National Aeronautics and
Space Administration

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October 7, 2011

Reply to Attn of: QD

U.S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, D.C. 20555

Subject: Final Status Survey Report, Attachment 9, Embedded Piping, for the Plum Brook Reactor Facility, Licenses Nos. TR-3, Docket No. 50-30 and R-93, Docket No, 50-185

Enclosed for your review is Attachment 9 to the Final Status Survey Report supporting eventual termination of the licenses for the Plum Brook Reactor Facility.

The complete Final Status Survey Report will consist of a series of Attachments, each addressing an individual survey area or group of survey areas or environmental areas as described in our NRC approved Final Status Survey Plan. The final submission will be the main body of the Final Status Survey Report which will consolidate and summarize the details presented in the Attachments.

This Attachment addresses the Final Status Survey of the Embedded Piping. It supports our conclusion that radiological remediation of the building has been completed and the area meets the criteria for unrestricted release specified in 10 CFR 20.1402.

Should you have any questions or need additional information, please contact me at NASA Plum Brook Station, 6100 Columbus Avenue, Sandusky, Ohio 44870, or by telephone at (419) 621-3242.

Peter C. Kolb, R.E.M.
Acting NASA Decommissioning Program Manager

FSME20

Enclosure

1. Plum Brook Reactor Facility Final Status Survey Report, Attachment 9, Embedded Piping, revision 0, dated October 6, 2011.

cc:
USNRC/C. J. Glenn (FSME)
USNRC/J. Webb (FSME)
USNRC/J. Tapp RIII/DNMS/DB
ODH/M. J. Rubadue

Plum Brook Reactor Facility

Final Status Survey Report

Attachment 9

Revision 0

Embedded Piping

FINAL STATUS SURVEY REPORT
ROUTING AND APPROVAL SHEET

Document Title: Final Status Survey Report,
Attachment 9
Embedded Piping

Revision Number: 0

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LIST OF ACRONYMS & SYMBOLS

Ag-108m	Silver-108 metastable
ALARA	As Low As Reasonably Achievable
Am-241	Americium 241
β	beta; denotes beta radiation
C-14	Carbon 14
Co-60	Cobalt 60
CFR	Code of Federal Regulations
Cm-243/244	Curium 243/244
cm	centimeters
cpm	counts per minute
CsI	Cesium Iodide
Cs-137	Cesium 137
CV	Containment Vessel
DCGL	Derived Concentration Guideline Level
$DCGL_W$	DCGL for average concentrations over a survey unit, used with statistical tests. (the "W" suffix denotes "Wilcoxon)"
dpm	disintegrations per minute
D and D	Decommissioning and Decontamination
EP	Embedded Piping
EPA	US Environmental Protection Agency
Eu-152	Europium 152
Eu-154	Europium 154
FSS	Final Status Survey
FSSP	Final Status Survey Plan
FSSR	Final Status Survey Report
ft	feet
γ	gamma, denotes gamma radiation
g	gram
g/cc	grams per cubic centimeter
H-3	Tritium
HDS	Hot Dry Storage
HTD	Hard to Detect nuclides
HRA	Hot Retention Area
I-129	Iodine 129
in.	inch
m^2	square meters
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
MDC	Minimum Detectable Concentration
MDCR	Minimum Detectable Count Rate
N	measurements
mrem	millirem
mrem/hr	millirem per hour
mrem/yr	millirem per year
mSv/hr	milliSeivert per hour

LIST OF ACRONYMS & SYMBOLS, Continued

NASA	National Aeronautics and Space Administration
Nb-94	Niobium 94
N/A	Not Applicable
NaI	Sodium Iodide
Ni-63	Nickel 63
NRC	US Nuclear Regulatory Commission
PBRF	Plum Brook Reactor Facility
Pu-238	Plutonium 238
Pu-241	Plutonium 241
%	percent
PCW	Primary Cooling Water
QC	Quality Control
Quad	Quadrant
Rm	room
ROLB	Reactor Office and Laboratory Building
s	seconds
SEB	Service Equipment Building
Sn-126	Tin 126
SR	Survey Request
Sr-90	Strontium 90
TBD	Technical Basis Document
μ	Mean activity concentration
VSP	Vitrified Storm Pipe
WHB	Waste Handling Building

1.0 Introduction

This report presents the results of the final status radiological surveys of the Plum Brook Reactor Facility (PBRF) Embedded Piping (EP). It is Attachment 9 of the PBRF Final Status Survey Report (FSSR). [1] This attachment describes the EP, its operational history and final condition for the final status survey (FSS). It describes the methods used in decontaminating and surveying the EP 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/yr. Subpart E also requires that residual contamination be reduced to levels as low as reasonably achievable (ALARA). Derived Concentration Guideline Levels (DCGL) have been established for residual contamination in the EP. As presented in the FSSP, Section 3.3, the EP dose goal is $\leq$ 1mrem/yr. Considering the radionuclides established in the FSSP for EP, gross beta DCGLs range from 2.408E+05 to 3.785E+06 dpm/100-cm^2 as presented in Table 1a.

The survey measurement results and supporting information are presented to demonstrate that residual contamination levels in each embedded pipe of the PBRF are below the respective DCGLs. It is also shown that residual contamination has been reduced to levels that are consistent with the ALARA requirement. Therefore, the EP contribution to the total dose assessment of any given structural survey unit meets the criteria for unrestricted release as described in the FSSP.

Section 2.0 of the report provides a description of EP. The specific definition of EP and examples of EP as situated in PBRF buildings are provided.

In Section 3.0, a description of the operational history with radioactive materials is presented for the various groups of EP. Post shutdown decommissioning remediation and survey activities are described. An introduction to the sampling efforts in support of radiological characterization is included.

Section 4.0 presents the FSS design process for the EP. This section includes applicable characterization efforts in support of FSS, DCGL and nuclide distribution development. FSS Plan specifics concerning DCGLs and EP Dose Modeling are presented.

Survey results are presented in Section 5.0. The survey design approach, instrumentation and measurement sensitivities are presented. This section includes a summary of the survey measurements performed in the EP, comparison to DCGLs, tests performed and an evaluation of residual contamination levels relative to the ALARA criterion, and a conclusion with regard to the FSS of EP at PBRF.

Section 6.0 provides the references that were used to support the development of this Attachment.

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[1] The PBRF Final Status Survey Report comprises the report main body and several attachments. This attachments presents survey results for individual runs of embedded piping and their contribution to applicable structural survey units. The entire final report will provide the basis for requesting termination of Nuclear Regulatory Commission (NRC) Licenses TR-3 and R-93 in accordance with 10CFR50.82 (b) (6).

Section 7 provides supporting information as contained in Appendices. Appendix A contains photos to supplement the text. Appendix B provides EP penetration location maps. Appendix C provides table(s) identifying the structural survey units which coincide with EP and the total dose combination of the EP and the structural survey units. Appendix D details the survey and data evaluation process unique to pipes EP 1.11 and EP 1.12.

2.0 Embedded Piping Description

Embedded piping (EP) is any pipe situated below the minus three foot elevation (628 foot mean sea level[2]) that is totally encased in concrete or piping directly beneath building floors that may not be totally encased in concrete, but contained within the structural foundation of the building. Additionally, EP is grouted at the time of license termination to demonstrate compliance with the release criterion as developed in the FSSP. Examples include Containment Vessel Quadrant and Canal drain piping and remaining sections of the Primary Cooling Loop. All references to EP in this attachment fulfills all the criteria described above.

