCGL values are adjusted to account for dose contributions from "insignificant radionuclides" and embedded piping.

Survey designs incorporate requirements for scan coverage and investigation levels derived from the MARSSIM classification of survey units. The values applicable to the HL are shown in Table 3.

Table 3, Class-Based Survey Scan Coverage and Action Level Requirements

Classification	Scan Survey Coverage	Scan Investigation Levels (1)	Static Measurement or Sample Result Investigation Levels
Class 1	100%	> $DCGL_{EMC}$	> $DCGL_{EMC}$
Class 2	10 to 100%	> $DCGL_W$ or > MDC_{scan} if MDC_{scan} is > $DCGL_W$	> $DCGL_W$
Class 3	Minimum of 10%	> $DCGL_W$ or > MDC_{scan} if MDC_{scan} is > $DCGL_W$	≥ 50% of the $DCGL_W$

Table 3 Note:

1. The scan investigation levels shown above are as listed in the FSS Plan, Table 8-1. However, as described in Section 4.4 of this report, the scan investigation level was set to the $DCGL_W$ for Class 1 survey units.

4.2 Area Classification and Survey Unit Breakdown

The HL was divided into 41 areas for initial classification and final status survey planning as shown in Table 2-1 of the FSS Plan. All except two areas, the building roof and exterior walls, were classified as MARSSIM Class 1 in the FSS Plan. The roof was classified as Class 2 and the building exterior as Class 3. As part of the FSS implementation, individual survey units were established and their final MARSSIM classification assigned. The HL was divided into 140 survey units for the FSS (137 Class 1, two Class 2 and one Class 3). These are identified in Table 4. The table also shows the surface area of each survey unit and identifies key FSS implementation documents associated with each survey unit: the FSS Design and Survey Request. Note that Table 4 includes two soil survey units, both Class 1 (the FSS Plan did not identify any potentially contaminated soil areas associated with the HL).

Table 4, HL Survey Units for FSS

Survey Unit (1)	Class	Area (m^2)	Survey Design #	SR #	Description	Class in FSSP (2)
HL-1-1	1	61.9	25	125	Viewing Gallery Floor – Section 1	1
HL-1-2	1	54.9	25	125	Viewing Gallery Floor – Section 2	1
HL-1-3	1	45.2	25	125	Viewing Gallery Floor – Section 3	1
HL-1-4	1	50.6	25	125	Viewing Gallery Floor – Section 4	1
HL-1-5	1	46.1	25	125	Manipulator Repair Room Floor	1
HL-1-6	1	51.8	25	125	Locker Room Floor – Section 1	1
HL-1-7	1	53.4	25	125	Locker Room Floor – Section 2	1
HL-1-8	1	94.5	25	126	Viewing Gallery Wall - Section 1	1
HL-1-9	1	98.0	25	126	Viewing Gallery Wall - Section 2	1
HL-1-10	1	90.9	25	126	Viewing Gallery Wall - Section 3	1
HL-1-11	1	98.2	25	126	Viewing Gallery Wall - Section 4	1
HL-1-12	1	97.3	25	126	Viewing Gallery Wall - Section 5	1
HL-1-13	1	59.1	25	126	Manipulator Repair Room Wall – Section 1	1
HL-1-14	1	79.6	25	126	Manipulator Repair Room Wall – Section 2	1
HL-1-15	1	51.8	25	126	Locker Room Walls – Section 1	1
HL-1-16	1	75.4	25	126	Locker Room Walls – Section 2	1
HL-1-17	1	92.6	25	127	Viewing Gallery - Ceiling Section 1	1
HL-1-18	1	92.7	25	127	Viewing Gallery - Ceiling Section 2	1
HL-1-19	1	50.8	25	127	Viewing Gallery - Ceiling Section 3	1
HL-1-20	1	65.3	25	127	Manipulator Repair Room Ceiling & Steel Beams	1
HL-1-21	1	88.2	25	127	Locker Room Ceiling	1
HL-1-22	1	95.4	25	127	Locker Room Ceiling Beams	1
HL-1-23	1	95.4	40A	214	Hot Lab – Room 16 Ceiling – Section 1	1
HL-1-24	1	95.8	40A	214	Hot Lab – Room 16 Ceiling – Section 2	1
HL-1-25	1	96.8	40A	214	Hot Lab – Room 16 Ceiling – Section 3	1
HL-1-26	1	82.4	40A	214	Hot Lab – Room 16 Ceiling – Section 4	1
HL-1-27	1	82.4	40A	214	Hot Lab – Room 16 Ceiling – Section 5	1
HL-1-28	1	83.3	40A	214	Hot Lab – Room 16 Ceiling – Section 6	1
HL-1-29	1	70.2	40B	219	Room 24 – Floor & Sumps	1
HL-1-30	1	83.4	40B	219	Room 24 – North & East Walls	1

Table 4, HL Survey Units for FSS

Survey Unit (1)	Class	Area (m^2)	Survey Design #	SR #	Description	Class in FSSP (2)
HL-1-31	1	94.7	40B	219	Room 24 – South & West Walls, & Cantilever	1
HL-1-32	1	94.5	40B	219	Room 24 - Ceiling	1
HL-1-33	1	33.0	40B	219	Hot Work Area Crane – Section A	1
HL-1-34	1	72.2	40B	219	Hot Work Area Crane – Section B	1
HL-1-35	1	85.5	40C	221	Hot Handling Room - East Walls & Ceiling - North	1
HL-1-36	1	99.7	40C	221	Hot Handling Room - East Walls & Ceiling - East	1
HL-1-37	1	86.8	40C	221	Hot Handling Room - East Walls & Ceiling - South Wall	1
HL-1-38	1	95.3	40C	221	Hot Handling Room - East Walls & Ceiling - East	1
HL-1-39	1	65.7	40C	221	Hot Handling Room - East Walls & Ceiling - East	1
HL-1-40	1	59.7	40H	329	Hot Handling Room - Floor	1
HL-1-41	1	92.7	40E	298	Hot Handling Room – Room 17- North Wall	1
HL-1-42	1	79.5	40E	298	Hot Handling Room-Room 17 –Cell 1 and 2 Wall	1
HL-1-43	1	33.3	40E	298	Hot Handling Room-Room 17- Cell 1 and 2 Upper	1
HL-1-44	1	58.3	40E	298	Hot Handling Room-Room 17- South Wall 1	1
HL-1-45	1	72.9	40E	298	Hot Handling Room-Room 17- South Wall 2	1
HL-1-46	1	97.6	40E	297	Hot Handling Room-Room17- West Ceiling 1	1
HL-1-47	1	88.0	40E	297	Hot Handling Room-Room 17- West Ceiling 2.	1
HL-1-48	1	90.8	40E	297	Hot Handling Room-Room 17- West Ceiling 3	1
HL-1-49	1	85.3	40F	230	Hot Work Area Room 16- West Crane Steel (3)	1
HL-1-50	1	93.8	40F	231	Hot Work Area 16- West Crane Steel Section 2 (3)	1
HL-1-51	1	50.9	40F	231	Hot Work Area 16- West Crane Steel Section 3 (3)	1
HL-1-52	1	62.3	40F	230	Hot Work Area Mezzanine-Steel (3)	1
HL-1-53	1	90.1	40F	231	Hot Work Area 16- East Crane Steel Section 1 (3)	1
HL-1-54	1	94.7	40F	231	Hot Work Area 16- East Crane Steel Section 2 (3)	1
HL-1-55	1	77.5	40F	230	Hot Work Area 16- East Crane Steel Section 3 (3)	1
HL-1-56	1	52.9	40F	231	Hot Work Area 16-High Roof Framing Section 1(3)	1
HL-1-57	1	90.0	40F	231	Hot Work Area 16- High Roof Framing Section 2(3)	1
HL-1-58	1	80.5	40F/ 40G	230	Hot Work Area 16- High Roof Framing Section 3(3)	1
HL-1-59	1	87.5	40F	230	Hot Work Area 16-Low Roof Framing Section 1(3)	1
HL-1-60	1	97.7	40F	232	Hot Work Area 16- Low Roof Framing Section 2 (3)	1
HL-1-61	1	99.3	40F	232	Hot Work Area 16- Low Roof Framing Section 3 (3)	1
HL-1-62	1	89.5	40F	232	Hot Work Area 16- Low Roof Framing Section 4(3)	1
HL-1-63	1	52.2	40F	232	Hot Work Area 16- Low Roof Framing Section 5(3)	1
HL-1-64	1	44.3	41B	234	Hot Cells 3- 7 Floor	1
HL-1-65	1	85.3	41B	235	Hot Cell 3 Walls	1
HL-1-66	1	72.8	41B	235	Hot Cell 4 Walls	1
HL-1-67	1	73.0	41B	235	Hot Cell 5 Walls	1
HL-1-68	1	72.5	41B	235	Hot Cell 6 Walls	1

Table 4, HL Survey Units for FSS

Survey Unit (1)	Class	Area (m^2)	Survey Design #	SR #	Description	Class in FSSP (2)
HL-1-69	1	87.4	41B	235	Hot Cell 7 Walls	1
HL-1-70	1	49.0	41A	299	Hot Cells 1-2 Floor	1
HL-1-71	1	83.8	41A	300	Hot Cell 1 North & East Walls	1
HL-1-72	1	69.3	41A	300	Hot Cell 1 South & West Walls	1
HL-1-73	1	99.4	41A	300	Hot Cell 2 Walls	1
HL-1-74	1	81.8	40D	276	Hot Work Area 16-Storage Area (3)	1
HL-1-75	1	99.8	40D	276	Hot Work Area 16- West Wall Upper (3)	1
HL-1-76	1	79.6	40D	276	Hot Work Area 16-West Wall Lower (3)	1
HL-1-77	1	93.4	40D	276	Hot Work Area 16-North Wall West (3)	1
HL-1-78	1	78.6	40D	276	Hot Work Area 16-North Wall East (3)	1
HL-1-79	1	91.3	40D	276	Hot Work Area 16-East Wall Lower (3)	1
HL-1-80	1	96.4	40D	276	Hot Work Area 16-East Wall Upper (south) and South Wall (3)	1
HL-1-81	1	96.5	40D	276	Hot Work Area 16-East Wall Upper (3)	1
HL-1-82	1	93.6	40D	276	Hot Work Area 16-Columns A (3)	1
HL-1-83	1	37.6	40D	276	Hot Work Area 16-Columns B (3)	1
HL-1-84	1	96.8	40E	297	Hot Handling Room Crane - Section #1	1
HL-1-85	1	98.5	40E	297	Hot Handling Room Crane - Section #2	1
HL-1-86	1	66.3	40H	329	Hot Work Area Floor, Section #1 (3)	1
HL-1-87	1	66.0	40H	329	Hot Work Area Floor, Section #2 (3)	1
HL-1-88	1	67.3	40H	329	Hot Work Area Floor, Section #3 (3)	1
HL-1-89	1	60.6	40H	329	Hot Work Area Floor, Section #4 (3)	1
HL-1-90	1	65.7	40H	329	Hot Work Area Floor, Section #5 (3)	1
HL-1-91	1	62.9	40I	330	Hot Work Area Soils (3)	NC (3)
HL-2-1	1	70.8	40B	219	Mezzanine – Floor Section 1	1
HL-2-2	1	57.8	40B	219	Mezzanine – Floor Section 2	1
HL-2-3	1	86.9	40B	219	Mezzanine – Wall Section 1	1
HL-2-4	1	90.5	40B	219	Mezzanine – Wall Section 2	1
HL-3-1	1	50.1	24A	158	HPT - Floor – Section 1 & Sump	1
HL-3-2	1	71.4	24A	158	HPT - Floor – Section 2	1
HL-3-3	1	74.6	24A	158	HPT - Floor – Section 3	1
HL-3-4	1	71.7	24A	158	HPT - Floor – Section 4	1
HL-3-5	1	70.4	24A	158	HPT - Floor – Section 5	1
HL-3-6	1	63.9	24A	159	HPT - Corrugated Pipe Tunnel – Section 1	1
HL-3-7	1	63.2	24A	159	HPT - Corrugated Pipe Tunnel – Section 2	1
HL-3-8	1	68.9	24A	159	HPT - Corrugated Pipe Tunnel – Section 3	1
HL-3-9	1	47.9	24A	160	HPT - Walls – Section 1	1
HL-3-10	1	74.0	24A	160	HPT - Walls – Section 2	1
HL-3-11	1	87.7	24A	160	HPT - Walls – Section 3	1
HL-3-12	1	92.6	24A	160	HPT - Walls – Section 4	1
HL-3-13	1	96.2	24A	160	HPT - Walls – Section 5	1
HL-3-14	1	88.5	24A	160	HPT - Walls – Section 6 & Air Duct	1

Table 4, HL Survey Units for FSS

Survey Unit (1)	Class	Area (m^2)	Survey Design #	SR #	Description	Class in FSSP (2)
HL-3-15	1	88.9	24A	161	HPT - Ceiling – Section 1	1
HL-3-16	1	69.7	24A	161	HPT - Ceiling – Section 2	1
HL-3-17	1	89.0	24A	161	HPT - Ceiling – Section 3	1
HL-3-18	1	99.9	24A	161	HPT - Ceiling – Section 4	1
HL-3-19	1	42.0	24A	161	HPT - Ceiling – Vents & Penetrations	1
HL-3-20	1	57.0	24B	138	HPT - Floor – soil section	NC (4)
HL-3-21	1	20.7	24B	138	HPT - Floor – edges of removed section	1
HL-4-1	1	37.5	38B	212	Off-Gas - Floor, 6'6" Walkway, Top of North Wall	1
HL-4-2	1	88.9	38A	207	Off-Gas – North & East Walls	1
HL-4-3	1	93.4	38A	207	Off-Gas - South & West Walls	1
HL-4-4	1	77.5	38A	207	HDS - Beam	1
HL-4-5	1	43.6	38B	212	HDS – Floor – West section	1
HL-4-6	1	41.9	38B	212	HDS – Floor – East section	1
HL-4-7	1	95.7	38A	207	HDS – North Wall & Observation Window	1
HL-4-8	1	93.6	38A	207	HDS – West Wall	1
HL-4-9	1	96.3	38A	207	HDS – East Wall below beam	1
HL-4-10	1	86.2	38A	207	HDS – South Wall & East Wall above beam	1
HL-4-11	1	23.8	38B	212	Interim Storage – Floor and Pit	1
HL-4-12	1	56.9	38A	207	Interim Storage – East & West Walls	1
HL-4-13	1	69.8	38A	207	Interim Storage – North & South Walls and	1
HL-4-14	1	62.7	42A	243	Canal K - Floor	1
HL-4-15	1	95.3	42A	243	Canal K - North Wall	1
HL-4-16	1	84.6	42A	243	Canal K - East Wall & East Section of South Wall	1
HL-4-17	1	97.0	42A	243	Canal K - West Wall & West Section of South Wall	1
HL-4-18	1	46.30	42B	305	Canal J - Floor	1
HL-4-19	1	72.9	42B	305	Canal J - West Wall - North Section	1
HL-4-20	1	72.0	42B	305	Canal J - East Wall - North Section	1
HL-4-21	1	72.6	42B	305	Canal J - E & W Walls - South Section	1
HL-5-1	2	750	67	346	HL Exterior – Low Roof	2 (5)
HL-5-2	2	606	67	346	HL Exterior –High Roof	2 (5)
HL-5-3	3	1344	67	346	Hot Laboratory Exterior Walls	3

Table 4 Notes:

1. The FSSP Table 2-1 identified 41 HL survey areas that encompassed the survey units listed in this table. For the FSS, the HL areas were divided into survey units to meet FSS Plan classification-based size limits. Note that the HL survey units include two soil survey units, HL-1-91 and HL-3-20.
2. The FSS Plan classification was based on area history and available characterization data.
3. Survey units in Room 16 are identified in some FSS maps and documents as being in the "Warm Work Area". The correct identification is "Hot Work Area".
4. NC identifies a survey unit not included in the areas assigned a classification in the FSSP.
5. The low and high portions of the HL roof were not distinguished in the FSS Plan.

Table 5 summarizes the survey unit breakdown by major elevation.[14] The table illustrates the physical scale and complexity of the Hot Laboratory FSS. Note the inclusion of the Hot Pipe Tunnel in the HL FSS.