2.1 Embedded Piping Systems

The EP at PBRF is divided into categories based on similar histories and operational system liquids for characterization of residual contamination and development of radionuclide profiles (Technical Basis Document (TBD), PBRF-06-004 [PBRF 2006b], *Activity Ratios of Radionuclides in Embedded and Buried Piping*). The objective is to provide a basis for assignment of radionuclide profiles. Breakdown of the PBRF piping systems into similar groups considers facility design, operating history, results from recent inspections, radiological surveys and sample results. The EP comprises interconnected piping systems that can be described by a simplified conceptual model. The model consists of four main elements or compartments:

- Source compartments,
- Processing compartments,
- Mixing compartments and
- Connecting piping

The principal source compartments are the:

- Primary Cooling Water System
- Fuel Storage (and Mock-up Reactor)
- Irradiated test materials (ROLB Laboratories, Hot Cells and transfer system piping)
- Waste Cleanup System

This model assumes that each of these sources has a characteristic radionuclide profile. The radionuclides present in the piping were deposited over the period of facility operation and during the post-shutdown period. During PBRF operation, processing of liquid waste streams occurred in the Reactor Building, Primary Pump House, Fan House and Waste Handling

[2] The reference grade level at the Reactor building is 631 feet above mean sea level as described in the *NACA Reactor Plot Plan and Soil Boring Data*, December 1956.

Building. During the post-shutdown period, the radionuclide composition and activity ratios of the piping deposits have changed over time due to radioactive decay and movement (and mixing) of contaminated waste water. Water movement has occurred from intermittent pumping, entry into floor drains from in-leakage and flooding, and losses from leakage and discharge to the effluent pathway.

Compartments where mixing occurred includes:

- Main Quads and Canals
- Hot Retention Area
- Cold Retention Basins
- Miscellaneous sumps and tanks

3.0 History of Operations with Radioactive Materials

The internals of the EP systems reported in this attachment were utilized to contain and transport various system waters in support of reactor operation and reactor facility support. The system models introduced in Section 2.0 were developed into piping groups with similar radioactive characteristics. Four of these piping groups are EP groups. Histories of the radioactive material transported by these systems during operations and removal of those radioactive materials during decommissioning are described below.

3.1 Piping Group 1, Primary Cooling Water (PCW)

The remnants of this piping system include about 700 to 800 feet of piping, comprising about 15 separate runs, most of which is embedded in concrete. The most significant portion is the 24-inch primary cooling water piping ~ 280 feet in length. The PCW piping also includes the embedded remnants of the By-pass Cleanup, Instrument Cooling and Shutdown loops, and drain lines. The PCW piping is stainless steel and it is the only EP system that operated significantly above ambient temperature and pressure and under controlled chemistry conditions. Most of this piping is presently in good physical condition and contains relatively uniform radioactive corrosion layer deposits. The uniform corrosion deposits are characteristic of those that occur in controlled chemistry, pressure and temperature environments as found in water cooled power reactor primary circuits. These deposits are overlaid by some non-uniform deposits from formerly suspended corrosion and fission products. The radionuclide composition of residual contamination deposits in PCW piping is relatively uniform throughout. In addition to the primary cooling water piping itself, piping from nearby drains and other drain piping whose main source of waste water is from the PCW system have been included in Group 1.

3.2 Piping Group 2, Quadrant and Canal Piping

This piping totals over 2000 ft. and comprises about 45 runs of stainless and carbon steel piping ranging from 2 to 10 inches in diameter. This piping, mostly drain piping, received water from or supplied water to the Quads and Canals (mostly low temperature water). Much of this piping was exposed to the atmosphere for various periods of time and is significantly degraded. Piping deposits range from loose scale and sediment-debris, loosely adhered corrosion scale, "bathtub

line deposits" and possibly some more tightly adhered corrosion layer deposits (prior to cleaning and inspection). This piping includes the pipe runs that were modeled in the dose calculations to obtain the EP DCGL published in the FSSP. The water in this piping is not "well mixed", as some lines were only sporadically filled or drained.

3.3 Piping Group 3, Hot Drains

This is a large and diverse group of piping, with 50 or more runs totaling over 5,000 feet in length. Much of this piping has been removed during the D and D process. These drain lines received water from the Reactor Building, Primary Pump House, Reactor Office and Laboratory Building (ROLB) Lab Drains, process buildings (Waste Handling Building and Fan House) and the Hot Laboratory. In addition to drains from the aforementioned buildings, it includes Hot Pipe Tunnel piping and drains. The piping is comprised of stainless and carbon steel and the condition of these piping runs is similar to Group 2 piping. As with Quad and Canal piping, the hot drains have variable radionuclide composition, activity levels and activity ratios throughout. Also, as with the Quad and Canal piping, the Hot Drains received water from diverse sources. The water in this piping was not considered to be "well mixed".

3.4 Piping Group 4, Cold Drains

This is a group of long-run piping with approximately 25 pipe runs totaling about 5,000 feet in length. It includes a portion of Cold Pipe Tunnel piping and floor drains and the ROLB and Service Equipment Building (SEB) basement drains. This piping is comprised mostly of carbon steel and believed to be in similar condition to Quad and Canal piping, except there are no residual radioactivity levels.

3.5 Labeling of Embedded Piping

Labeling for EP was begun by project personnel in 2004 and began with system identifications numbers as presented on plant system drawings. Subsequent consultations between retired personnel and decommissioning project engineers resulted in a comprehensive listing of piping meeting the definition for EP as described in Section 2.0 of this attachment and the FSSP. This listing of EP is identified in the plant buildings with markings on the walls and floors of the facility structures which use the numerical designator for the EP from the final inventory for EP which has been grouted in accordance with Section 3.3 of the FSSP. Each individual EP opening on the walls and floors is transcribed to maps which include building elevations, easily identified physical representations of the building surfaces, appropriately sized and positioned pipe openings, and the pipe number (label) from the EP inventory. These maps are reproduced in Appendix B to this attachment.

3.6 Cleaning Process to Remediate Radioactive Materials in EP

Decontamination was performed on 100% of the interior surfaces of radiologically contaminated EP. Decontamination involves the use of vacuuming, mechanical cleaning, grit blasting, and high-pressure water (Appendix A, Exhibits 1 & 4). Remediation activities commence with the simplest remediation processes and graduate to more aggressive remediation processes based on representative survey results. This graduated approach minimizes radioactive waste generation and handling, allows use of those remediation efforts

with the lowest safety hazards to be utilized first, and provides the best flexibility when coordinating workspace availability with other decommissioning efforts.

The simplest remediation technique is vacuuming with vacuum heads to remove debris deposits from the piping. This method does not appreciably remove corrosion or scale deposits and is rarely the only remediation process required (Appendix A, Exhibit 2).

Corrosion and scale removal requires mechanical agitation of interior piping surfaces; these methods employ rotating snakes and abrasive or pulverizing heads to mechanically separate radioactivity bearing scale and corrosion deposits from the interior piping surfaces(Appendix A, Exhibits 5 & 8). These mechanical processes utilize a vacuum head in close proximity to the piping surfaces being remediated to remove scale and corrosion fragments as they are generated.

When mechanical agitation is insufficient to achieve the remediation goal, aggressive remediation escalates to grit blasting. Interior piping surfaces are grit blasted to remove tightly adhered corrosion layers from the piping. Industrial grit blast media are applied using standard and proprietary techniques with the continuous removal of waste materials using vacuum heads as described earlier.