Table 5, HL Survey Unit Breakdown by Major Elevation

Major Elevation	No. of Survey Units	Surface Area (m^2)	% of Survey Units	% of Surface Area
Main Floor	91	7,057	65	54
Mezzanine	4	306	3	2
Hot Pipe Tunnel	21	1,488	15	11
- 25 ft. Elevation	21	1,508	15	12
Roof & Ext Walls	3	2,700	2	21
Total	140	13,060	100	100

4.3 Number of Measurements and Samples

The number of measurements and samples for each survey unit was determined using the MARSSIM statistical hypothesis testing framework as outlined in the FSS Plan. The Sign Test is selected because background count rates of instruments used in the FSS are equivalent to a small fraction of the applicable $DCGL_W$.[15] Decision error probabilities for the Sign Test are set at $\alpha = 0.05$ (Type I error) and $\beta = 0.10$ (Type II error) in accordance with the FSSP.

The Visual Sample Plan (VSP) software was used to determine the number of FSS measurements in the HL.[16] When the Sign Test is selected, the VSP software uses MARSSIM Equation 5-2 to calculate the number of measurements. The equation is shown below:

$$N = 1.2\frac{(Z_{1-\alpha} + Z_{1-\beta})^2}{4\left[\Phi\left(\frac{\Delta}{\sigma}\right) - 0.5\right]^2} \quad \textbf{(Equation 1)}$$

where:

[14] The calculations performed in preparation of Table 5 and other evaluations in preparation of this report are documented in a memorandum to the PBRF Decommissioning Project File [PBRF 2011].

[15] Background count rates for the LMI 44-116 detector, the instrument of choice for FSS surface beta activity measurements on structures, range from 200 to 300 cpm for most materials. This is equivalent to about 2500 dpm/100-cm^2; less than 10% of PBRF structure DCGLs (this assumes a detection efficiency of ~ 12%).

[16] The FSS Plan (Section 5.2.4) states that a qualified software product, such as Visual Sample Plan© [PNL 2010], may be used in the survey design process.

1.2 = adjustment factor to add 20% to the calculated number of samples, per a MARSSIM requirement to provide a margin for measurement sufficiency,
N = Number of measurements or samples,
α = the type I error probability,
β = the type II error probability,
$Z_{1-\alpha}$ = proportion of standard normal distribution < 1 – α (1.6449 for σ = 0.05),
$Z_{1-\beta}$ = proportion of standard normal distribution < 1 - β (1.2816 for β = 0.1),
Φ (Δ/σ) = value of cumulative standard normal distribution over the interval - ∞, Δ/σ,
Δ = the "relative shift", defined as the DCGL – the Lower Bound of the Gray Region (LBGR) and
σ = the standard deviation of residual contamination in the area to be surveyed (or a similar area). This may include the variation in measured "ambient" background plus the material background (for total surface beta measurements).

The MARSSIM module of VSP requires user inputs for the following parameters: α, β, LBGR, the $DCGL_W$ and σ. The numbers of measurements were calculated for the 140 HL survey units using the parameters established in 21 survey designs. Table 6 summarizes the HL survey designs and lists the values of the key VSP input parameters.

Table 6, HL Survey Design Summary

Design No.	Survey Units	Class (1)	DCGL (1) (2)	LBGR (1) (2)	Δ (1) (2)	σ (1) (2)	Δ/σ (1)	N (1)
25	HL-1-1 thru HL-1-22	1	34,782	32,502	2,280	760	3.0	11
40A	HL-1-23 thru HL-1-28	1	34,782	33,939	843	281	3.0	11
40B	HL-1-29 thru HL-1-34 Hl-2-1 thru HL-2-4	1	34,782	33,939	843	281	3.0	11
40C	HL-1-35 thru HL-1-39	1	34,782	33,939	843	281	3.0	11
40E	HL-1-40 thru HL-1-48	1	34,782	33,939	843	281	3.0	11
40F	HL-1-49 thru HL-1-63	1	34,782	33,939	843	281	3.0	11
40G	HL-1-58 resurvey	1	34,782	33,939	843	281	3.0	11
40H	HL-1-86 thru HL-1-90	1	34,782	33,939	843	281	3.0	11
40I (3)	HL-1-91, Hot Work Area Soils	1	9.7	4.85	4.85	1.9	2.55	11
41B	HL-1-64 thru HL-1-69	1	30,960	27,864	3,096	1,297	2.39	11
41A	HL-1-70 thru HL-1-73	1	30,960	18,576	12,384	5,226	2.37	11
40D	HL-1-74 thru HL-1-83	1	34,782	33,939	843	281	3.0	11
24A (4)	HL-3-1 thru HL-3-19	1	34,350	32,976	1374	763	1.8	12
24B (5)	HL-3-20 (soil)	1	5.87	2.935	2.935	1.77	1.7	14
24B	HL-3-21	1	34,350	17,175	17,175	10,305	1.7	14

Table 6, HL Survey Design Summary

Design No.	Survey Units	Class (1)	DCGL (1)(2)	LBGR (1)(2)	Δ (1)(2)	σ (1)(2)	Δ/σ (1)	N (1)
38B	HL-4-1, HL-4-5, Hl-4-6 & HL-4-11	1	33,236	19,649	13,587	4529	3.0	11
38A	HL-4-2 thru HL-4-4, Hl-4-7 thru HL-4-10, Hl-4-12 & HL-4-13	1	33,236	19,739	13,497	4529	3.0	11
42A	HL-4-14 thru HL-4-17	1	33,236	28,251	4,985	1856	2.7	11
42B	HL-4-18 thru HL-4-21	1	33,236	28,251	4,985	1856	2.7	11
42C	HL-4-18 resurvey	1	33,236	28,251	4,985	1856	2.7	11
67	HL-5-1 thru HL-5-3	2/3	24,449	12,224	12,225	4,890	2.5	11

Table 6 Notes:

1. The data reported in this table is obtained from the Survey Design reports listed where the DCGLs published in TBD-07-001 were used to calculate the number of measurements. As shown in Appendix D, the revised DCGLs do not result in any changes to the number of measurements shown in this table.
2. Units are dpm/100-cm^2, except for soil survey unit designs (Design 24B and 40I) which are pCi/g.
3. The DCGL used in Design 40I is 9.7 pCi/g Cs-137, with Cs-137 being the surrogate for Sr-90. The Co-60 DCGL for soil samples is 3.8 pCi/g.
4. Data shown for Design 24A are in conventional units for structure designs, dpm/100-cm^2. The original VSP design calculations used net cpm (for LMI 44-116 detector with typical detection efficiency). The values in the table are scaled to provide equivalent values in dpm/100-cm^2.
5. The DCGL used in Design 24B is the surrogate DCGL, calculated under the assumption that Cs-137 is the only nuclide measured. Both Co-60 and Sr-90 are "surrogated" to Cs-137.

Selection of design input parameters followed guidance in the FSS Plan. The Plan states that "the LBGR is initially set at 0.5 times the $DCGL_W$, but may be adjusted to obtain a value for the relative shift (Δ/σ) between 1 and 3" [NASA 2007].

The VSP software automatically performs an analysis to examine the sensitivity of N, the number of samples, to critical input parameter values. The following is an example obtained from the VSP report for survey unit HL-1-11. The sensitivity of N was explored by varying the following parameters: standard deviation, lower bound of gray region (as % of DCGL), beta, probability of mistakenly concluding that the survey unit mean concentration, μ, is greater than the DCGL and alpha, probability of mistakenly concluding that the survey unit mean concentration, μ, is less than the DCGL. Table 7 summarizes this analysis. The region of interest is for $\alpha = 0.05$ (required to be fixed), $\beta = 0.10$ (may be adjusted) and the LBGR at 70% to 90% of the DCGL. In this region, doubling σ causes no increase in N (for $\beta = 10$).The sensitivity of N to an incorrect conclusion that the survey unit will pass (regulator's risk) is quite low; increasing α from 0.05 to 0.10 and 0.15 and holding σ constant at 760 dpm/100-cm^2, shows that the number of measurements is 11 or fewer in all cases. These results show that N = 11 represents a conservative design.

Table 7, Sensitivity Analysis for HL FSS Design

Number of Samples							
DCGL=34,782 (1)		α=0.05 (2)		α=0.10		α=0.15	
		σ= 1520 (1) (3)	σ= 760	σ= 1520	σ= 760	σ= 1520	σ= 760
LBGR=90% (1) (4)	β=0.05	15	14	11	11	10	10
	β=0.10	11	11	9	9	8	8
	β=0.15	10	10	8	8	6	6
LBGR=80%	β=0.05	14	14	11	11	10	10
	β=0.10	11	11	9	9	8	8
	β=0.15	10	10	8	8	6	6
LBGR=70%	β=0.05	14	14	11	11	10	10
	β=0.10	11	11	9	9	8	8
	β=0.15	10	10	8	8	6	6

Table 7 Notes:

1. Units of DCGL, σ and LBGR are dpm/100-cm^2.
2. α = alpha, probability of mistakenly concluding that μ < DCGL.
3. σ = Standard Deviation.
4. LBGR = Lower Bound of Gray Region (as % of DCGL).
5. β = beta, probability of mistakenly concluding that μ > DCGL.

Visual Sample Plan was also used to determine the grid size, the random starting location coordinates (for Class 1 and 2 survey units) and to display the measurement locations on survey unit maps drawn to scale. Refer to Appendix B for location coordinate tables and scale VSP maps showing measurement locations for each HL survey unit.

The survey designs also specify scan survey coverage and action levels based on the MARSSIM classification listed in Table 3. If the scan sensitivity of the detectors used in Class 1 survey units is below the $DCGL_W$, the number of measurements in each survey unit is determined solely by the Sign Test. If the scan sensitivity is not below the $DCGL_W$, the number of measurements is increased as determined by the Elevated Measurement Comparison (EMC). As discussed in the next section, the scan sensitivities of instruments used in the FSS of the HL are below the $DCGL_W$, and no increase in the number of measurements above the value calculated using the Sign Test was required.

4.4 Instrumentation and Measurement Sensitivity

Instruments to be used in the FSS of each survey unit are selected in each survey design. Their detection sensitivities must be sufficient to meet the required action levels for the MARSSIM class of each survey unit. Minimum detection sensitivities for static alpha and beta measurements are calculated using the following equation:

$$MDC_{static} = \frac{3 + 3.29\sqrt{B_R t_s (1 + \frac{t_s}{t_b})}}{t_s E_{tot} \frac{A}{100}}, \qquad \textbf{(Equation 2)}$$

where:

MDC_{static} = Minimum Detectable Concentration (dpm/100-cm^2),

B_R = Background Count Rate (cpm),

t_b = Background Count Time (min),

t_s = Sample Count Time (min),

A = Detector Open Area (cm^2) and

E_{tot} = Total Detection Efficiency (counts per disintegration). The total efficiency equals the product of Detector Efficiency, E_i and Surface Efficiency, E_s.

Scan sensitivities for detectors which measure alpha and beta surface activity are determined using the following equation:

$$MDC_{scan} = \frac{d'\sqrt{b_i}\,\frac{60}{i}}{E_i E_s \sqrt{p}\,\frac{A}{100}}, \qquad \textbf{(Equation 3)}$$

where:

MDC_{scan} = Minimum Detectable Concentration (dpm/100-cm^2),

d' = Index of sensitivity related to the detection decision error rate of the surveyor, from Table 6.5 of MARSSIM [USNRC 2000],

i = observation counting interval, detector width (cm) / scan speed (s),

b_i = background counts per observation interval,

E_i = Detector Efficiency (counts per disintegration),

Es = Surface Efficiency, typically 25% for alpha and 50% for beta per ISO 7503-1, Table 2 [ISO 1988],

p = Surveyor efficiency (typically 50%) and

A = Detector Open Area (cm^2).

A summary of the a priori detection sensitivities of instruments used in the FSS of the HL is provided in Table 8. Note that the detector sensitivities and other values shown in Table 8 are those published in the survey designs based on the DCGLs in TBD-07-001. In Appendix D, it is shown that in cases where the DCGLs were reduced to correct the errors in TBD-07-001, scan sensitivities were still sufficient to meet the FSS Plan investigation level requirements shown in Table 3.

Table 8, Detection Sensitivities of Field Instruments for Surface Activity Measurements

Detector Model (1)	Detector Efficiency (c/d) (2)	MDC_{scan} (dpm/100-cm^2) (3)	Net cpm Equivalent to $DCGL_W$ (4)	MDC_{static} (dpm/100-cm^2) (3)
LMI 44-116	0.140	2,587 (5)	4,066	491 (6)
LMI 43-37	0.125	889 (7)	4,348	N/A
LMI 44-9	0.143	19,699 (8)	298	6,413(9)

Table 8 Notes:

1. Values listed in this table are typical for the detector models used in the FSS for standard measurement conditions unless otherwise noted.
2. The detector efficiencies listed are total efficiency, i. e., $E_t = E_i + E_s$.
3. The a priori scan sensitivities are calculated using Equation 3 and static sensitivities are calculated using Equation 2.
4. The $DCGL_W$ used for this determination is 34,782 dpm/100-cm^2 used in Design No. 25.
5. The scan MDC for the LMI 44-116 is reported in Design No. 25 for background count rate = 200 cpm; scan speed =15.2 cm/s and $E_s = 0.5$. An efficiency correction factor = 0.8349 is applied to compensate for concrete roughness (the detector-to-surface distance is 0.5 in.).
6. The static MDC for the LMI 44-116 detector is reported in Design No. 25 for background count rate = 200 cpm, $E_s = 0.5$ and the detector-to-surface distance = 0.5 in. (one minute count times are assumed for both the background and sample counts).
7. The scan MDC for the LMI 43-37 is from Survey Design No. 25. The background count rate is 500 cpm; the scan speed is 27 cm/s, $E_s = 0.5$ and the detector-to-surface distance is 0.5 in.
8. The scan MDC for the LMI 44-9 is obtained from Survey Design No. 25. The background count rate is 125 cpm with a scan speed of 4.4 cm/s and the detector in contact with the surface.
9. The static MDC for the LMI 44-9 is obtained from Survey Design No. 25. The background count rate is 125 cpm and the detector in contact with the surface (one minute count times are assumed for both the background and sample counts).

The scan investigation level for Class 1 survey units listed in Table 3 is the $DCGL_{EMC}$, as specified in the FSS Plan Section 8.1. However, the scan investigation level is typically set at an instrument count rate corresponding to the $DCGL_w$ established in the survey design for each structure survey unit. For example, as seen in Table 8 above, the 44-116 detector count rate that corresponds to the $DCGL_W$ is 4066 net cpm. In this design (Design 25) the $DCGL_W$ is 34,782 dpm/100-cm^2. In practice, the scan investigation level was rounded downward to 3500 gcpm in typical survey instructions. This practice was established early in the FSS of structures and has been continued. It is also noted the FSS Plan states that technicians are to respond to indications of increased count rates even though scan count rates may not be above the investigation level specified in survey instructions. [17]
Modifications to survey instructions are adjusted to account for unusual measurement conditions encountered in structure survey units. Modified detection sensitivities may be applied taking into account adjustments in detector efficiency. Scan speeds may be reduced to ensure that required scan sensitivities are achieved. The bases for adjustments due to non-standard conditions are provided in PBRF Technical Basis Documents.[18] Examples of areas or locations in HL survey units where special measurement conditions apply are shown in Exhibits 25 through 27 of Appendix A.

[17] From FSS Plan Section 7.1.1: "Technicians will respond to indications of elevated areas while surveying. Upon detecting an increase in visual or audible response, the technician will reduce the scan speed or pause and attempt to isolate the elevated area. If the elevated activity is verified to exceed the established investigation level, the area is bounded (e.g., marked and measured to obtain an estimated affected surface area). Representative static measurements are obtained as determined by the FSS/Characterization Engineer. The collected data is documented on a Radiological Survey Form" [NASA 2007].

[18] The PBRF-TBD-07-004 [PBRF 2007a] presents efficiency correction factors developed for the LMI 44-116 detector. The correction factors are presented as a function of detector-to-surface distance. Application of the factors requires empirical measurements of the effective detector-to-surface distance for areas with non-standard surface conditions as part of the survey unit inspection process.

Scan sensitivities for detectors used for gamma scan surveys of soil are determined using the method referenced in the PBRF FSS Plan and described in NUREG-1507 [USNRC 1998]. Scan sensitivities for the Ludlum Model 44-10 NaI detectors used in FSS of soils at PBRF were developed in the PBRF technical basis document TBD-09-002 [PBRF 2009a]. The method is summarized and the key equations presented. The scan MDC is calculated using the following equations adapted from NUREG-1507 for walkover gamma scanning with NaI detectors [USNRC 1998]:

$$MDCR_{SURV} = \frac{d' \sqrt{bi}}{\sqrt{p}} \left(\frac{60}{i} \right)$$ **(Equation 4)**

$$MDC_{scan} = \frac{MDCR_{surv}}{Conv * MS_O}$$ **(Equation 5)**

where:

MDC_{SURV} = the minimum detectable count rate in cpm that can be reliably detected by the "surveyor",

d' = index of sensitivity, unitless (MARSSIM default value of 1.38 is assigned),

b_i = background counts observed in the interval i,

i = observation interval (s),

p = surveyor efficiency, unitless (MARSSIM default value of 0.5 for walkover scans is assigned),

MDC_{scan} = the scan MDC, here in units of pCi/g,

Conv = instrument response conversion factor, units of cpm per μR/h and

MS_o = instrument response in units of μR/h per pCi/g (determined empirically or with a shielding algorithm).