The most aggressive technique employed is high pressure water hydro-lasing. No vacuum heads are used in conjunction for those pipes which are hydro-lased, runoff water is collected in drums and processed by PBRF operations personnel (Appendix A, Exhibits 3 & 6).

Prior to initial radiological survey activities and at any opportune phase of remediation, the piping is inspected using remote camera systems to assure the physical condition of the piping is acceptable for moving radiological detectors through the piping. Before performing any radiological survey activities using in-situ survey equipment, the piping to be surveyed is assessed for loose surface contamination using full piping length swabs by radiological controls personnel. This minimizes the potential of loose surface contamination being transported through the piping by the in-situ survey equipment, contaminating the in-situ survey equipment, or biasing the piping survey results.

3.7 Survey Method to Assess Final Status of Radioactive Materials in EP

Piping interior surfaces are surveyed using detectors mounted in engineered sleds. These sleds protect the detectors as they transit through the piping and assure reproducible in-situ geometries. These geometries are required to be consistent with the geometries and parameters established during the in-situ calibration of the detector. The sleds allow the connection of fish tapes, cables or fiber rods which are manipulated by technicians to move the detector and sled through the piping to be surveyed (Appendix A, Exhibits 7 & 9).

Sleds are not feasible to be used in some smaller diameter piping. For these scenarios the in-situ calibration does not utilize a sled, the detector is directly bound to the fishtape or cable used for movement through the piping, and movement through the piping is performed cautiously to minimize any chance of damage to the detector.

Detectors used to perform piping surveys are NaI or CsI gamma scintillating detectors of sizes appropriate to the piping size and the physical challenges of the piping runs. These detectors are optimized (windowed) to measure the gamma energies specific to either Co-60 or Cs-137. A static radiological survey measurement is taken for every foot of pipe traveled.

Field measurements in cpm are converted to equivalent beta measurements in dpm/100cm^2 through application of surrogate calculations and piping correction factors. These calculated activity densities are assessed against the applicable DCGL from the FSSP for compliance with the EP dose goal. As these post-remediation surveys demonstrate the EP dose goal has been achieved, the surveyed piping is placed in to isolation and control, and the survey results are documented into a release record.

The 24" primary cooling lines are surveyed using a different method from that described above due to circumstances as described in Appendix D to this attachment. These surveys utilize scintillating beta-gamma detectors mounted on an in-situ, variable geometry, pipe sled. This sled allows the detectors to traverse elbows and risers while assuring a consistent geometry for each survey measurement. 100% assay by scan survey of all accessible surfaces and static radiological measurements at specified increments are assessed to demonstrate compliance with the EP dose goal. These surveys are detailed in Appendix D of this attachment.

4.0 Embedded Piping FSS Design Approach

The approach for EP FSS is as follows:[3]

- Determine if piping meets the definition of EP.
- Determine the piping group of the piping.
- Perform remediation and radiological surveys of the piping.
- Remediate and survey the piping until the EP dose goal is achieved.
- Establish controls on the piping to ensure the piping system is not impacted by site operations that could change the condition of the piping.

4.1 Embedded Piping DCGLs & Radionuclide Distributions

The PBRF contains a number of pipe runs that are embedded in concrete. As stated above, EP is any pipe situated below the minus three (-3) foot elevation that is totally encased in concrete or piping directly beneath building floors that are not totally encased in concrete, but contained within the structural foundation of the building. Examples include the Containment Vessel Quadrant and Canal drain piping and remaining sections of the Primary Cooling Loop. The EP DCGL values are listed in Table 1a. These values represent surface activity concentrations that correspond to an annual dose of 1 mrem/yr to a future building occupant. In order to utilize the EP DCGL values, piping must be grouted prior to license termination.

The PBRF dose goal for EP was 1 mrem/yr. However, in accordance with Section 3.3 of the PBRF FSSP, different dose goals can be applied in different areas as long as the residual contamination on the structure surface in the survey unit containing the given EP is sufficiently

[3] The EP DCGLs are determined in accordance with Attachment C of the FSSP.

low to allow for the selected dose goal. For example, if the FSS results indicate that the residual contamination level in Hot Dry Storage is 0.5 times the DCGL, the dose from EP in this survey unit could be as high as 12.5 mrem/yr.

Table 1a, DCGL Values for Embedded Piping

Radionuclide	DCGL (dpm/100 cm^2 per mrem/yr)
Co-60	2.408E+05
Eu-154	5.325E+05
Eu-152	7.352E+05
Nb-94	9.082E+05
Ag-108m	1.312E+06
Cs-137	3.785E+06

Radionuclide distributions and activity ratios were developed in TBD-06-004 [PBRF 2006b]. Recognizing that radionuclide composition in the piping varies considerably across the PBRF, the piping has been divided into groups with similar characteristics for development of radionuclide profiles. The EP has been divided into four main groups for this purpose. The January 2006 study evaluated information from laboratory analysis results of 55 samples of piping deposits. The Cs-137 to Co-60 activity ratio is an important parameter for evaluation of survey measurements in PBRF EP. When piping surveys are conducted using surface activity measurements, this ratio "controls" the gross beta DCGL. This is because these two radionuclides are found in all piping group residual contamination and they, in effect "bracket" the DCGLs, as seen in Table 1a. The Co-60 dose contribution is about 16 times the Cs-137 contribution per unit activity and Co-60 yields the most restrictive individual nuclide DCGL. Correspondingly, the Cs-137 DCGL is about 16 times the Co-60 DCGL and is the least restrictive DCGL of the gamma emitters that are consistently observed in PBRF piping deposit samples. Other gamma emitters such as Eu-152 and Eu-154 found in some PBRF EP samples have unit dose factors intermediate between Co-60 and Cs-137. However, these are not usually seen in the absence of Co-60 and do not greatly influence the gross beta DCGL. A summary table of the radionuclide distributions utilized to surrogate field measurements and develop activity profiles for the EP is shown below as Table 1b. Detailed explanation for the development of Table 1b can be reviewed in TBD-06-004.

Table 1b, Radionuclide Activity Profiles for All Piping Groups								
Radionuclide (1)	Primary Emission (2)	Activity Fraction (%)						
		Group 1	Group 2	Group 3.1(3)	Group 3.2 (4)	Group 3.3(5)	Group 4.1(6)	Group 4.2(6)
Am-241	4	0.2	0.01	1.17	1.19			
C-14	3	1.36	1.38	0.029		0.04		
Cs-137	1	0.91	10.63	65.90	39.89	79.9	44.3	84.1
Co-60	1	22.96	20.50	4.04	4.37	3.94	55.7	15.9
Cm-243/244	4	0.82						
Eu-152	1	21.78	0.17					
Eu-154	1	5.79	0.12	0.27	0.28			
I-129	1	3.37						
Ni-63	3	12.93	57.90	10.60	16.37	7.87		
Nb-94	1	0.67	0.01					
Ag-108m	1	0.16	0.59					
Pu-238	4	0.63						
Pu-241	4	0.72						
Sr-90	2	2.21	0.92	17.85	37.84	8.13		
Sn-126	1	0.71						
H-3	3	23.42	7.55	0.03	0.03	0.03		

Table 1b notes:

1. Radionuclides are included in the table if their activity fraction is 0.5% or greater in any of the piping group results (some activity fractions may be reported, even though <0.5% because the radionuclide is > 0.5% in at least one piping group).
2. Primary emission codes are: 1 = gamma (beta-gamma), 2 = beta-only, 3 = HTD and 4 = alpha.
3. Group 3.1 (Miscellaneous Hot Drains) activity fractions for individual radionuclides are assigned the average values from all the group 3 samples (no samples from group 3.1 were sent for comprehensive analysis).
4. Group 3.2 (Hot Lab Hot Work Areas) activity fractions are obtained from the results of comprehensive analysis of sample No EP-11 (Hot Lab Room 16 Floor Drain).
5. Group 3.3 (activity fractions are obtained from the results of comprehensive analysis of sample Nos. CS050823-012 (HRA Pit drain pipe scale) and EP-4 (WHB Evaporator Room floor drain). The activity fractions are the averages of the activity fraction values from the two samples.
6. No comprehensive analysis results are available for piping group 4. Activity fractions are available for gamma emitters only – from gamma spectroscopy results.