Site-specific parameter values for the MDC_{scan} equation are obtained from the technical basis document, TBD-09-002 [PBRF 2009a]. The instrument response factor for Cs-137 is 0.139 μR/h per pCi/g, calculated using the MicroShield code. The most conservative instrument response conversion factor measured for detectors in the PBRF LMI 44-10 inventory is 232.39 cpm per μR/h for Cs-137.

Using these values, detection sensitivities of the instruments used in the FSS of the HL soil survey units are provided in Table 9. Minimum detectable count rates and MDC_{scan} values for 44-10 detectors operated in the Cs-137 window vs. background count rates are shown in Table 9.

Table 9, Typical Detection Sensitivities of Field Instruments used for Soil Scans

LMI 44-10 with Cs-137 Window [1]		
Background (cpm) [2]	Scan Investigation Level (ncpm)	MDC_{scan} (pCi/g) [3]
≤ 175	80	2.9
> 175 to ≤ 200	87	3.2
> 200 to ≤ 225	95	3.4

Table 9 Notes:

1. Ludlum Model 44-10 NaI detector with Model 2350-1 data logging scaler-rate meter setup to count in Cs-137 energy window. Data from Survey Design No. 24B. Scan speed = 0.5 m/s, detector to soil surface = 10 cm.
2. Specified as average background count rate.
3. The MDCscan sensitivity values shown in the table are for Cs-137. The associated scan action level is the $DCGL_W$ for Cs-137, 5.59 pCi/g, where both Co-60 and Sr-90 are "surrogated" to Cs-137.

5.0 HL Survey Results

Results of the HL FSS are presented in this section. Results of scan surveys are presented first, followed by results of systematic total surface activity measurements in each of the structural survey units. Scan survey results include scan survey frequencies (% of areas covered) for each survey unit and occurrence of events where scan investigation levels were exceeded. Investigations initiated by scan surveys are described. Investigative measurements and results of investigations are presented. Removable surface activity measurement results for each survey unit are presented. The results of comparison tests of survey unit maximum and average values with the $DCGL_W$ are reported. Results of soil sample analysis for the two soil survey units are reported. As discussed below, no statistical tests were required. It is shown that levels of residual contamination have been reduced to levels that are ALARA. This section closes with a summary which concludes that applicable criteria for release of the HL for unrestricted use are satisfied and all FSS Plan requirements are met.

5.1 Scan Surveys

Results of the HL FSS scan surveys are presented in Table 10. The table lists the HL survey units and for each identifies the MARSSIM Class, the scan coverage in percent of surface area, the Survey Request No., whether or not an investigation was performed and the percent coverage of the QC scan survey. Scan surveys were performed on 100% of the accessible area of the 137 HL Class 1 survey units. These included two soil survey units (discussed in Section 5.4). Scan survey results were reviewed to confirm that the scan coverage requirement (as % of survey unit area) was satisfied for all survey units. The results of QC replicate scan surveys were also reviewed to confirm that the minimum coverage requirement of 5% (of the area scanned in the original survey) was satisfied. The table shows that scan coverage requirements were satisfied for all survey units. The table also shows that investigations initiated during scan surveys were conducted in 37 survey units. The investigations are discussed in Section 5.3.

Table 10, Scan Survey Results

Survey Unit	Class	Scan Survey Coverage (%) (1)	Survey Request No.	Investigation Performed	QC Replicate Scan Coverage (%) (2) (3) (4)
HL-1-1	1	100	125	No	5.7
HL-1-2	1	100	125	No	5.7
HL-1-3	1	100	125	No	5.7
HL-1-4	1	100	125	No	5.7
HL-1-5	1	100	125	No	5.7
HL-1-6	1	100	125	No	5.7
HL-1-7	1	100	125	No	5.7
HL-1-8	1	100	126	No	5.9
HL-1-9	1	100	126	No	5.9
HL-1-10	1	100	126	No	5.9
HL-1-11	1	100	126	No	5.9
HL-1-12	1	100	126	No	5.9
HL-1-13	1	100	126	No	5.9
HL-1-14	1	100	126	No	5.9
HL-1-15	1	100	126	No	5.9
HL-1-16	1	100	126	No	5.9
HL-1-17	1	100	127	No	5.2
HL-1-18	1	100	127	No	5.2
HL-1-19	1	100	127	No	5.2
HL-1-20	1	100	127	No	5.2
HL-1-21	1	100	127	No	5.2
HL-1-22	1	100	127	No	5.2
HL-1-23	1	100	214	No	5.5
HL-1-24	1	100	214	No	5.5
HL-1-25	1	100	214	No	5.5
HL-1-26	1	100	214	No	5.5
HL-1-27	1	100	214	No	5.5
HL-1-28	1	100	214	No	5.5
HL-1-29	1	100	219	No	5.4
HL-1-30	1	100	219	No	5.4
HL-1-31	1	100	219	No	5.4
HL-1-32	1	100	219	No	5.4
HL-1-33	1	100	219	No	5.4
HL-1-34	1	100	219	No	5.4
HL-1-35	1	100	221	No	5.7
HL-1-36	1	100	221	No	5.7
HL-1-37	1	100	221	No	5.7
HL-1-38	1	100	221	No	5.7
HL-1-39	1	100	221	No	5.7
HL-1-40	1	100	329	Yes	7.8
HL-1-41	1	100	298	No	7.2
HL-1-42	1	100	298	No	7.2
HL-1-43	1	100	298	Yes	7.2

Table 10, Scan Survey Results

Survey Unit	Class	Scan Survey Coverage (%) (1)	Survey Request No.	Investigation Performed	QC Replicate Scan Coverage (%) (2) (3) (4)
HL-1-44	1	100	298	No	7.2
HL-1-45	1	100	298	No	7.2
HL-1-46	1	100	297	No	5.7
HL-1-47	1	100	297	No	5.7
HL-1-48	1	100	297	No	5.7
HL-1-49	1	100	230	No	5.5
HL-1-50	1	100	231	Yes	5.4
HL-1-51	1	100	231	Yes	5.4
HL-1-52	1	100	230	No	5.5
HL-1-53	1	100	231	Yes	5.4
HL-1-54	1	100	231	Yes	5.4
HL-1-55	1	100	230	No	5.5
HL-1-56	1	100	231	Yes	5.4
HL-1-57	1	100	231	Yes	5.4
HL-1-58	1	100	230	Yes	5.5
HL-1-59	1	100	230	Yes	5.5
HL-1-60	1	100	232	No	5.8
HL-1-61	1	100	232	Yes	5.8
HL-1-62	1	100	232	Yes	5.8
HL-1-63	1	100	232	No	5.8
HL-1-64	1	100	234	Yes	6.8
HL-1-65	1	100	235	No	5.7
HL-1-66	1	100	235	No	5.7
HL-1-67	1	100	235	No	5.7
HL-1-68	1	100	235	Yes	5.7
HL-1-69	1	100	235	Yes	5.7
HL-1-70	1	100	299	Yes	6.1
HL-1-71	1	100	300	Yes	6.0
HL-1-72	1	100	300	Yes	6.0
HL-1-73	1	100	300	No	6.0
HL-1-74	1	100	276	No	5.7
HL-1-75	1	100	276	No	5.7
HL-1-76	1	100	276	No	5.7
HL-1-77	1	100	276	No	5.7
HL-1-78	1	100	276	No	5.7
HL-1-79	1	100	276	Yes	5.7
HL-1-80	1	100	276	No	5.7
HL-1-81	1	100	276	No	5.7
HL-1-82	1	100	276	No	5.7
HL-1-83	1	100	276	No	5.7
HL-1-84	1	100	297	No	5.7
HL-1-85	1	100	297	No	5.7
HL-1-86	1	100	329	Yes	7.8
HL-1-87	1	100	329	Yes	7.8
HL-1-88	1	100	329	Yes	7.8
HL-1-89	1	100	329	No	7.8

Table 10, Scan Survey Results

Survey Unit	Class	Scan Survey Coverage (%) (1)	Survey Request No.	Investigation Performed	QC Replicate Scan Coverage (%) (2) (3) (4)
HL-1-90	1	100	329	No	7.8
HL-1-91	1	100	330	Yes	5.6
HL-2-1	1	100	219	No	5.4
HL-2-2	1	100	219	No	5.4
HL-2-3	1	100	219	No	5.4
HL-2-4	1	100	219	No	5.4
HL-3-1	1	100	158	No	6.4
HL-3-2	1	100	158	No	6.4
HL-3-3	1	100	158	No	6.4
HL-3-4	1	100	158	No	6.4
HL-3-5	1	100	158	No	6.4
HL-3-6	1	100	159	No	5.9
HL-3-7	1	100	159	No	5.9
HL-3-8	1	100	159	No	5.9
HL-3-9	1	100	160	No	5.1
HL-3-10	1	100	160	No	5.1
HL-3-11	1	100	160	No	5.1
HL-3-12	1	100	160	No	5.1
HL-3-13	1	100	160	No	5.1
HL-3-14	1	100	160	No	5.1
HL-3-15	1	100	161	No	5.2
HL-3-16	1	100	161	No	5.2
HL-3-17	1	100	161	No	5.2
HL-3-18	1	100	161	No	5.2
HL-3-19	1	100	161	No	5.2
HL-3-20	1	100	138	No	10.3
HL-3-21	1	100	138	Yes	7.7
HL-4-1	1	100	212	No	6.9
HL-4-2	1	100	207	No	6.0
HL-4-3	1	100	207	No	6.0
HL-4-4	1	100	207	Yes	6.0
HL-4-5	1	100	212	Yes	6.9
HL-4-6	1	100	212	No	6.9
HL-4-7	1	100	207	No	6.0
HL-4-8	1	100	207	Yes	6.0
HL-4-9	1	100	207	No	6.0
HL-4-10	1	100	207	Yes	6.0
HL-4-11	1	100	212	Yes	6.9
HL-4-12	1	100	207	No	6.0
HL-4-13	1	100	207	Yes	6.0
HL-4-14	1	100	243	Yes	5.7
HL-4-15	1	100	243	Yes	5.7
HL-4-16	1	100	243	No	5.7
HL-4-17	1	100	243	Yes	5.7
HL-4-18	1	100	305	Yes	5.7
HL-4-19	1	100	305	Yes	5.7

Table 10, Scan Survey Results

Survey Unit	Class	Scan Survey Coverage (%) (1)	Survey Request No.	Investigation Performed	QC Replicate Scan Coverage (%) (2) (3) (4)
HL-4-20	1	100	305	Yes	5.7
HL-4-21	1	100	305	Yes	5.7
HL-5-1	2	30	346	No	5.2
HL-5-2	2	41	346	No	5.2
HL-5-3	3	11	346	No	5.2

Table 10 Notes:

1. One hundred percent of the accessible surface area of Class 1 survey units was scanned. A fraction of the surface area of a few survey units was inaccessible for scanning. In most such survey units, it was less than one percent of the total surface area.
2. Replicate QC Scan % coverage values are rounded to the nearest tenth of a per cent. Values reported when the second decimal is 5, e. g., 5.75, are rounded downward.
3. The QC Replicate % scan coverage is given as the % of the area scanned in the initial survey.
4. Replicate QC scan results are reported for multiple survey units in most Survey Requests. For these, the QC scan percentages are reported as % of the scanned area of the survey units combined.

5.2 Systematic Measurements

Results of the HL FSS total surface beta activity measurements at the locations established in the survey designs are presented. In Class 1 and 2 survey units, the locations were established on a triangular grid with random starting location and in the Class 3 survey unit, the measurement locations were selected at random without a grid. Total surface beta measurement results are presented in Table 11 (individual measurements in each survey unit are reported in Appendix B). The table presents the number of measurements, maximum, average and standard deviation for each survey unit.[19] Table 11 compares the maximum activity measured in each survey unit to the $DCGL_W$. It is demonstrated that all systematic measurements of total surface activity are less than the $DCGL_W$. The mean activity of each survey unit is also compared to the $DCGL_W$, and as expected, are all less than the $DCGL_W$. The average of 1574 total surface beta measurements reported in the HL release records is: 587 ± 620 dpm/100-cm^2 (one standard deviation). [20]

As described in Appendix D, the systematic beta activity measurements were re-evaluated against the revised DCGLs to ensure that the measurements were below the $DCGL_W$ values in cases where the DCGLs were reduced. The Appendix shows that the systematic measurement maximum and average values for each HL structure survey unit are all below the revised DCGLs.

[19] It is noted that in converting total surface activity measurements in cpm to dpm/100-cm^2, the detector background response from surface materials is not subtracted. As a result, the total surface activity measurement results are biased high.

[20] Calculations performed to obtain results derived specifically for this report are documented in an Engineering Record Memo to Project Files [PBRF 2011].

Table 11, HL Total Surface Beta Activity Measurement Summary and Test Results

Survey Unit ID	No. of Measurements (1)	Maximum (2)	Test Result: Maximum < $DCGL_W$ (3)	Average (2)	Standard Deviation (2) (4)	Test Result: Average < $DCGL_W$ (3)
HL-1-1	11	1,030	Yes	753	161	Yes
HL-1-2	11	1,055	Yes	783	196	Yes
HL-1-3	11	1,000	Yes	808	174	Yes
HL-1-4	11	1,250	Yes	758	248	Yes
HL-1-5	11	678	Yes	531	162	Yes
HL-1-6	13	1,280	Yes	725	307	Yes
HL-1-7	11	1,060	Yes	691	208	Yes
HL-1-8	11	1,240	Yes	695	318	Yes
HL-1-9	11	771	Yes	586	188	Yes
HL-1-10	11	979	Yes	588	325	Yes
HL-1-11	11	993	Yes	694	253	Yes
HL-1-12	11	1,060	Yes	761	172	Yes
HL-1-13	11	1,090	Yes	559	248	Yes
HL-1-14	11	1,360	Yes	615	418	Yes
HL-1-15	11	2,360	Yes	1,201	761	Yes
HL-1-16	11	1,810	Yes	754	534	Yes
HL-1-17	13	979	Yes	782	154	Yes
HL-1-18	12	1,140	Yes	860	151	Yes
HL-1-19	11	1,120	Yes	866	142	Yes
HL-1-20	11	1,040	Yes	617	335	Yes
HL-1-21	12	1,130	Yes	784	187	Yes
HL-1-22	11	406	Yes	102	137	Yes
HL-1-23	11	220	Yes	35	99	Yes
HL-1-24	11	492	Yes	-141	252	Yes
HL-1-25	11	195	Yes	-37	175	Yes
HL-1-26	12	219	Yes	-15	127	Yes
HL-1-27	12	274	Yes	67	135	Yes
HL-1-28	12	313	Yes	43	196	Yes
HL-1-29	11	1,100	Yes	702	276	Yes
HL-1-30	11	921	Yes	538	277	Yes
HL-1-31	11	1,040	Yes	493	304	Yes
HL-1-32	12	273	Yes	1	180	Yes
HL-1-33	11	789	Yes	212	289	Yes
HL-1-34	11	384	Yes	89	147	Yes
HL-1-35	11	852	Yes	637	164	Yes
HL-1-36	11	690	Yes	511	134	Yes
HL-1-37	11	963	Yes	705	205	Yes
HL-1-38	11	810	Yes	461	179	Yes
HL-1-39	12	1,090	Yes	734	182	Yes
HL-1-40	11	1,130	Yes	681	247	Yes
HL-1-41	11	1,021	Yes	742	239	Yes
HL-1-42	11	1,020	Yes	557	329	Yes
HL-1-43	11	860	Yes	676	145	Yes
HL-1-44	11	986	Yes	735	215	Yes
HL-1-45	11	1,287	Yes	831	256	Yes

Table 11, HL Total Surface Beta Activity Measurement Summary and Test Results

Survey Unit ID	No. of Measurements (1)	Maximum (2)	Test Result: Maximum < $DCGL_W$ (3)	Average (2)	Standard Deviation (2) (4)	Test Result: Average < $DCGL_W$ (3)
HL-1-46	11	1,030	Yes	793	145	Yes
HL-1-47	11	1,010	Yes	822	162	Yes
HL-1-48	12	1,180	Yes	711	314	Yes
HL-1-49	11	503	Yes	97	152	Yes
HL-1-50	11	248	Yes	42	195	Yes
HL-1-51	11	494	Yes	24	192	Yes
HL-1-52	11	221	Yes	60	107	Yes
HL-1-53	11	1,030	Yes	234	393	Yes
HL-1-54	11	290	Yes	127	108	Yes
HL-1-55	11	305	Yes	83	107	Yes
HL-1-56	11	1,640	Yes	392	535	Yes
HL-1-57	11	8,690	Yes	1,470	2637	Yes
HL-1-58 (5)	11	165	Yes	-38	151	Yes
HL-1-59	11	610	Yes	97	253	Yes
HL-1-60	11	2,400	Yes	361	758	Yes
HL-1-61	11	309	Yes	78	133	Yes
HL-1-62	12	146	Yes	58	54	Yes
HL-1-63	11	653	Yes	99	198	Yes
HL-1-64	11	2,230	Yes	1,019	596	Yes
HL-1-65	11	966	Yes	508	314	Yes
HL-1-66	11	721	Yes	307	307	Yes
HL-1-67	11	815	Yes	365	309	Yes
HL-1-68	11	1,050	Yes	522	274	Yes
HL-1-69	11	1,580	Yes	566	396	Yes
HL-1-70	11	1,430	Yes	827	323	Yes
HL-1-71	11	1,530	Yes	969	373	Yes
HL-1-72	11	1,030	Yes	523	337	Yes
HL-1-73	11	783	Yes	404	254	Yes
HL-1-74	11	849	Yes	558	203	Yes
HL-1-75	11	364	Yes	111	147	Yes
HL-1-76	11	909	Yes	730	176	Yes
HL-1-77	11	1,200	Yes	747	350	Yes
HL-1-78	12	1,070	Yes	720	258	Yes
HL-1-79	11	1,050	Yes	712	165	Yes
HL-1-80	11	657	Yes	296	263	Yes
HL-1-81	11	281	Yes	61	171	Yes
HL-1-82	11	210	Yes	57	147	Yes
HL-1-83	11	595	Yes	209	218	Yes
HL-1-84	11	1,920	Yes	201	584	Yes
HL-1-85	12	168	Yes	40	83	Yes
HL-1-86	11	1,400	Yes	929	263	Yes
HL-1-87	11	1,170	Yes	764	223	Yes
HL-1-88	11	2,100	Yes	905	548	Yes
HL-1-89	11	1,620	Yes	895	331	Yes
HL-1-90	11	1,070	Yes	709	241	Yes

Table 11, HL Total Surface Beta Activity Measurement Summary and Test Results

Survey Unit ID	No. of Measurements (1)	Maximum (2)	Test Result: Maximum < $DCGL_W$ (3)	Average (2)	Standard Deviation (2) (4)	Test Result: Average < $DCGL_W$ (3)
HL-2-1	11	1,000	Yes	602	213	Yes
HL-2-2	11	1,150	Yes	652	252	Yes
HL-2-3	11	919	Yes	284	426	Yes
HL-2-4	11	1,120	Yes	375	437	Yes
HL-3-1	15	4,980	Yes	1,191	1083	Yes
HL-3-2	15	1,450	Yes	944	319	Yes
HL-3-3	15	1,350	Yes	935	220	Yes
HL-3-4	15	1,430	Yes	733	272	Yes
HL-3-5	15	5,150	Yes	1,272	1445	Yes
HL-3-6	12	3,650	Yes	580	1111	Yes
HL-3-7	12	2,356	Yes	631	791	Yes
HL-3-8	12	662	Yes	225	340	Yes
HL-3-9	14	1,140	Yes	767	240	Yes
HL-3-10	12	1,340	Yes	859	277	Yes
HL-3-11	12	7,980	Yes	1,246	2130	Yes
HL-3-12	12	925	Yes	607	267	Yes
HL-3-13	12	1,070	Yes	691	255	Yes
HL-3-14	12	1,310	Yes	823	196	Yes
HL-3-15	12	950	Yes	713	151	Yes
HL-3-16	12	1,190	Yes	859	261	Yes
HL-3-17	12	899	Yes	738	104	Yes
HL-3-18	12	1,020	Yes	657	175	Yes
HL-3-19	12	1,550	Yes	710	400	Yes
HL-3-21	15	701	Yes	436	179	Yes
HL-4-1	11	968	Yes	490	240	Yes
HL-4-2	11	899	Yes	482	183	Yes
HL-4-3	11	880	Yes	616	199	Yes
HL-4-4	11	260	Yes	29	152	Yes
HL-4-5	11	8,650	Yes	1,872	2325	Yes
HL-4-6	12	1,700	Yes	974	355	Yes
HL-4-7	11	1,010	Yes	663	202	Yes
HL-4-8	11	753	Yes	492	233	Yes
HL-4-9	11	1,050	Yes	569	231	Yes
HL-4-10	11	1,660	Yes	586	416	Yes
HL-4-11	11	7,620	Yes	2,184	1942	Yes
HL-4-12	11	1,032	Yes	678	176	Yes
HL-4-13	11	4,850	Yes	1,139	1344	Yes
HL-4-14	11	753	Yes	541	154	Yes
HL-4-15	11	1,138	Yes	717	269	Yes
HL-4-16	11	899	Yes	687	171	Yes
HL-4-17	11	1,025	Yes	732	182	Yes
HL-4-18 (5)	11	1,470	Yes	812	312	Yes
HL-4-19	11	1,050	Yes	682	201	Yes
HL-4-20	11	1,050	Yes	666	235	Yes
HL-4-21	11	1,260	Yes	589	415	Yes

Table 11, HL Total Surface Beta Activity Measurement Summary and Test Results

Survey Unit ID	No. of Measurements (1)	Maximum (2)	Test Result: Maximum < $DCGL_W$ (3)	Average (2)	Standard Deviation (2) (4)	Test Result: Average < $DCGL_W$ (3)
HL-5-1	11	784	Yes	474	232	Yes
HL-5-2	11	797	Yes	373	298	Yes
HL-5-3	11	1,030	Yes	660	313	Yes

Table 11 Notes:

1. In the FSS design calculation for survey units developed using VSP; "extra" fixed measurement locations are sometimes added when "fitting" the calculated grid size onto the survey unit layout.
2. The units for: maximum, average and standard deviation are dpm/100-cm^2.
3. The most restrictive $DCGL_W$ used in HL survey designs for Class 1 structures, 30,960 dpm/100-cm^2, was used for the comparison tests reported in this table. Note that the measurements for the Class 2 and Class 3 structure survey units, HL-5-1 through HL-5-3 easily meet the applicable $DCGL_W$ (24,449 dpm/100-cm^2).
4. Standard deviations of the measurements in each survey unit are reported for comparison to the values used in the survey design. In most HL structural survey units, values of σ obtained from the FSS measurements are much less than values used in the survey designs, as reported in Table 6. This confirms that the survey designs for the HL were conservative.
5. The designated survey units (HL-1-58 & HL-4-18) were resurveyed following discovery of contamination near or in excess of the DCGL, or significant removable surface contamination, during the initial survey. The measurement results reported in this table are from the final-resurvey. See discussion in Section 5.3.

5.3 Investigations and Additional Measurements

Additional static measurements were performed as a result of investigations initiated during scan surveys of the HL survey units. These measurements and results of the investigations are presented in Table 12 (investigative measurements are designated as IM-1, 2 etc, or EMA-1, 2, etc). It is noted that most of the investigations were initiated when technicians observed increased count rates during scans as opposed to observing count rates above action levels. As shown in the table, scan investigation-action levels were exceeded in several instances. Evaluations of investigative measurements resulted in the FSS "failure" of two survey units (HL-1-58 and HL-4-18). These survey units were remediated as necessary and re-surveyed under "new" Survey Instructions. Table 13 identifies the survey designs and survey requests which document the original and the FSS resurvey of these two survey units.

The effects of the revised DCGLs published in TBD-11-002 on investigative measurements are evaluated in Appendix D. A result of this evaluation is that several investigative measurements are identified that were below the original DCGLs, but are above the revised-reduced DCGLs. These measurements were added to the measurements which required evaluation for EMC and EMT tests.

Table 12, Summary of Investigative Static Measurements and Results

Survey Unit	Static Measurement (1) (dpm/100-cm^2)	Size of Elevated Area (cm^2)	Measurement ID	Comments/Results
HL-1-29	10,800	100	IM-1	< DCGL, no further action required.
HL1-34	4,490	2000	IM-1	< DCGL, no further action required.
HL-1-38	18,100	100	IM-1	< DCGL, no further action required.
HL-1-40	18,480	100	IM-1	< DCGL, no further action required.
HL-1-40	46,900	100	EMA-1	> DCGL. EMC/EMT performed; see Table 14.
HL-1-40	47,700	100	EMA-2	> DCGL. EMC/EMT performed; see Table 14
HL-1-43	6,080	12	IM-1	< DCGL, no further action required.
HL-1-43	32,000	100	IM-2	< DCGL, no further action required.
HL-1-43	22,200	100	IM-3	< DCGL, no further action required.
HL-1-50	14,700	67	IM-1	< DCGL, no further action required.
HL-1-51	15,300	100	IM-1	See entry below.
HL-1-51	19,320	25	IM-1A	Additional measurement taken at IM-1 with 44-9 detector. Estimated area was revised to 25 cm^2. < DCGL no further action required.
HL-1-53	18,500	100	IM-1	< DCGL, no further action required.
HL-1-54	9,440	200	IM-1	< DCGL, no further action required.
HL-1-54	8,050	200	IM-2	< DCGL, no further action required.
HL-1-54	3,400	12.5	IM-3	< DCGL, no further action required.
HL-1-56	2,510	12.5	IM-1	< DCGL, no further action required.
HL-1-56	12,800	100	IM-2	< DCGL, no further action required.
HL-1-56	9,640	100	IM-3	< DCGL, no further action required.
HL-1-56	30,500	32	IM-4	< DCGL, no further action required.
HL-1-57	18,700	100	IM-1	< DCGL, no further action required.
HL-1-57	13,300	100	IM-2	< DCGL, no further action required.
HL-1-57	13,900	"discrete particle" (2)	IM-3	Initial measurement was 13,900 dpm/100-cm^2. Particle removed by smear. Follow-up measurement at this location showed only 809 dpm/100-cm^2 (both measurements with 44-116); < DCGL, no further action required.
HL-1-57	32,200	67	IM-4	< DCGL, no further action required.
HL-1-58 (3)	36,500 62,500	12.5	Not given ID	Probe sized area (44-9) of elevated activity found; smear was collected and found to contain a "discrete particle" (2). Survey unit failed. See Table 13.
HL-1-59	4,640	12.5	IM-1	During QC scan, probe sized area (44-9) of elevated activity found; < DCGL, no further action required.
HL-1-61	14,400	100	IM-1	< DCGL, no further action required.
HL-1-62	7,230	100	IM-1	< DCGL, no further action required.
HL-1-64	23,800	100	IM-1	In Hot Cell 7; < DCGL, no further action required.
HL-1-64	23,800	100	IM-1	In Hot Cell 5; < DCGL, no further action required.
HL-1-68	9,900	100	IM-1	< DCGL, no further action required.

Table 12, Summary of Investigative Static Measurements and Results

Survey Unit	Static Measurement (1) (dpm/100-cm^2)	Size of Elevated Area (cm^2)	Measurement ID	Comments/Results
HL-1-68	11,200	100	IM-2	< DCGL, no further action required.
HL-1-68	2,440	12.5	IM-3	< DCGL, no further action required.
HL-1-68	24,700	60	IM-4	< DCGL, no further action required.
HL-1-68	14,300	60	IM-5	Repeat of measurement at IM-4.
HL-1-69	20,100	100	IM-1	< DCGL, no further action required.
HL-1-70	12,900	100	IM-1	< DCGL, no further action required.
HL-1-71	24,200	100	IM-1	< DCGL, no further action required.
HL-1-71	23,700	100	IM-2	< DCGL, no further action required.
HL-1-71	35,800	100	IM-3	> DCGL. EMC/EMT performed; see Table 14.
HL-1-72	30,500	100	IM-1	< DCGL, no further action required.
HL-1-72	23,000	300	IM-2	< DCGL, no further action required.
HL-1-79	23,169	100	IM-1	< DCGL, no further action required.
HL-1-79	25,587	100	IM-2	< DCGL, no further action required.
HL-1-86	31,804	100	IM-1	< DCGL, no further action required.
HL-1-87	18,899	100	IM-1	< DCGL, no further action required.
HL-1-88	53,847	100	IM-1	> DCGL. EMC/EMT performed; see Table 14.
HL-1-91	490 ncpm (4)	480	IM-1	Soil survey unit IM recorded as static measurement. Soil sample results: 0.35 pCi/g Cs-137 (<DCGL) and < MDA Co-60.
HL-1-91	240 ncpm (4)	225	IM-2	Soil survey unit IM recorded as static measurement. Soil sample results: 4.12 pCi/g Cs-137 (<DCDL) and < MDA Co-60.
HL-2-4	4,280	100	IM-1	< DCGL, no further action required.
HL-3-2	19,600	100	IM-1	< DCGL, no further action required.
HL-3-5	16,400	100	IM-1	< DCGL, no further action required.
HL-3-6	7,922	Not specified (5)	IM-1	< DCGL, no further action required.
HL-3-7	15,400	Not specified (5)	IM-1	< DCGL, no further action required.
HL-3-8	10,300	Not specified (5)	IM-1	< DCGL, no further action required.
HL-3-8	17,700	Not specified (5)	IM-2	< DCGL, no further action required.
HL-3-13	11,300	Not specified (5)	IM-1	< DCGL, no further action required.
HL-3-13	18,400	Not specified (5)	IM-2	< DCGL, no further action required.
HL-3-13	17,300	Not specified (5)	IM-3	< DCGL, no further action required.
HL-3-19	6,150	Not specified (5)	IM-1	< DCGL, no further action required.
HL-3-19	12,200	Not specified (5)	IM-2	< DCGL, no further action required.
HL-3-19	10,600	100	IM-3	Identified as "probe sized area" (44-116 probe open area is 100 cm^2); < DCGL, no further action required.
HL-3-19	17,100	Not specified (5)	IM-4	< DCGL, no further action required.
HL-3-21	42,400	4	IM-5	>DCGL. EMC/EMT performed; see Table 14.
HL-4-4	5,400	100	IM-1	< DCGL, no further action required.
HL-4-5	28,700	12.5	IM-1	< DCGL, no further action required.
HL-4-5	18,200	100	IM-2	< DCGL, no further action required.
HL-4-5	24,600	100	IM-3	< DCGL, no further action required.
HL-4-5	29,600	100	IM-4	< DCGL, no further action required.

Table 12, Summary of Investigative Static Measurements and Results

Survey Unit	Static Measurement (1) (dpm/100-cm^2)	Size of Elevated Area (cm^2)	Measurement ID	Comments/Results
HL-4-5	42,500	420	IM-5	IM-5 & IM-6 at same location, IM-5 > DCGL. EMC/EMT performed. See Table 14.
HL-4-5	33,600	420	IM-6	See entry above.
HL-4-5	33,100	100	IM-7	< DCGL, no further action required.
HL-4-5	15,700	100	IM-8	< DCGL, no further action required.
HL-4-5	22,200	100	IM-9	< DCGL, no further action required.
HL-4-8	9,890	100	IM-1	< DCGL, no further action required.
HL-4-8	40,390	100	IM-2	>DCGL. EMC/EMT performed; see Table 14.
HL-4-10	15,400	100	IM-1	< DCGL, no further action required.
HL-4-11	15,500	100	IM-1	< DCGL, no further action required.
HL-4-11	12,100	100	IM-2	< DCGL, no further action required.
HL-4-13	25,800	100	IM-1	< DCGL, no further action required.
HL-4-13	13,600	100	IM-2	< DCGL, no further action required.
HL-4-13	16,800	100	IM-3	< DCGL, no further action required.
HL-4-14	26,600	100	IM-1	< DCGL, no further action required.
HL-4-14	15,200	100	IM-2	< DCGL, no further action required.
HL-4-14	12,700	100	IM-3	< DCGL, no further action required.
HL-4-15	26,200	100	IM-1	< DCGL, no further action required.
HL-4-17	29,500	200	IM-1	< DCGL, no further action required.
HL-4-18	36,100	100	IM-1	Observed high gamma activity from beneath steel door frame/sill. Decision made to fail the survey unit, remove door frame and remediate the underlying concrete; see Table 13.
HL-4-18	22,700	100	IM-2	< DCGL, no further action required.
HL-4-18	6,130	100	IM-3	< DCGL, no further action required.
HL-4-19	44,450	1100	EMA-1	Average activity measured in a paint strip of area = 0.11 m^2. Activity is > DCGL. EMC and EMT performed.
HL-4-19	48,100	1000	EMA-2	Activity measured in a paint strip of area = 0.1 m^2. Activity is > DCGL. EMC and EMT performed; see Table 14.
HL-4-20	17,400	100	IM-1	Painted seam at N end of survey unit; < DCGL, no further action required.
HL-4-20	17,100	100	IM-2	Painted seam at N end of survey unit; < DCGL, no further action required.
HL-4-20	19,900	100	IM-3	Painted seam at S end of survey unit; < DCGL, no further action required.