4.2 Embedded Piping Conceptual Dose Model for Final Status Survey

Various piping configurations were evaluated to determine which EP scenario delivered the highest dose to a building occupant [PBRF 2006]. The EP configuration that delivers the highest dose to a future building occupant is the 9-pipe cluster in the Canal F – Pump Walkway. The individual is assumed to occupy the walkway between Canal F and the Pump Room at the Reactor Building -25 ft. elevation and is exposed to a group of pipes (a pipe cluster) embedded in the concrete beneath the walkway. Plant drawings were reviewed and inspections performed to confirm that the pipe cluster located beneath the Canal F – Pump Room Walkway represents the most conservative case. That is, this pipe cluster is the highest concentration of embedded pipes to which a future building occupant could be exposed while

occupying a single location in the facility. Table 2 describes the piping layout used in the dose model.

Table 2, Description of Pipe Cluster in Canal F – Pump Walkway						
Piping Run ID	Description	ID (in.)	Length (ft)	Horizontal Offset From Dose Point CL[3] (ft)	Pipe CL[3] Depth (in.)	Pipe Top Surf Depth Below floor (in.)
1.21	Canal H Drain	6	81	1.5	16	13.25
1.23	Canal G Drain	6	42	1.5	16	13.25
1.24	Canal G Purge	3	39	3	16	14.75
1.25	Canal F Drain	6	20	4.5	16	13.25
1.26	Canal F Purge	3	19.5	6	16	14.75
1.641	Canal F&G OF Header [1]	8	25	3	38	34.25
1.81	Canal K Floor Drain	6	25	6	25	22.25
1.82	Canal J & HDS Riser [2]	3	25	4.5	25	23.75
1.83	HDS Floor Drain	4	25	7	38	36.25
Average Dimensions =>		5.0	33.5		22.9	20.6

Table 2 Notes:

1. Overflow Header
2. Hot Drain System Riser
3. CL denotes centerline

4.3 Dose Calculations for 9-Pipe Cluster for Final Status Survey

All dose calculations were performed using MicroShield® Version 5.04. [PBRF 2006] For the primary DCGL dose calculations, MicroShield® geometry option 10 was used for the 9-pipe cluster Canal F – Pump Room Walkway model.[4] This is a cylindrical surface source with external dose point. The following assumptions were used to establish the MicroShield® case runs and for determination of DCGL values:

- The dose receptor (dose point) is located one meter above the walkway floor surface on the longitudinal centerline of the pipe cluster and at a distance midway between the pipe ends.
- The 9 pipes lie in parallel runs (parallel to each other and to the floor surface) at the same elevation. The actual pipe centerline depths range from 16 to 38 inches and the average depth is 22.9 inches.

[4] The MicroShield® code has several standard options for combinations of source and shield configurations. These are called "geometries". The geometry used for the default case, Geometry 10 is suitable for dose-receptor points external to the piping and located at positions that lie between the pipe ends (within the two planes perpendicular to the pipe longitudinal axis).

- The concrete in which the piping is embedded is modeled as a concrete slab shield (density 2.4 g/cc), 12 in. thick, placed between the top pipe surface and the floor elevation.

- All the pipes are cleaned by vacuuming and pressure blasting or mechanical means to remove loose scale and loosely adherent surface contamination. The pipes are filled with grout (concrete) with density 1.8 g/cc.

- The pipes are all assumed to be 25 ft. in length. Note that the pipe lengths vary from 19.5 to 81 ft. with average length of 33.5 ft. It is found that the calculated dose is not sensitive to pipe length as the length is increased beyond 20 ft.

- The pipe wall is modeled as a ¼ in. thick (0.65 cm) cylindrical shield. This corresponds to Schedule 40 piping wall thickness for 5 in. piping, the average ID of the 9-pipe cluster. Note that the actual piping is all Schedule 80 (0.95 cm. wall thickness) and the "buildup" medium for the MicroShield® dose calculations is selected as the grout-filled pipe core.

- The model includes a piping corrosion layer surrounding the cylindrical surface source, modeled as "cladding" of 0.025 cm thickness.

- The only exposure pathway that is operative for EP is direct dose from gamma-emitting radionuclides. All the radionuclides that were present in piping residual contamination are fixed in place by the grout and are not available for transport to ground water or to ingestion or inhalation pathways to a future building occupant.

- This DCGL calculation uses MicroShield® case run output dose rates in units of mSv/h (Deep Dose Equivalent Rate). The output dose rates are then converted to mrem/hr (100 mrem/h per mSv/h).

The MicroShield® source, dose point coordinates and shield dimensions are summarized in Table 3 below.

Table 3, Dose Calculation Model Dimensions

Source Dimensions (cm)		Dose Point Coordinates (cm)			Shields (cm)		
Pipe Length	Radius [1]	X [2]	Y [3]	Z [4]	Wall Clad	Pipe Wall	Concrete
762 (25 ft.)	Pipe-specific	Pipe-specific	381 (12.5 ft.)	Pipe-specific	0.025	0.65	30.48 (1 ft)

Table 3 Notes:

1. This is the radius in cm. corresponding to each pipe ID.
2. The x coordinate is the total distance from the center axis of each pipe to the dose point. This includes the pipe radius, wall clad, pipe wall-shield thickness, the 12 in. concrete slab-shield thickness and the 1-meter distance from floor surface to the dose point (receptor center-height above the floor).

3. The y coordinate places the dose point at the center of the pipe lengths.
4. The z coordinate is the offset distance from the centerline of each pipe to the pipe cluster centerline (the dose point is located directly above the pipe cluster centerline).

The dose to the receptor from each radionuclide is obtained as the sum of the contributions from each piping run in the 9-pipe cluster. The results are shown in Table 4. It is noted that DCGL values for radionuclides that emit only beta particles are not calculated for EP, even though several have been measured in piping deposits. They do not contribute to the dose to future building occupants because the piping that remains in place is filled with grout.

Table 4, Calculated Doses from Principal Gamma Emitting Radionuclides Canal F - Pump Room Walkway 9-pipe Cluster

Piping Line No.	mrem/hr per dpm/100-cm^2					
	Co-60	Cs-137	Eu-152	Eu-154	Ag-108m	Nb-94
1.21	5.54E-10	3.90E-11	1.82E-10	2.50E-10	1.11E-10	1.58E-10
1.23	5.54E-10	3.90E-11	1.82E-10	2.50E-10	1.11E-10	1.58E-10
1.24	1.79E-10	1.08E-11	5.84E-11	8.08E-11	3.13E-11	4.60E-11
1.25	8.64E-11	3.60E-12	2.79E-11	3.95E-11	1.10E-11	1.74E-11
1.26	1.76E-11	5.33E-13	5.68E-12	8.19E-12	1.71E-12	2.87E-12
1.641	2.90E-10	1.64E-11	9.42E-11	1.31E-10	4.79E-11	7.11E-11
1.81	2.43E-11	7.02E-13	7.87E-12	1.14E-11	2.27E-12	3.83E-12
1.82	6.12E-11	2.70E-12	1.97E-11	2.79E-11	8.16E-12	1.28E-11
1.83	8.29E-12	1.87E-13	2.71E-12	3.97E-12	6.32E-13	1.11E-12
Total	1.77E-09	1.13E-10	5.81E-10	8.03E-10	3.25E-10	4.71E-10

Table 4 Notes:

The dose rates from I-129 (9.89E-35 mrem/hr), Sn-126 (1.45E-17 mrem/hr) and Eu-155 (4.10E-16 mrem/hr) were calculated, but are found to be at least 5 orders of magnitude below the dose rates from the other gamma emitting radionuclides. They are of no consequence and are eliminated from further consideration.