Table 12 Notes.

1. This table includes only investigative measurements that were assigned an IM Number and the measured activity recorded in survey documentation. All are surface activity measurements reported in units of dpm/100-cm^2, except as noted in Note 5.
2. Here, the term "discrete particle" is used to identify a very small localized source of measurable surface contamination, usually a single particle (invisible, or nearly invisible).
3. These measurements are included in this table even though they are not representative of FSS final conditions. They illustrate the range of activities encountered during the FSS.

4. In accordance with FSS/Characterization procedures, static investigative measurements on soil areas are recorded as ncpm (measured with an LMI 44-10 NaI detector).
5. The size of elevated areas of surface contamination where investigative static measurements are performed are not always recorded when the measured activity is < DCGL and an EMC is not required. In most such cases the areas are "probe sized" or smaller (100 cm^2 or less, for the primary detector, the LMI 44-116).

Table 13, Survey Units Failed and Re-surveyed

Survey Unit ID	Description	Initial		Final		Comments
		Design	Survey Request	Design	Survey Request	
HL-1-58	Hot Work Area Room 16 - High Roof Framing Section 3	40F	230	40G	246	Discrete activity particle found on wall ledge – was removed by the smear. The survey unit was failed, a new FSS design prepared and the entire survey unit was resurveyed.
HL-4-18	Canal J - Floor	42B	249	42C	305	The survey unit was failed due to contamination beneath a steel door sill. The area was then remediated, a new FSS design prepared and the entire survey unit resurveyed.

As a result of investigations initiated during scan surveys, elevated measurement comparisons (EMC) and elevated measurement tests (EMT) were performed in seven survey units. These were prompted by investigative measurements which showed elevated activity in excess of the $DCGL_W$ in small localized areas. In accordance with the FSS Plan, Section 8.3, the $DCGL_{EMC}$ is calculated as the product of the Area Factor (AF) and the $DCGL_W$. The EMT is defined by the following equation:

$$\frac{\delta}{DCGL_W} + \frac{(average\ concentration\ in\ elevated\ area) - \delta}{(AF)\ (DCGL_W)} \leq 1.0 \qquad \textbf{[Equation 6]}$$

Where: δ is the average residual activity concentration in the survey unit.

If more than one elevated area is found in a survey unit, the second term in Equation 6 is calculated for each and summed with the first term to perform the unity rule calculation for the EMT. Results of the $DCGL_{EMC}$ and EMT calculations are presented in Table 14. Note that these represent "as-left" conditions in the affected survey units.

Table 14, EMC and EMT Calculations and Results

Survey Unit	Measurement ID	Measured Activity (dpm/100-cm^2)	Size of Elevated Area (cm^2)	DCGL$_W$ (dpm/100-cm^2)	Calculated DCGL$_{EMC}$ (dpm/100-cm^2) (1)	Average Activity in Survey Unit (dpm/100-cm^2)	EMT Unity Value
HL-1-40	EMA-1 (2)	46,900	100	34782	1.398E+06	6.810E+02	0.086 (3)
HL-1-40	EMA-2 (2)	47,700	100	34782	1.398E+06	6.810E+02	0.086 (3)
HL-1-71	IM-3	35,800	100	30960	1.245E+06	9.690E+02	0.059
HL-1-88	IM-1	53,847	100	34782	1.398E+06	9.050E+02	0.064
HL-3-21	IM-5	42,400	4	34350	1.381E+06	4.360E+02	0.043
HL-4-5	IM-5, IM-6	38,050 (4)	462	33236	1.336E+06	1.872E+03	0.083
HL-4-8	IM-2	40,390	100	33326	1.340E+06	4.920E+02	0.045
HL-4-19	EMA-1 (2)	44,450 (4)	1100	33236	1.336E+06	8.120E+02	0.092 (3)
HL-4-19	EMA-2 (2)	48,100 (4)	1000	33236	1.336E+06	8.120E+02	0.092 (3)

Table 14 Notes:

1. Calculated as the product of the AF and the DCGL$_W$. Per Table 3-5 of the FSS Plan, the AF for areas up to 0.25 m^2 is 40.2 [NASA 2007].
2. EMA is used to designate an area of elevated activity where more than one investigative measurement is recorded.
3. Unity value includes the sum of contributions from each of the individual elevated areas where measurements exceeded the DCGL.
4. The average of investigative measurements taken within an individual elevated area.

As noted above, an effect of the revised-reduced DCGLs on the investigative measurements is that several additional measurements are now below the DCGLs. The EMC and EMT were performed on these measurements and the measurements shown in Table 14. The revised DCGLs were used to calculate DCGL$_{EMC}$ and EMT unity values. Appendix D shows that all the investigative measurements so tested are well below the revised DCGL$_{EMC}$ and EMT unity values.

In accordance with the FSS Plan, removable surface activity measurements were taken at each systematic measurement location in structural survey units. The Plan requires that removable surface activity in each survey unit be less than 10% of the DCGL$_W$. Removable surface activity is measured by counting 100 cm^2 smear samples for beta and alpha activity.[21] Smear results were below counting instrument MDA values in all but 21 survey units. Results of removable surface activity measurements in excess of counting instrument MDA values are presented in Table 15. The table includes results of both systematic and investigative measurements. Removable activity measurement results are less than 10% of the applicable survey unit DCGL$_W$ for the final conditions in all survey units. One survey unit (HL-1-58) where removable surface activity in excess of 10% of the DCGL was measured was "failed" and the survey unit resurveyed after the source of the activity was removed.

[21] Smears are counted in the PBRF Counting Laboratory on automated sample changer proportional counters. Two such counters are available for this purpose: Tennelec Model LB-5100 and Tennelec Model 5X-LB.

Table 15, Summary of Removable Surface Activity Measurements

Survey Unit ID	Max. Beta Activity (1) (2) (3)	Max. Alpha Activity (1) (2) (3)	Comments (1)
HL-1-34	31.49 (SM)	< MDA	Additional beta smear > MDA was: 14.92 (SM).
HL-1-40	26.32 (IM)	< MDA	
HL-1-50	27.93 (IM)	< MDA	
HL-1-53	50.35 (IM)	< MDA	Additional beta smear > MDA was: 17.5 (SM).
HL-1-54	143.5 (IM)	< MDA	
HL-1-56	161.6 (IM)	< MDA	Additional beta smears > MDA were: 32.18 (SM) 48.74 (SM), 118.75 (IM) 134.39 (IM), 138.16 (SM) & 142.55 (IM).
HL-1-57	273.1 (IM)	18.03 (IM)	An initial IM smear measured 9131 beta gamma and 60.3 alpha. A discrete particle was removed by the smear. Additional smears > MDA were: all beta: 27.2 (SM), 48.74 (SM), 159.1 (IM), & 180.68 (SM).
HL-1-58	31.66 (IM)	< MDA	Additional beta smears > MDA were: 17.69 (SM) & 20.48 (SM).
HL-1-59	50.4 (IM)	< MDA	Additional beta smear > MDA was: 28.24 (SM).
HL-1-71	17.27 (IM)	< MDA	
HL-1-73	16.57 (SM)	< MDA	
HL-1-79	19.31 (IM)	< MDA	
HL-3-8	18.0 (IM)	< MDA	
HL-3-16	23.87 (SM)	< MDA	
HL-3-17	17.93 (SM)	< MDA	
HL-3-18	17.93 (SM)	< MDA	
HL-3-19	36.11(IM)	< MDA	Additional beta smears > MDA were 17.93 (IM) & 32.79 (IM).
HL-4-5	53.45 (IM)	< MDA	Systematic measurements were all < MDA. Additional investigative measurements > MDA were: 17.51, 20.08 & 20.27.
HL-4-15	126.18 (IM)	< MDA	
HL-4-17	57.53 (IM)	< MDA	
HL-4-19	14.66 (IM)	< MDA	

Table 15 Notes:

1. Units are dpm/100-cm^2. SM denotes systematic measurement. IM denotes investigative measurement.
2. Maximum removable surface activity measured in the survey unit.
3. Beta MDA values for these measurements ranged from 8.2 to 22.5 dpm. Alpha MDA values for these measurements ranged from 8.4 to 18.4 dpm.

5.4 Soil Survey Unit Results

Two soil survey units were established for the Hot Laboratory FSS. Survey Unit HL-1-91, Hot Work Area Soils, was established to cover soil contaminated by leaking piping located beneath the floor in the rear of Room 16 near the east freight door. Survey unit HL-3-20 addresses surface soil beneath the Hot Pipe Tunnel. A large section of the floor was removed because it was volumetrically contaminated. The soil was also potentially contaminated by embedded drains, which were removed. These survey units were designated Class 1. Surface soil samples were collected from each survey unit and analyzed by gamma spectroscopy by the PBRF laboratory. The results are summarized in Table 16 (see Appendix B for individual sample results). As shown in Table 10, 100 % of the soil areas were scanned (by NaI detectors set up to count in the Cs-137 energy window).

Table 16, Hot Laboratory Soil Survey Unit Sample Results

Survey Unit ID	Survey Design	No. of Measurements (1)	Maximum Concentration (pCi/g) (2)		
			Cs-137	Co-60	Sr-90 (3)
HL-1-91	401	11	1.44 (4)	< MDA (5)	0.27
HL-3-20	24B	14	1.74	< MDA (5)	0.16

Table 16 Notes:

1. The No. of measurements is systematic measurements (samples) per survey design. Additional samples were collected as part of investigations (two in HL-1-91).
2. The maximum concentrations shown are from systematic samples.
3. Sr-90 concentrations are inferred from measured Cs-137 activity concentration. The Sr-90: Cs-137 activity ratio is 0.094 per Design 24B and 0.19 per Design 40I.
4. The maximum measured Cs-137 concentration in this survey unit was 4.12 pCi/g (investigative measurement IM-2). The inferred Sr-90 concentration from this sample is 0.78 pCi/g.
5. All Co-60 sample MDAs are less than 0.14 pCi/g.

Since the maximum concentration of each radionuclide is a fraction of the respective $DCGL_W$, the calculated unity rule sum-of-fractions are less than 1.0 for the two soil survey units. Hence the soil survey units meet the release criteria.

5.5 QC Measurements

Per FSS Plan requirements, QC replicate measurements were taken for at least 5% of the Hot Laboratory FSS measurements. This included scan surveys, systematic total surface activity measurements and soil samples. Scan QC survey results are shown in Table 10 wherein the 5% scan QC coverage is confirmed. No QC scan surveys identified areas of elevated activity – these surveys confirmed the results of the original scan surveys of the areas covered.

Replicate total surface activity measurements were performed at selected measurement locations including systematic and investigative measurements. The 5 % requirement is satisfied in that 115 QC measurements were reported; this represents 6.9 % of the combined total of 1674 systematic and investigative measurements. Appendix C contains the individual measurement results for the 115 surface activity original and QC replicate measurement pairs. The FSS Plan (Section 12.7) specifies that the relative percent difference (RPD) between original and replicate measurements be within 20% [NASA 2007]. Forty five of the 115 measurement pairs exceeded the 20% criterion. Each measurement pair failing to meet the 20% criterion was individually investigated in accordance with FSS Plan requirements and implementing procedures. Each case in which the original and QC replicate measurement pairs did not meet the 20% RPD acceptance criterion was investigated, resolved and determined to be acceptable.[22]

It is found that most of the measurement pairs that exceeded the 20% RPD criterion were low activity measurements (below 1000 dpm/100-cm^2). Results of the replicate QC measurement evaluation are summarized in Table 17. The table shows that the average RPD is inversely proportional to the magnitude of residual surface contamination levels.

Table 17, RPD Evaluation of Replicate QC Surface Activity Measurements

Activity Range (1)(2)	No. of Measurement Pairs	Average Original Activity (1)	Average QC Rep. Activity (1)	Average RPD (%) (3)	No. of Measurement Pairs Exceeding 20% RPD
< 1000	43	527	497	120	27
1000 to 10000	37	3388	3442	22	13
>10,000	35	22051	22388	9	5

Table 17 Notes:

1. Units are dpm/100-cm^2.
2. The activity range is specified for the original measurements.
3. Calculated as the average of the individual measurement pair RPDs.

Replicate QC samples (one each) from the two HL soil survey units were collected and analyzed. All the results were < MDA, except the Cs-137 results for HL-1-91 (SP-7 & SP-7QC). These results are: SP-7: 0.65 ± 0.09 pCi/g, SP-7 QC: 0.83 ± 0.11 pCi/g (one-sigma uncertainty).

The HL-1-91 QC results were compared in accord with the method in the FSS Plan, Section 12.7.2 [NASA 2007]. In this method, the sample resolution is calculated as the quotient of the original sample one-sigma uncertainty and the sample result. Then the ratios of QC to original sample results are compared to acceptance values specified for each range of resolution given in FSS Plan Table 12-2. The ratio of sample results (1.28) is within the acceptable range provided in Table 12-1 of the FSS Plan (0.5 – 2.0).

[22] When the acceptance criterion is not met, an investigation is performed to determine the cause and corrective actions. The investigation may include repetition of the replicate QC measurement or other actions determined by the FSS/Characterization Supervisor. If upon repetition, the RPD criterion is still not satisfied, the result may be accepted if the original and QC replicate measurement are in agreement that both are below the $DCGL_W$ for the survey unit, the FSS/Characterization Supervisor reviews the investigation and concurs that the measurement is acceptable and the results of the investigation are documented in the Survey Request Summary and Close-out (Procedure CS-01, *Survey Methodology to Support PBRF License Termination*).

5.6 ALARA Evaluation

It is shown that residual contamination in the HL has been reduced to levels that are ALARA, using a method acceptable to the NRC. The NRC guidance on determining that residual contamination levels are ALARA includes the following:

> "In light of the conservatism in the building surface and surface soil generic screening levels developed by the NRC, NRC staff presumes, absent information to the contrary, those licensees who remediate building surfaces or soil to the generic screening levels do not need to provide analyses to demonstrate that these screening levels are ALARA. In addition, if residual radioactivity cannot be detected, it may be presumed that it had been reduced to levels that are ALARA. Therefore the licensee may not need to conduct an explicit analysis to meet the ALARA requirement."[23]

Screening level values published by the NRC for the mix of radionuclides in structural surface residual contamination potentially present in the HL are shown in Table 18. Since individual radionuclide activity concentrations are not measured in the FSS of structures, a direct comparison of residual contamination levels to individual radionuclide screening level values is not possible. A comparison can be made to an appropriate gross activity DCGL. A screening level value that is equivalent to the gross activity DCGL was calculated using the equations in Section 3.6 of the FSS Plan.[24] The activity fractions listed in Table 2 (also shown in Table 18) were used in the calculation. The screening level equivalent DCGL for the HL interior is calculated to be 8,132 dpm/100-cm^2.

The best estimate of average residual total surface beta activity in the HL structure is the mean of the 1574 systematic measurements. This is 587 ± 620 dpm/100-cm^2 (one standard deviation). The upper limit of the confidence interval about the mean at the 95% probability level is 617 dpm/100-cm^2.[25] This value is well below the screening level gross activity DCGL of 8,132 dpm/100-cm^2.[26]

Soil activity concentrations measured in the two HL soil survey units, HL-1-91 and HL-3-20, are compared to NRC soil screening level values in Table 19. As shown in the table, all soil activity concentrations are well below their respective screening level values. From these comparisons, it is concluded that the ALARA criterion is satisfied.

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[23] This guidance was initially published in Draft Regulatory Guide DG-4006, but has been reissued in NUREG-1757 Volume 2, Appendix N.

[24] The equivalent screening level gross activity DCGL is calculated using an EXCEL template [PBRF 2011]. This template incorporates the equations in section 5.3 of the FSS Plan [NASA 2007].

[25] The upper limit of the confidence interval, 95% probability level value, is calculated as: UL = mean + 1.96 $\sigma/\sqrt{n}$, where n = 1541systematic measurements.

[26] The effect of the revised DCGLs and radionuclide activity fractions published in TBD-11-002 on the ALARA evaluation is described in Appendix D. It is shown that the conclusion that the HL surface activity measurements satisfy the ALARA criterion is unchanged.

Table 18, Screening Level Values for HL and Radionuclide Activity Fractions

Radionuclide	Screening Level Value (dpm/100-cm^2)	HL Activity Fraction (%) (1)
H-3	1.2 E+08 (2)	0.0060
Co-60	7.1E+03 (2)	0.0203
Sr-90	8.7E+03 (2)	0.3444
I-129	3.5E+04(2)	0.0
Cs-137	2.8E+04 (2)	0.6240
Eu-154	1.2E+04(3)	0.0
U-234	9.1E+01 (3)	0.0048
U-235	9.8E+01(3)	0.005

Table 18 Notes.

1. Activity fractions used to develop the $DCGL_W$ for HL interior surfaces. Values from Table 2, with most conservative mix, (highest Uranium fractions - Hot Pipe Tunnel).
2. Values from NUREG-1757 Vol. 2, Table H.1 [USNRC 2006].
3. Values from NUREG/CR-5512, Vol. 3, Table 5.19 [SNL 1999]. These are 90th percentile values of residual surface activity corresponding to 25 mrem/y to a future building occupant.

Table 19, NRC Soil Screening Level ALARA Comparison

Radionuclide	NRC Screening Level (pCi/g)	Maximum Measured Concentration (pCi/g)
Co-60	3.8	< MDA(1)
Cs-137	11	1.74 (2)
Sr-90	1.7	0.16 (3)

Table 19 Notes:

1. The average Co-60 MDA for all HL soil samples (systematic and investigative) is 0.077 ± 0.037 pCi/g.
2. The maximum of 25 systematic samples collected in the two survey units. Of these samples, 11 showed measured Cs-137 concentrations < MDA. The maximum Cs-137 concentration in all HL soil samples, including investigative samples was 4.12 pCi/g.
3. Maximum Sr-90 concentration inferred from maximum measured Cs-137 concentration in systematic samples and SR-90: Cs-137 activity ratio of 0.094. The inferred Sr-90 concentration obtained from the maximum investigative sample Cs-137 result is 0.78 pCi/g.

5.7 Comparison with EPA Trigger Levels

The PBRF license termination process includes a review of residual contamination levels in groundwater and soil, as applicable, in accordance with the October 2002 Memorandum of Understanding (MOU) between the US NRC and the US Environmental Protection Agency (EPA) [USEPA 2002]. Concentrations of individual radionuclides, identified as "trigger levels" for further review and consultation between the agencies, are published in the MOU.

Maximum activity concentrations of radionuclides of concern measured in the HL FSS are compared to EPA trigger levels. This comparison is shown in Table 20. The table shows that the measured soil activity concentrations are well below EPA trigger levels. It is noted that groundwater is not within the scope of the HL FSS.

Table 20, Comparison of Soil Sample Results with EPA Trigger Levels

Radionuclide	EPA Trigger Level (pCi/g)	Maximum Measured Concentration (pCi/g)
Co-60	4	< MDA (1)
Cs-137 (4)	6	4.12 (2)
Sr-90 (4)	23	0.78 (3)

Table 20 Notes:

1. The maximum Co-60 MDA in all HL soil samples is 0.13 pCi/g.
2. The maximum Cs-137 concentration measured in all HL soil samples including investigative samples.
3. Maximum Sr-90 concentration inferred from maximum measured Cs-137 concentration and SR-90: Cs-137 activity ratio of 0.094.
4. Specified in the MOU as including daughter activity [USEPA 2002].

5.8 Conclusions

The results presented in this section demonstrate that the Hot Laboratory satisfies all FSS Plan commitments and meets the release criteria in 10CFR20 Subpart E. Principal results are:

- Scan surveys were performed in 100 % of the accessible surfaces of the 137 HL Class 1 survey units.
- Investigations resulting from scan surveys were conducted in 37 survey units. As a result of these investigations:
    - Two survey units were failed, then remediated and re-surveyed – both satisfied the release criteria after the FSS resurvey.
    - Elevated measurement comparisons and elevated measurement tests were performed in seven survey units – all were successful.
- All fixed total surface activity measurements (locations established by survey designs) are less than the applicable $DCGL_W$.
- All structural survey unit mean fixed measurement results (total surface beta activity) are below the $DCGL_W$, hence no statistical tests were required.
- Soil sample analysis results from the two HL soil survey units are less than the DCGLs for the radionuclides of concern.
- Removable surface activity measurements in all survey units are less than 10% of the $DCGL_W$.[27]

[27] Removable surface beta activity greater than 10% of the $DCGL_W$ was measured in one survey unit; however this survey unit was failed, remediated and resurveyed.

- Residual surface activity and soil activity concentration measurement results are shown to be less than NRC screening level values - demonstrating that the ALARA criterion is satisfied.
- Only minor changes from what was proposed in the FSS Plan were made – the HL was divided into 140 survey units, whereas the FSS Plan had identified 41 survey areas, not divided into survey units. Two areas classified as Class 2 in the FSS Plan were changed to Class 1 for the FSS.
- There was one change from initial assumptions (in the FSS Plan) regarding the extent of residual activity in the HL. Two areas of contaminated soil were identified underneath the HL building; these were not identified in the FSS Plan. No reclassification of survey units was required as a result of FSS measurements and investigations.
- Errors in several of the DCGLs and radionuclide activity fractions published in a supporting technical basis document were recently discovered and were revised in a new technical basis document. The potential impacts of these changes on the Hot Lab FSS were evaluated and it is found that all FSS Plan requirements remain satisfied and the conclusions hold that the 25 mrem/y and ALARA criteria are satisfied.

6.0 References

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ORISE 2011 — Oak Ridge Institute for Science and Education, Independent Environmental Assessment and Verification Program, *Final – Independent Confirmatory Survey Report for the Reactor Building, Hot Laboratory, Primary Pump House, and Land Areas at the Plum Brook Reactor Facility, Sandusky, Ohio*, October 2011.

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USNRC 1998 US Nuclear Regulatory Commission, *Minimum Detectable Concentrations with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions*, NUREG-1507, June 1998.

USNRC 2000 US Nuclear Regulatory Commission, *Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)*, NUREG-1575, Rev.1, August 2000.

USNRC 2006 US Nuclear Regulatory Commission, *Consolidated Decommissioning Guidance, Characterization, Survey and Determination of Radiological Criteria*, NUREG 1757, Vol. 2, Rev.1, September 2006.

7.0 Appendices

Appendix A – Exhibits

Appendix B – Survey Unit Maps and Tables Showing Measurement Locations and Results

Appendix C – QC Measurements

Appendix D – Evaluation of Revised DCGLs

Final Status Survey Report

Attachment 8

Hot Laboratory
(Building 1112)

Revision 0

Appendix A

Exhibits

List of Exhibits

Exhibit 1, Views of Hot Laboratory Exterior

Overhead View of Hot Laboratory and Reactor Building from the West (2011)

Ground Level View of Hot Lab from Southeast (2010)

Exhibit 2, Hot Laboratory Main Operating Floor Model

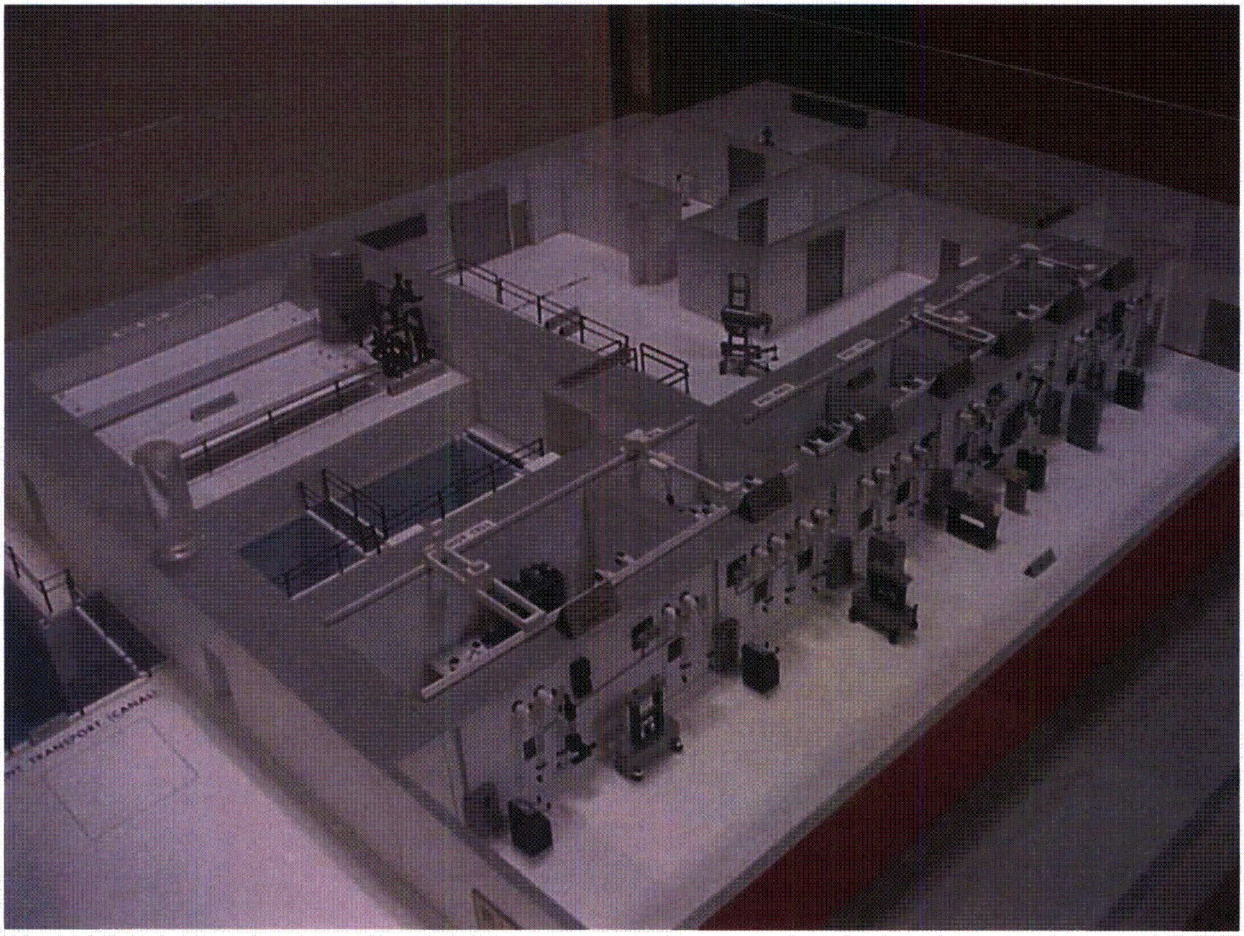
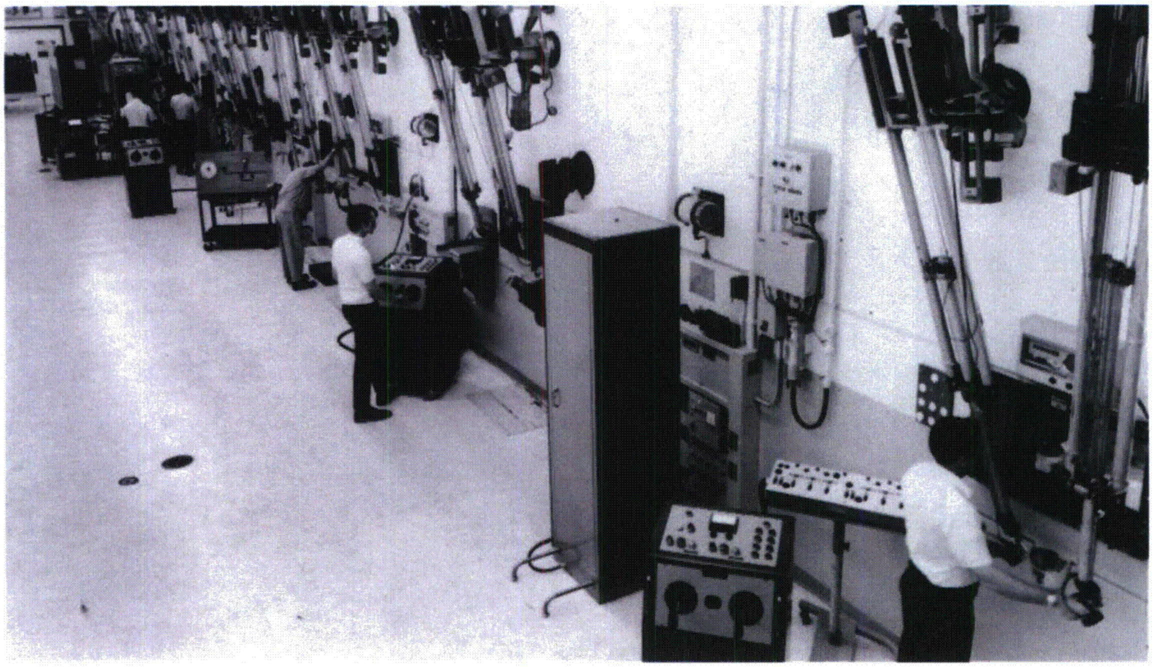


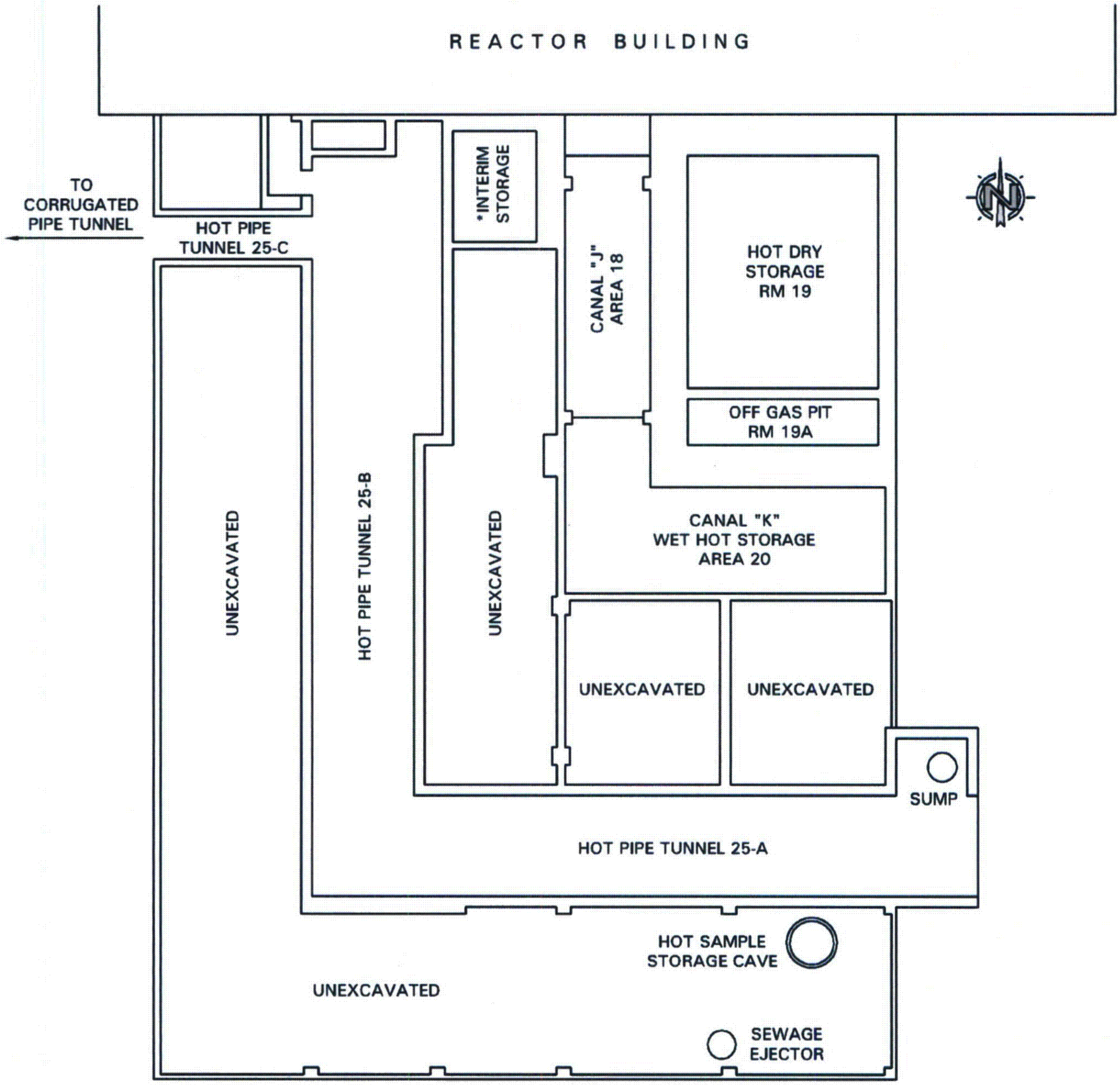
Exhibit 3, Hot Cell Operator Viewing Gallery – Historical Photos