4.4 Embedded Piping DCGL Values for 9-Pipe Cluster for Final Status Survey

To obtain individual radionuclide DCGL values, the dose rate for each radionuclide is converted to annual dose by multiplying by 2340 h/yr, the exposure-hours for the occupant in the building occupancy scenario. The DCGL values are then obtained as the reciprocal of the

annual dose. The results of these calculations are provided in Table 5. The individual radionuclide DCGL values range from 2.408E05 dpm/100-cm^2 for Co-60 to 3.785E06 dpm/100-cm^2 for Cs-137. The calculated doses and DCGL values are strongly dependent on the thickness of concrete shielding that surrounds the EP. The concrete typically provides a minimum of 12 to 14 inches of shielding for the piping.

Table 5, Individual Radionuclide DCGL Values for Embedded Piping

Radionuclide	Dose from all Pipes (mrem/hr)	Annual Dose to Building Occupant (mrem/yr)	DCGL (dpm/100-cm^2 per mrem/yr)
Co-60	1.77E-09	4.17E-06	2.408E+05
Eu-154	8.03E-10	1.89E-06	5.325E+05
Eu-152	5.81E-10	1.37E-06	7.352E+05
Nb-94	4.71E-10	1.11E-06	9.082E+05
Ag-108m	3.25E-10	7.60E-07	1.312E+06
Cs-137	1.13E-10	2.64E-07	3.785E+06

The gross activity DCGL for the EP is calculated using equations in the FSSP for gross activity and surrogate DCGLs, based on the radionuclide mixture in residual contamination. Activity fractions for the EP are shown in Table 1b, individual DCGL values for EP are shown in Table 5.

4.5 Embedded Piping Reporting Units in Piping Release Records

Embedded piping release records collate EP radiological surveys and assess compliance with the EP dose goal in units of unity where 1.0 is 1 mrem/yr. These unity values are determined in accordance with the FSSP, and reference the DCGL values (from the FSSP) as presented in Table 5 above.

The unity calculation is as follows:

$$\frac{C_1}{DCGL_1} + \frac{C_2}{DCGL_2} + \frac{C_n}{DCGL_n} \leq 1$$

Where: Cn = concentration of radionuclide n and

DCGLn = DCGL of radionuclide n.

Scenario's where EP unity is > 1.0 are discussed in section 5.0 below.

5.0 Embedded Piping Survey Results

The surveys to establish the final status of EP systems are conducted after cleaning and remediation surveys are performed in accordance with the applicable Work Execution Package

(WEP). As stated earlier these survey results are collated and assessed against the EP dose goal in units of unity where 1.0 is 1 mrem/yr . For survey conclusions which result in a unity of greater than one, there are two follow-on actions:

- Further remediation and radiological surveys with assessment against the EP dose goal.
- Select an appropriate EP dose goal as described in the FSSP and Section 4.1 above.

Further remediation and surveys are performed when it is ALARA and physically safe to do so. Selection of a dose goal greater than one is performed when the safety constraints of additional remediation do not justify the reduction in contamination levels. This decision also considers ALARA concerns and the residual contamination on the structure surface in the structure survey units affected by the embedded pipe run(s). If selection of an EP dose goal greater than one cannot result in a dose of 25 mrem/yr or less for the affected structure survey units then the application of area factors as described in Section 3.7 of the FSSP may be used to demonstrate compliance with the release criterion. Selection of a dose goal greater than one is more conservative than applying area factors. Area factors were not required to demonstrate compliance with the release criterion for any embedded pipes.

5.1 Detector Efficiencies and MDCs

The detectors utilized for EP surveys were gamma scintillating detectors constructed of NaI or CsI crystals with photo-multiplier tubes in a single housing purchased from various vendors. These detectors were optimized during calibration to measure gamma energies representative of Co-60 or Cs-137 gamma energies with the use of discriminator settings (windowing) [5].

After calibration and the establishment of the detector operating parameters, the detectors is assigned specific efficiencies for each unique combination of detector, sled, nuclide of concern, co-axial cable length and pipe diameter. An example of how these unique efficiencies are determined follows;

- A detector (e.g. detector #1003) requires an efficiency determination for Cs-137 in a 4 inch pipe.
- A sled suitable for the physical layout of the 4 inch pipe(s) to be surveyed is selected to be used with detector #1003 (e.g. sled #104)
- A four inch section of clean piping will be loaded with a large, flexible conformal single nuclide source which has a vendor certified, traceable to the National Institute of Standards and Technology, homogenous activity deposition of Cs-137 activity across its surface area. The source is loaded inside the 4 inch clean pipe section, in continuous contact with the pipes inside diameter. The pipe section is significantly longer then the sources maximum dimension, and the source is verified to be completely within the pipe section.
- The detector is fitted into the sled and inserted into the 4 inch pipe containing the conformal Cs-137 source. The detectors centerline is centered on the middle of the

[5] Two pipe runs (EP 1.11 and EP 1.12) were surveyed using a different methodology from the other embedded pipes. The details for these two unique runs are described in Appendix D of this attachment.

Cs-137 source (Photographs of a detector-sled-pipe and cable setup are located in Appendix A, Exhibit 10 of this attachment).

- The detector parameters are verified prior to acquiring activity measurements for the efficiency determination, and the cable length being used for the efficiency determination is documented.
- A series of counts are collected as prescribed by approved procedures for efficiency determination.
- The resultant efficiency determination is a unique efficiency defined by the detector number, sled number, pipe size, co-axial cable length, and nuclide of concern.

As mentioned previously, sleds are not feasible for some small diameter piping surveys. For these instances, the same procedure for efficiency determination is followed with the sled listed as "No Sled" in the detector efficiency determination and history file. Enhanced caution is applied when acquiring field measurements as the added protection of the sled is not available. Survey data quality is not adversely affected due to the scenario of having no sled with the detector. Detector sleds perform two purposes, the primary purpose is to facilitate ease of movement through piping and protect the detector from physical damage, the secondary purpose is to maintain the in-situ geometry consistent between field measurements and the efficiency determination. Detectors used with no sled have efficiency determinations which recreate the least optimal field geometry, and movement through the piping is performed cautiously to minimize any chance of damage to the detector during field surveys.

After any efficiency determination is completed the unique efficiency is used to calculate MDCs and MDCRs for that efficiency. All calibrations, efficiencies and MDC/MDCR calculations are entered into the detector history files and referenced for converting field measurements in counts per minute to activity measurements in disintegrations per minute per 100 centimeters squared. Detector sensitivity is verified to be compliant for use in Class 1 areas as defined in the FSSP (all embedded pipes are classified as Class 1). An additional measure of conservatism is that embedded pipes have static survey measurements performed over 100% of their surface area. This greatly enhances retrospective power curves when necessary to demonstrate compliance with the EP dose goal.

Table 6 lists efficiencies and MDCs for the numerous detector-sled-pipe and nuclide of concern combinations utilized during surveys of the EP presented in this attachment. Cable lengths have not been included in this table.

Table 6, Embedded Piping MDC and Efficiency Ranges for Cobalt-60 and Cesium-137 using Various Detectors

Pipe Diameter		Detector	Co-60 MDC (dpm/100 cm^2)			Co-60 Efficiencies[1]			Cs-137 MDC (dpm/100 cm^2)			Cs-137 Efficiencies[1]		
(Inches)	Sled #	#	High	Avg.	Low	High	Avg.	Low	High	Avg.	Low	High	Avg.	Low
0.75	None	70006-0047 212701 204402	9808	9808	9808	0.00069	0.00069	0.00069	10260	10260	10260	0.00075	0.00075	0.00075
1.0	None	70006-0047 70006-0048 212701 204402 215957 238367 238369	6687	6687	6687	0.0006	0.0006	0.0006	21002	12247	7587	0.0007	0.00048	0.00019
1.5	None	247696 247697 70006-0047 70006-0048	6897	4596	2935	0.0005	0.00046	0.00028	17490	5560	2330	0.004	0.00085	0.00019
1.5	121	212701 212701 204402 215957	9688	9688	9688	0.00028	0.00028	0.00028						
2.0	None	238367 238369 247696 247697 212701	1085	5842	2946	0.0008	0.0004	0.00017						
2.0	121	204402 238369	7836	5234	3268	0.0003	0.00024	0.00016	11221	10190	9158	0.0003	0.00026	0.00021
2.5	121	212701	4099	4099	4099	0.0015	0.0015	0.0015						
3.0	None	238367		1535			1535			1535			0.00086	

Table 6, Embedded Piping MDC and Efficiency Ranges for Cobalt-60 and Cesium-137 using Various Detectors

Pipe Diameter (Inches)	Sled #	Detector #	Co-60 MDC (dpm/100 cm^2)			Co-60 Efficiencies[1]			Cs-137 MDC (dpm/100 cm^2)			Cs-137 Efficiencies[1]		
			High	Avg.	Low	High	Avg.	Low	High	Avg.	Low	High	Avg.	Low
3.0	101	212701 204402 LVS1 238369	3414	2710	2249	0.00066	0.00043	0.00014						
3.0	121	212701 204402 238369	12683	7396	2779	0.0003	0.00021	0.00013						
4.0	None	247696 LVS1	2899	2899	2899	0.00043	0.00043	0.00043	2151	1874	1596	0.00069	0.00069	0.00069
4.0	101	238367 238369 247696	10416	4973	1509	0.00064	0.00032	0.00013	9453	4280	1852	0.00083	0.00043	0.00019
4.0	107	247697 238367							1398	1398	1398	0.00066	0.00066	0.00066
6.0	101	238367 238369 LVS1	10856	6467	3143	0.0002	0.00013	0.00008	3393	2662	1394	0.00071	0.00040	0.0002
6.0	106	238367 LVS1	3406	3406	3406	0.00018	0.00018	0.00018	1206	1206	1206	0.00051	0.00051	0.00051
6.0	107	LVS1	2066	1200	333	0.002	0.00119	0.00038	3306	2566	1286	0.00077	0.00047	0.0003
8.0	107	LVS1 238369	4049	2358	695	0.0044	0.00171	0.0001						
8.0	108	B566A B577A	16192	6135	1037	0.004	0.00333	0.003	1052	1026	999	0.006	0.006	0.006
10.0	107	A689X LVS1	4320	4320	4320	0.0001	0.0001	0.0001						
10.0	108	B566A B577A A689X	11223	2832	378	0.0046	0.00382	0.003	994	874	712	0.0069	0.00597	0.005
10.0	111	B566A B566A B577A	13177	5294	631	0.0048	0.00372	0.003	1044	799	348	0.007	0.00645	0.006
20.0	118	B577A	12504	12504	12504	0.0001	0.0001	0.0001						

Table 6 Notes:

1. Efficiencies are determined in-situ with the detector-sled-pipe size and nuclide of concern as identified.
2. Range and average efficiencies were determined by adding similar detector efficiencies in the same configuration.

5.2 Survey Results

The EP remediation and survey campaign began in 2005 and continued through the decommissioning effort at PBRF. As a result of this remediation and survey campaign, 167 runs of EP were remediated, surveyed and grouted in compliance with the FSSP and its implementing procedures. Table 7 and Table 8 provide a summary of the EP survey results. The tables are divided into piping where Co-60 is the nuclide of concern (Table 7) and piping where Cs-137 is the nuclide of concern (Table 8).

Tables 7 & 8 identify those pipes which utilized Co-60 or Cs-137 as the surrogate nuclide. Each pipe run is identified with the label applied to the pipe run, a short description of the pipe run, the pipe run's length and the number of survey measurements acquired in the pipe run. For each pipe run the appropriate DCGL, maximum activity, mean activity and standard deviation of the survey measurements for that pipe run is listed. It should be noted that background is not subtracted from EP surface activity measurements; therefore, the results are conservative. Each pipe run's dose as represented by the pipe run's average activity is listed along with a statement that confirms the average dose and the survey measurements supporting that dose are less than DCGL.

Occasional piping runs (e.g. ROLB-102) contain multiple sections of piping within the run where Co-60 is the nuclide of concern. After assessing sample coupons and system history other sections of the same piping run have been determined to present Cs-137 as the nuclide of concern. In this scenario example (ROLB-102) drain drops from Cs-137 systems empty into the main system which was surveyed as a Co-60 nuclide of concern. These scenarios are described in individual release records for similar piping runs and the results of any individual sections are presented in Tables 7 & 8.

Embedded piping DCGLs correspond to a dose contribution of 1 mrem/yr to the structural survey units which coincide with the EP's location in or under the building footprint as described in the FSSP. Those structural survey units which must adjust their DCGL for EP are identified in each structure's attachment to the Final Status Survey Report. Appendix C of this attachment presents those structural survey unit's dose with any corresponding dose contribution from EP to demonstrate compliance with the release criterion.