Hot Cells in Operation circa 1968



Post Shutdown – Pre-Decommissioning View circa 1999

Exhibit 4, Plan View of Hot Laboratory - 12 ft. Elevation



*INTERIM STORAGE AREA ADDED DURING DECOMMISSIONING

Exhibit 5, E-W Section View of Hot Laboratory Looking South

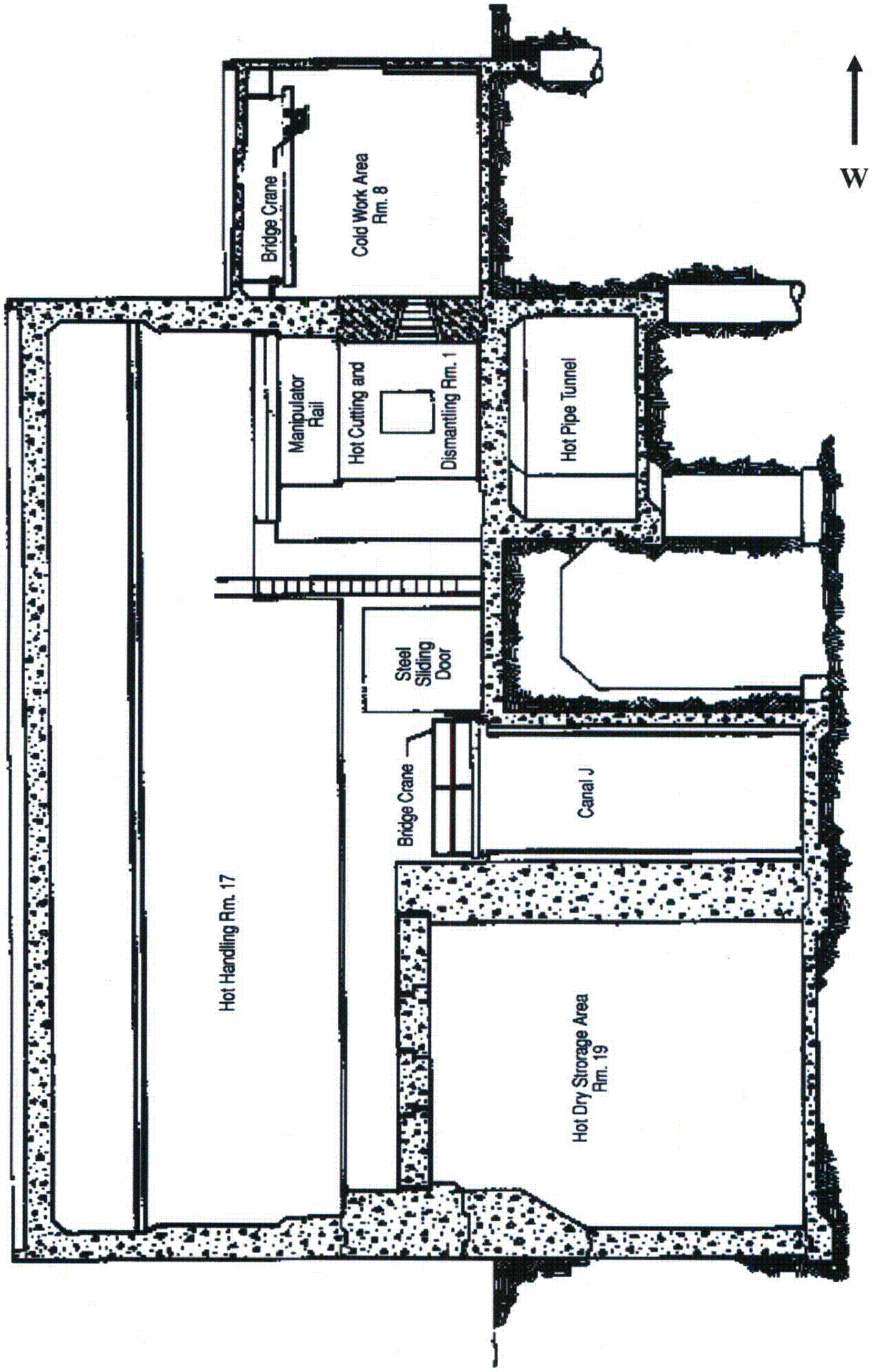


Exhibit 6, Operator Viewing Gallery Post-Decommissioning

Looking South (circa 2009) Showing Manipulator Ports, Viewing Window Frames and Poured Concrete Surfaces

South End of Viewing Gallery Showing Concrete Block Wall and Main Outside Entrance on the Right

Exhibit 7, Hot Cells 3 through 7 Viewed from Above circa 2010

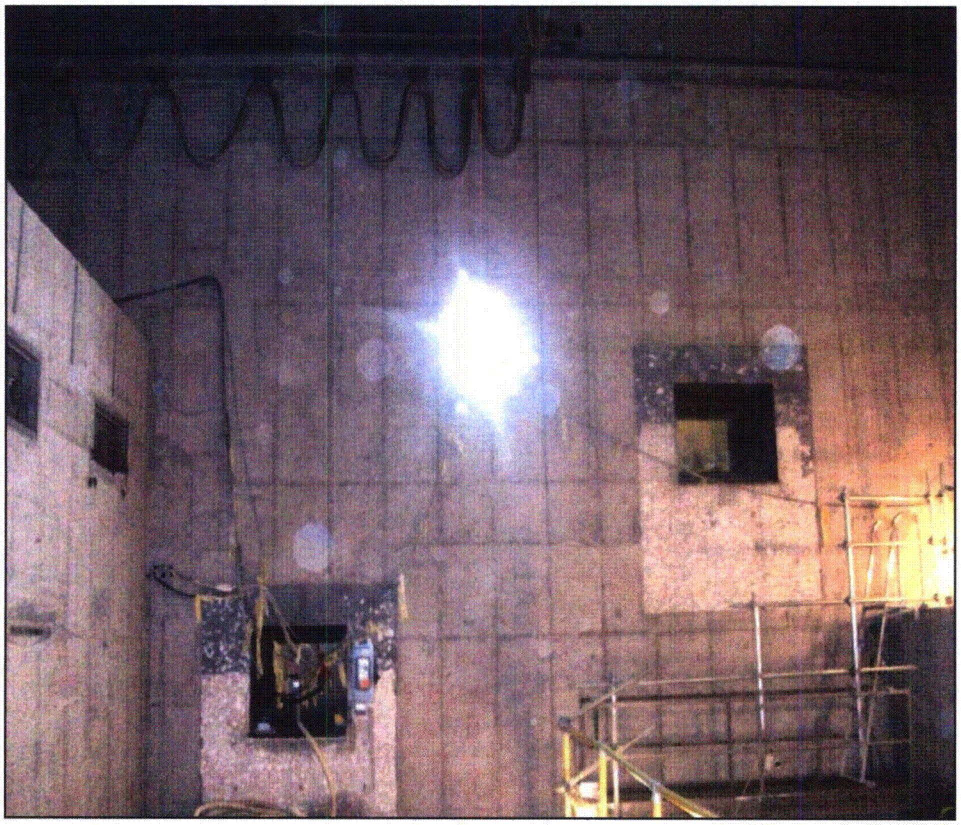
Exhibit 8, Hot Cell Interiors

Hot Cell 1 Floor

Hot Cell 2 West Wall Showing Lead Glass Viewing Window Frames

Exhibit 9. Hot Handling Room

View of North Wall, Showing Hot Cell Wall on Left



South Wall Looking South into Hot Work Area

Exhibit 10, Views of Hot Work Area

Operating Era Photo of Hot Work Area (Rm 16) Showing Hot Cell Shield Doors

Hot Work Area View Shown Above in 2010

Exhibit 11, Operating Floor Repair Shop and Storage Areas

Former Decontamination Room and Repair Shop Areas

Interior of Room 24 Storage Area, Showing Poured Concrete Floor and Walls

Exhibit 12, South Support Areas

View of Former Manipulator Repair Shop Looking North into Hot Cell Viewing Area

Former Locker Room, Janitor Closet Shower and Rest Room Area

Exhibit 13, Operating Floor Mezzanine

View of West Floor Section Overlooking Hot Work Area

South Wall above Mezzanine

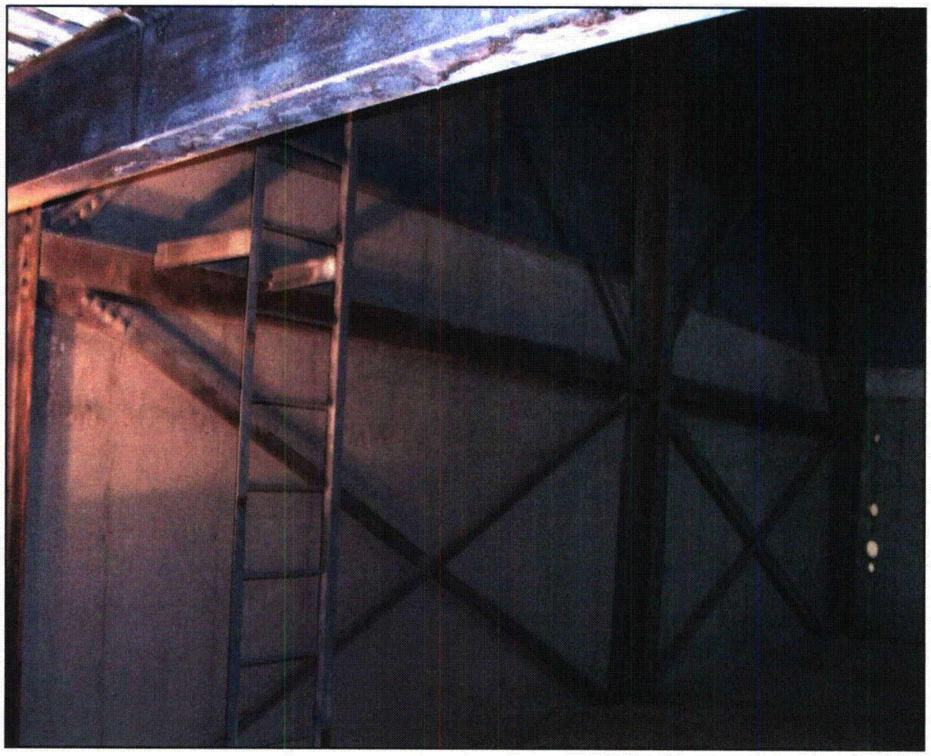


Exhibit 14, Interior Upper Walls in Rear Operating Areas

Poured Concrete Walls Above Hot Cells

Sheet Metal East Wall of Hot Work Area High Bay

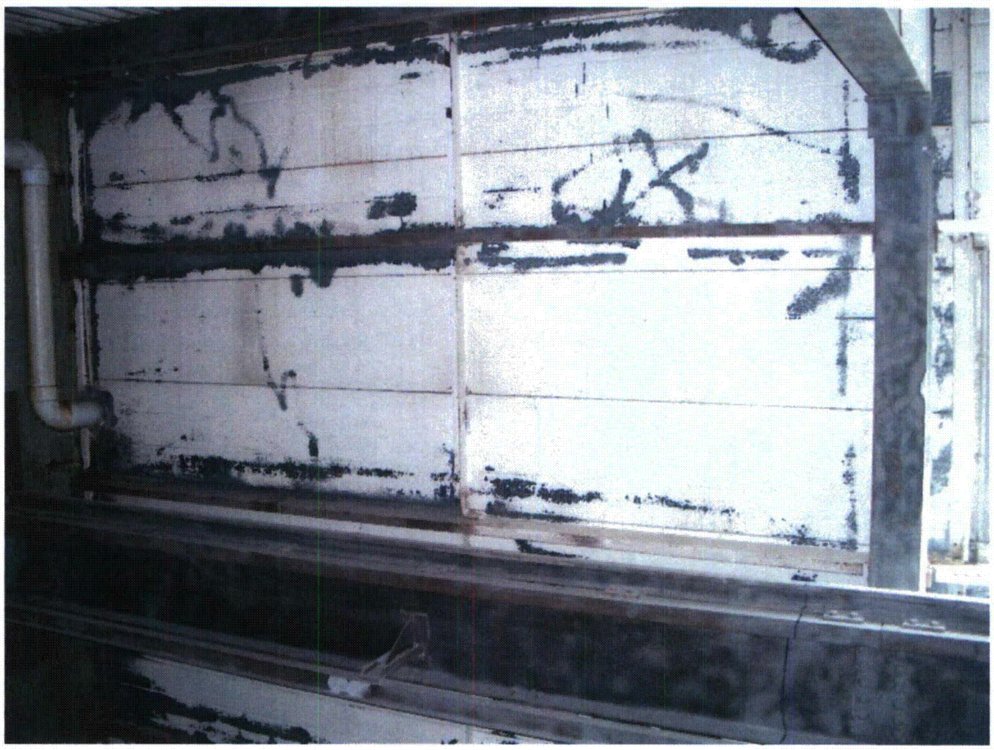


Exhibit 15, Hot Work Area Ceilings (Room 16)
Above Storage and Repair Shop Area

Above Hot Cells Looking Southwest

Exhibit 16, Hot Work Area Crane
Rolling Assembly Positioned Above Mezzanine

Close up View of Remaining Rolling Mechanism

Exhibit 17, Hot Handling Area Crane

In position above Hot Cells Prior to Disassembly Showing Hoist Trolley

View of Crane Rails after Removal of Hoist Trolley Mechanism and Prepared for FSS

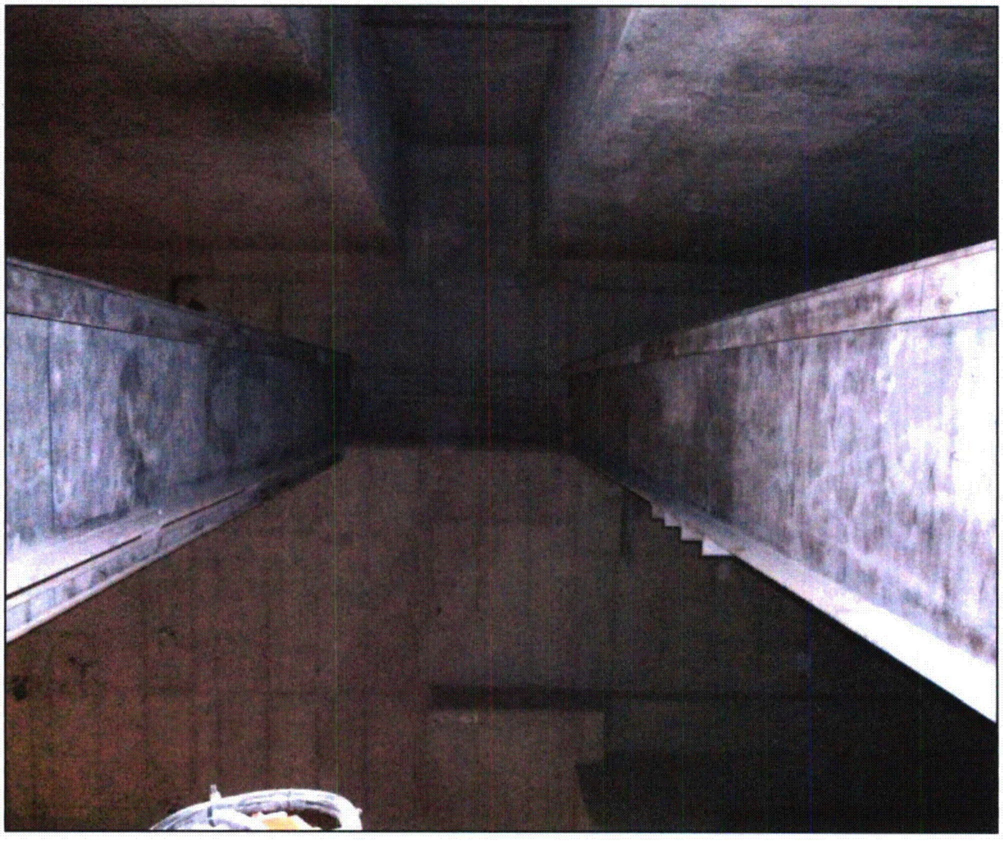
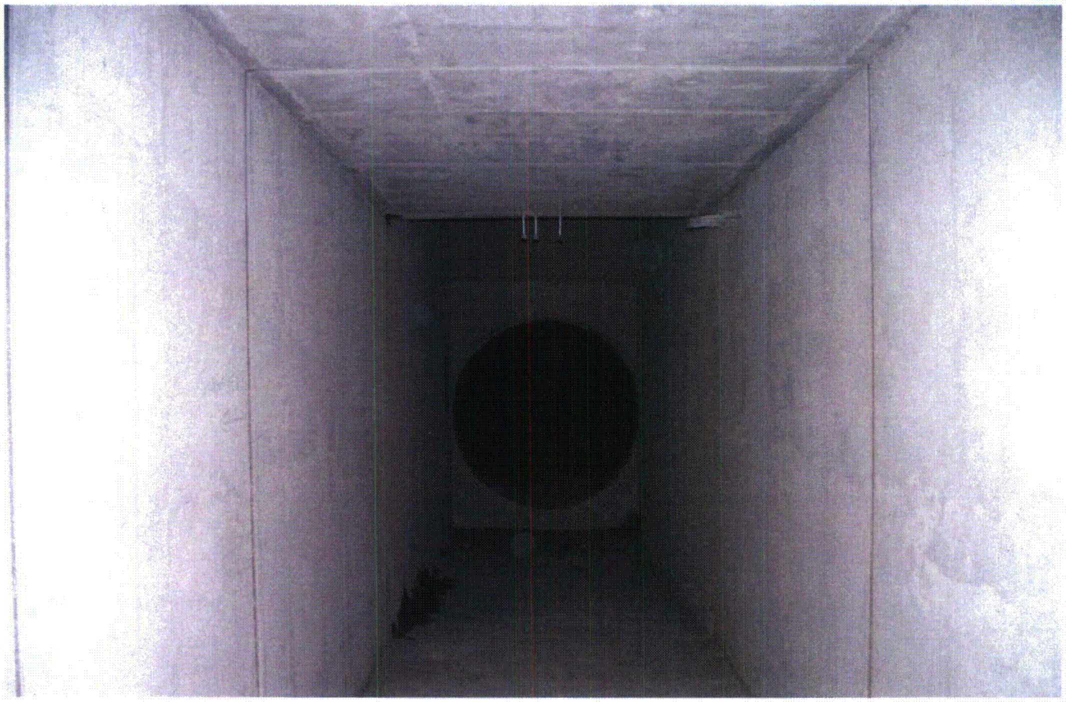