Table 7, Embedded Piping Survey Results for Co-60 Surrogate Piping

EP ID #	EP Description	Pipe Length (ft)	# of N	DCGL [1] (dpm/100 cm^2)	Maximum Activity (dpm/100 cm^2)	Mean Activity (dpm/100 cm^2)	Standard Deviation (dpm/100 cm^2)	Average Activity <DCGL	EP Dose (mrem/yr.)
Pump Room 22 on -25 Foot Elevation of Reactor Building									
1.31	Quad D Purge	141	141	3.57E+05	13,555	7,134	2,140	Yes	0.020
1.32	Quad D Drain	146	146	3.57E+05	82,248	17,135	13,708	Yes	0.048
1.33	Quad C Purge	90	90	3.57E+05	67,283	7,313	6,947	Yes	0.020
1.34	Quad C Drain	96	96	3.57E+05	38,725	8,226	4,113	Yes	0.023
1.35	Quad B Purge	78	78	3.57E+05	12,948	3,938	1,845	Yes	0.011
1.36	Canal E Drain	53	53	3.57E+05	53,573	10,358	7,857	Yes	0.029
1.37	Canal E Purge	36	36	3.57E+05	13,005	6,885	2,678	Yes	0.018
1.38	Quad B Drain	37	37	3.57E+05	7,695	5,497	1,099	Yes	0.015
1.39	Quad A Purge	38	38	3.57E+05	15,565	6,566	2,830	Yes	0.019
1.395	Quad A Drain	45	45	3.57E+05	9,488	4,744	1,459	Yes	0.013
1.21	Canal H Drain	80	80	3.57E+05	1,285	643	321	Yes	0.002
1.22	Canal H Purge	90	90	3.57E+05	8,336	3,574	1,516	Yes	0.009
1.23	Canal G Drain	42	42	3.57E+05	3,375	749	749	Yes	0.002
1.24	Canal G Purge	30	30	3.57E+05	11,065	6,278	1,785	Yes	0.019
1.25	Canal F Drain	20	20	3.57E+05	4,444	1,111	741	Yes	0.003
1.26	Canal F Purge	21	21	3.57E+05	12,059	8,039	1,827	Yes	0.022
1.71	Canal H Hot Drain	120	120	3.57E+05	54,313	4,502	4,934	Yes	0.013
1.72	Canal H Waste Air	100	100	3.57E+05	7,489	3,782	1,345	Yes	0.011
1.72A	Trench to sump (pipe under removed valve)	14	14	3.57E+05	39,948	14,829	12,899	Yes	0.042
1.641-8	Canal G&H Overflow	51	51	3.85E+05	24,217	6,594	3,278	Yes	0.018
1.641-4	Canal G&H Overflow	34	34	3.85E+05	12,361	7,466	1,969	Yes	0.019
1.81	Canal J&K Drains	20	20	3.57E+05	6,916	1,692	1,363	Yes	0.005
1.82	HDS Valve Box Header	16	16	3.57E+05	13,890	7290	2,066	Yes	0.019
Rx-151	Quad B Spare (closed)	21	21	3.57E+05	7,311	3,214	1,311	Yes	0.011
Rx-111	RT Drain to Sump	1	1	3.57E+05	20,022	20,022	20,022	Yes	0.056

Table 7, Embedded Piping Survey Results for Co-60 Surrogate Piping

EP ID #	EP Description	Pipe Length (ft)	# of N	DCGL [1] (dpm/100 cm^2)	Maximum Activity (dpm/100 cm^2)	Mean Activity (dpm/100 cm^2)	Standard Deviation (dpm/100 cm^2)	Average Activity <DCGL	EP Dose (mrem/yr.)
Rx-113	Water to Pump Rm	20	20	3.57E+05	6,191	3,967	312	Yes	0.012
Rx-148	2nd Cooling to tests	21	21	3.57E+05	4,739	3,912	611	Yes	0.009
Rx-150	Quad B utility air	21	21	3.57E+05	7,186	3,969	1,292	Yes	0.012
Rx-152	Quad B DI water	21	21	3.57E+05	5,911	3,169	983	Yes	0.011
Rx-113D	Water to Pump Rm Drain	17	17	3.57E+05	25,616	15,179	5,129	Yes	0.046
Rx-148D	2nd Cooling Drain	16	16	3.57E+05	27,612	14,732	4,933	Yes	0.044
Rx-150D	Quad B utility air Drain	15	15	3.57E+05	18,962	14,179	4,317	Yes	0.038
Rx-151D	Spare – drain line	15	15	3.57E+05	21,001	15,093	2,911	Yes	0.042
Rx-160	RT Drain to Sump	2	2	3.57E+05	5,551	5,551	5,551	Yes	0.016
Rx-155	Sump/trench vent	7	7	3.57E+05	5,069	4,111	649	Yes	0.012
Rx-152D	Drain Line for DI water	15	15	3.57E+05	35,166	17,311	7,494	Yes	0.051
Rx-129	Sump Room Hot Drain	3	3	3.85E+05	40,419	31,011	8,914	Yes	0.079
Rx-161	Canal E drain into QUAD. B	3	3	3.57E+05	857	750	804	Yes	0.002
Rx-126	Quad B (secondary cooling water return)	21	21	3.57E+05	10,713	7,649	1,931	Yes	0.022
Rx-126D	Quad B (sec. cooling water return DRAIN)	15	15	3.57E+05	22,914	13,319	3,408	Yes	0.038
Drain Trench on Reactor Bldg -25 ft									
1.41	Quad B Hot Drain	45	45	3.57E+05	31,492	6,910	4,007	Yes	0.019
1.42	Quad B Cooling Air	42	42	3.57E+05	12,144	5,009	2,001	Yes	0.015
1.43	Service Ring Return	47	47	3.57E+05	9,413	6,195	1,362	Yes	0.018
1.44	Sub-pile Suction	54	54	3.85E+05	156,116	81,009	25,881	Yes	0.211
1.45	CA-RT Vent line	112	112	3.85E+05	169,847	33,364	36,209	Yes	0.088
1.51	Annulus Floor Drain	3	3	3.85E+05	4,500	3,750	417	Yes	0.010
1.51D	Annulus Floor Drain	7	7	3.85E+05	11,099	6,747	2,373	Yes	0.018
1.51	Annulus Floor Drain	72	72	3.85E+05	29,191	6,909	5,559	Yes	0.019
1.51	Annulus Floor Drain	46	46	3.85E+05	15,193	9,197	2,579	Yes	0.024
1.51-A-4	Elect. CND to JB at point A	2	2	3.85E+05	3,151	3,151	0	Yes	0.008
RX-162	Cable Tray Quad D & A Drain Line to 1.51	27	27	3.85E+05	9,949	4,211	2,073	Yes	0.012

Table 7, Embedded Piping Survey Results for Co-60 Surrogate Piping

EP ID #	EP Description	Pipe Length (ft)	# of N	DCGL [1] (dpm/100 cm^2)	Maximum Activity (dpm/100 cm^2)	Mean Activity (dpm/100 cm^2)	Standard Deviation (dpm/100 cm^2)	Average Activity <DCGL	EP Dose (mrem/yr.)
RX-163	Cable Tray Quad D & C= Drain Line to 1.51	26	2	3.85E+05	8,636	4,361	1,619	Yes	0.013
RBDL-1	Rx-25 Hot Cold Drain (RX 127)	21	21	3.85E+05	36,177	6,626	7,003	Yes	0.018
RBDL-2	Rx-25 Hot Cold Drain (RX 147)	44	44	3.85E+05	28,644	7,166	6,141	Yes	0.020
RX 157	Drain Line from annulus at elevator pit	5	5	3.85E+05	11,694	11,161	2,116	Yes	0.029
HDS Valve Box, HDS & Off Gas									
1.641	Canal G&H Overflow	34	34	3.85E+05	12,919	7,761	1,878	Yes	0.019
1.64	Canal J K Overflow	60	60	3.57E+05	94,913	22,002	19,488	Yes	0.060
HL-111	Canal J Vent	3	3	3.57E+05	11,794	10,007	2,891	Yes	0.028
CV, Sub Pile & Corridor									
1.13	Supply Loop Drain	39	39	3.85E+05	31,289	8,161	4,987	Yes	0.022
1.14	Return Loop Drain	35	35	3.85E+05	122,562	14,699	17,732	Yes	0.039
1.15	Sheath Drain	60	4	3.85E+05	15,429	8,085	3,048	Yes	0.021
Rx-139	Quad B to RT PCW	4	4	3.85E+05	65,522	47,618	12,571	Yes	0.125
1.52	Hot Drain from annulus to sub pile room drain	49	49	3.85E+05	49,041	10,965	7,707	Yes	0.029
Rx-149	SPR Floor Drain	20	20	3.85E+05	7,244	4,108	1,459	Yes	0.011
Rx-135	Shield Drain	36	36	3.57E+05	95,139	56,869	21,011	Yes	0.163
Rx-137	PCW Valve Box Drain	9	9	3.85E+05	5,302	3,568	1,070	Yes	0.010
S1	Service conduit	16	16	3.85E+05	13,608	8,848	3,004	Yes	0.023
S2	Service conduit	16	16	3.85E+05	16,321	10,949	2,209	Yes	0.030
Quad A									
Rx-159	Quad A drain to Dry annulus	11	11	3.85E+05	25,664	16,741	5,239	Yes	0.043
Rx-130	Spare to SPR	21	21	3.57E+05	72,797	12,061	16,085	Yes	0.036
A1	Quad Conduit to Electrical Box D	49	49	3.57E+05	75,805	8,509	13,897	Yes	0.025
A2	Quad Conduit to Electrical Box A	35	35	3.57E+05	20,909	5,369	3,061	Yes	0.015
A3	Quad Conduit to Electrical Box A	33	33	3.57E+05	22,676	6,899	3,177	Yes	0.017