Exhibit 18, Hot Pipe Tunnel
East-West Leg Viewed from East (FH)

End of Northern Leg, showing Reactor Building Wall and Left Branch to ROLB Extension

Exhibit 19, Hot Pipe Tunnel Extension to ROLB

Entrance from Hot Pipe Tunnel in the Hot Laboratory



Corrugated Section Between the Hot Laboratory and ROLB

Exhibit 20, Hot Pipe Tunnel Soil Area Survey Unit

Main Soil Area at South End of North-South Leg of HPT

Small Soil Area on East-West Leg – Note Fresh Concrete was Poured in these Areas after FSS

Exhibit 21, Hot Dry Storage Area

N. Section Showing Viewing Port, Storage Wells and Access Ports to Lower Area

Room 19, Hot Dry Storage Area on – 25 ft. Elevation

Exhibit 22, Hot Dry Storage Area, Continued
Off Gas System Area

Exhibit 23, Canal J

View from 0 ft. Elevation Looking North into Reactor Building

View from 0 ft. Elevation Looking South into Canal K

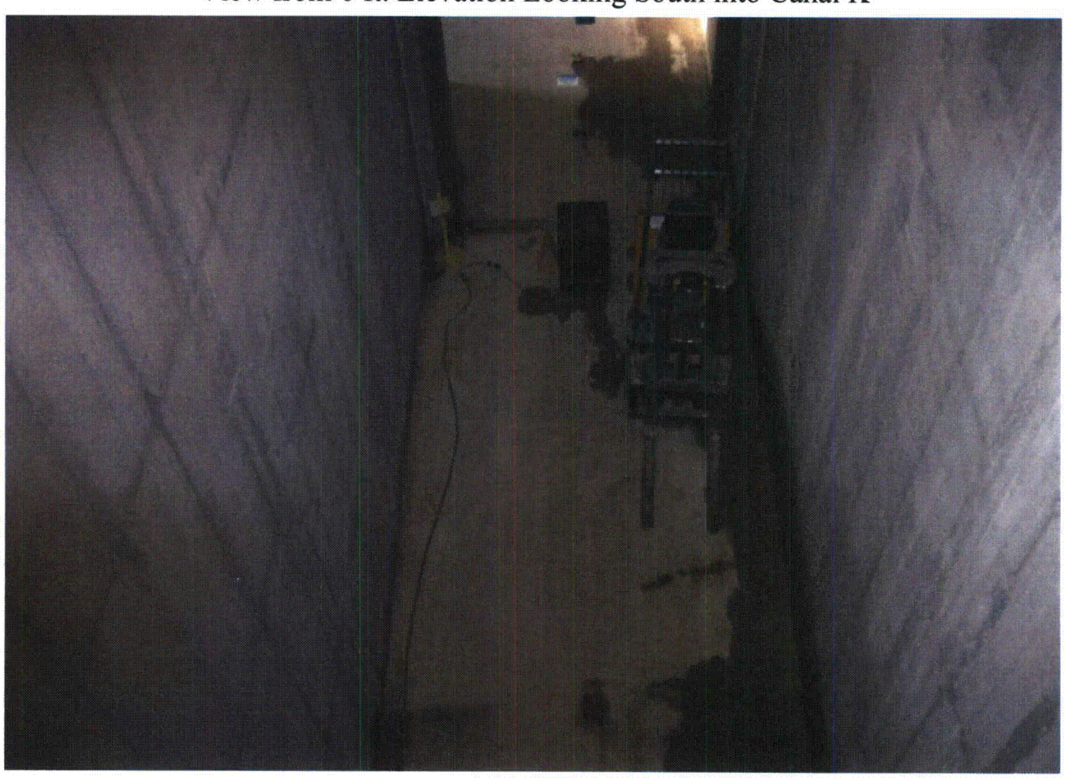


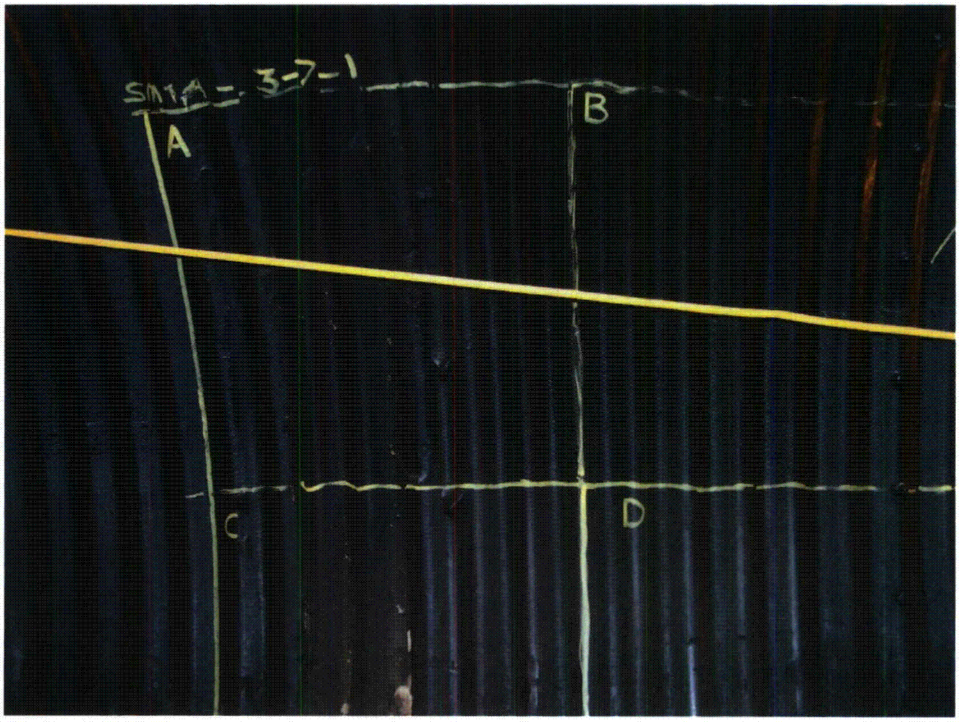
Exhibit 24, Canal K

Canal K Floor East End

North Wall Viewed from Southwest

Exhibit 25, Surface Measurement Test Areas (STMAs)

Area in Corrugated HL/ROLB Pipe Tunnel with Extruding Sealant (HL-3-7)



South Wall of Off Gas System Area (Rm 19A) – Unistruts and Scabbled Surfaces (HL-4-3)

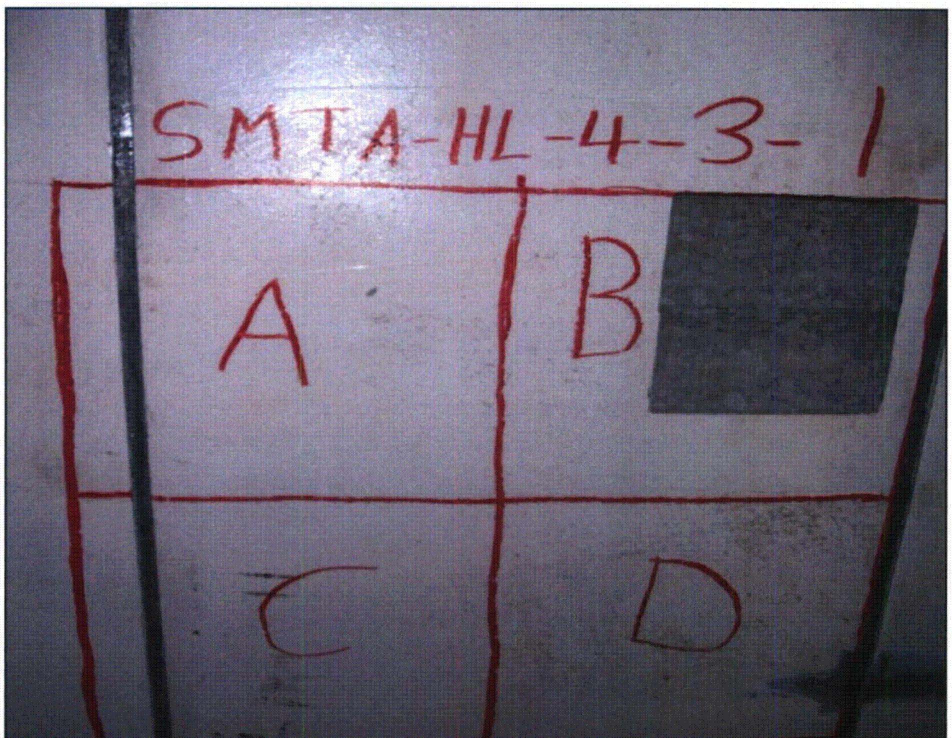


Exhibit 26, Unusual Condition Measurement Areas (UCMs)

Mezzanine Floor, Chipped Concrete, Exposed rebar and Handrail Post (HL-2-2)

Concrete Block Wall Opening with Embedded Conduit (HL-1-74)

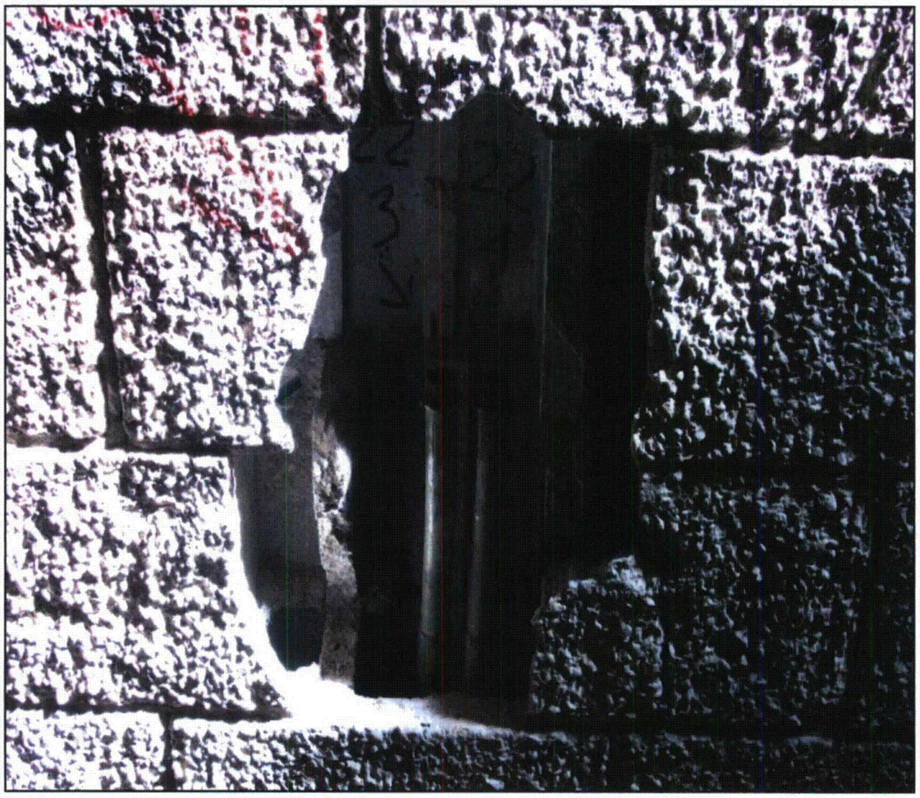


Exhibit 27, Unusual Condition Measurement Areas (UCMs), Continued

Rough Surface Area at Excavated Floor in Hot Pipe Tunnel (HL-3-21)

Cracked Concrete Surrounding Floor Drain (HL-1-29)

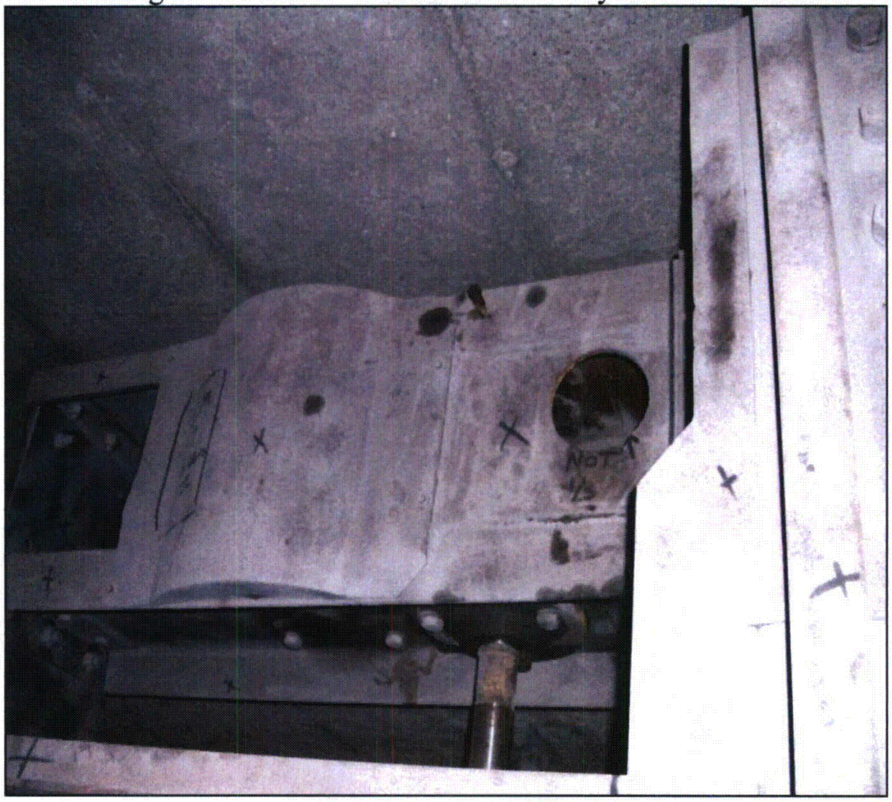
Exhibit 28, Examples of Other Special Measurement Conditions

Conduit Pit in Floor of Hot Cell Viewing Gallery

Radioactive Material Storage Pit in Room 24 Floor (HL-1-29)

Exhibit 29, Examples of Other Special Measurement Conditions, Continued

Hot Handling Room Crane – Remnants of Trolley Drive Mechanism



Warm Handling Room Upper Steel - Intersection of Support Beams and Brackets