Table 7, Embedded Piping Survey Results for Co-60 Surrogate Piping

EP ID #	EP Description	Pipe Length (ft)	# of N	DCGL [1] (dpm/100 cm^2)	Maximum Activity (dpm/100 cm^2)	Mean Activity (dpm/100 cm^2)	Standard Deviation (dpm/100 cm^2)	Average Activity <DCGL	EP Dose (mrem/yr.)
Quad B									
1.12-2.5	PCWS – Instrumentation	6	6	3.85E+05	10,211	4,916	2,647	Yes	0.013
1.41-2.5 INST	Hot Drain - Instrumentation	3	3	3.57E+05	16,505	7,336	8,069	Yes	0.020
1.42-2.5 INST	Waste Air - Instrumentation	7	7	3.85E+05	2,270	1,513	757	Yes	0.004
1.43-2 INST	PCWR – Instrumentation	1	1	3.85E+05	8,191	8,191	0	Yes	0.022
1.43-2.5 INST	PCWR – Instrumentation	5	5	3.85E+05	16,450	13,007	3,443	Yes	0.035
Rx-131	Spare to SPR	25	25	3.57E+05	37,877	11,197	8,847	Yes	0.029
Rx-204	Instrument line between access openings L&R	10	10	3.57E+05	187,446	92,463	44,253	Yes	0.257
Rx-205	Instrument line from access R to wall	6	6	3.57E+05	56,544	38,897	9,724	Yes	0.108
Rx 206H	Instrument line from access L to wall	7	7	3.57E+05	53,740	26,245	24,370	Yes	0.042
Rx 207	Instrument line from access R to Access hatch	3	3	3.57E+05	89,355	55,126	30,265	Yes	0.153
Rx 208	Instrument line from access R to wall	4	4	3.57E+05	20,081	15,061	6,096	Yes	0.042
B1	Quad Conduit to Electrical Box D	40	40	3.57E+05	6,919	4,044	1,255	Yes	0.012
B2	Quad Conduit to Electrical Box D	39	39	3.57E+05	7,505	3,737	1,343	Yes	0.010
B3	Quad Conduit to Electrical Box A	29	29	3.57E+05	9,991	5,596	2,029	Yes	0.016
B4	Quad Conduit to Electrical Box A	28	28	3.57E+05	9,975	6,106	2,271	Yes	0.016

Table 7, Embedded Piping Survey Results for Co-60 Surrogate Piping

EP ID #	EP Description	Pipe Length (ft)	# of N	DCGL [1] (dpm/100 cm^2)	Maximum Activity (dpm/100 cm^2)	Mean Activity (dpm/100 cm^2)	Standard Deviation (dpm/100 cm^2)	Average Activity <DCGL	EP Dose (mrem/yr.)
Quad C									
Rx-132	Spare to SPR	20	20	3.57E+05	5,587	3,173	1,865	Yes	0.014
1.12A-3	PCWS - Reactor Ring	48	48	3.85E+05	326,913	69,437	50,968	Yes	0.184
1.12B	PCWS - Primary Loop to Reactor Ring	19	19	3.85E+05	343,193	59,691	73,191	Yes	0.151
1.41A-4	Hot Drain - Reactor Ring	48	48	3.85E+05	119,094	33,192	19,719	Yes	0.089
1.41A-6	Hot Drain - Reactor Ring	16	16	3.85E+05	133,411	32,787	28,206	Yes	0.086
1.42A-4	Waste Air - Reactor Ring	48	48	3.85E+05	36,966	16,122	8,968	Yes	0.037
1.42A-6	Waste Air - Reactor Ring	15	15	3.85E+05	14,039	8,348	2,656	Yes	0.022
1.43A-4	PWCR _ Reactor Ring	48	48	3.85E+05	202,716	50,169	31,696	Yes	0.142
1.43A-6	PWCR _ Reactor Ring	16	16	3.85E+05	42,616	24,393	7,741	Yes	0.062
1.43A+B	PWCR - Primary Loop to Reactor Ring	24	24	3.85E+05	317,641	99,799	72,011	Yes	0.261
C1	Quad Conduit to Electrical Box D	32	32	3.57E+05	16,762	5,003	3,002	Yes	0.014
C2	Quad Conduit to Electrical Box D	33	33	3.57E+05	13,069	6,279	2,916	Yes	0.015
C3	Quad Conduit to Electrical Box A	50	50	3.57E+05	25,517	5,764	3,777	Yes	0.016
Quad D									
Rx-116	SD Cooling Supply	3	3	3.57E+05	89,067	55,892	29,929	Yes	0.155
Rx-117	SD Cooling Return	8	8	3.57E+05	111,621	63,012	23,044	Yes	0.175
Rx-1.33	Spare to SPR	29	29	3.57E+05	7,675	4,397	1,397	Yes	0.012
Rx-138-1	Pump Seal Box Drain	22	8	3.85E+05	196,701	81,736	62,257	Yes	0.211
Rx-138-2	Pump Seal Box Drain	22	8	3.85E+05	44,823	32,564	7,662	Yes	0.086
Rx-138-3	Pump Seal Box Drain	22	7	3.85E+05	150,289	87,351	51,876	Yes	0.229
Rx-138-4	Pump Seal Box Drain	22	7	3.85E+05	18,456	14,660	3,074	Yes	0.038
D1	Quad Conduit to Electrical Box D	34	34	3.57E+05	28,696	5,769	5,049	Yes	0.016
D2	Quad Conduit to Electrical Box D	34	34	3.57E+05	13,627	5,067	2,917	Yes	0.014

Table 7, Embedded Piping Survey Results for Co-60 Surrogate Piping

EP ID #	EP Description	Pipe Length (ft)	# of N	DCGL [1] (dpm/100 cm^2)	Maximum Activity (dpm/100 cm^2)	Mean Activity (dpm/100 cm^2)	Standard Deviation (dpm/100 cm^2)	Average Activity <DCGL	EP Dose (mrem/yr.)
D3	Quad Conduit to Electrical Box D	33	33	3.57E+05	8,179	3,895	1,993	Yes	0.011
D4	Quad Conduit to Electrical Box A	45	45	3.57E+05	11,906	6,481	2,649	Yes	0.016
D5	Quad Conduit to Electrical Box A	44	44	3.57E+05	13,169	7,416	2,318	Yes	0.019
D6	Quad Conduit to Electrical Box A	44	44	3.57E+05	11,684	6,171	2,319	Yes	0.017
Reactor Building – Reactor Tank									
201A	PCWR from Quad A	7	7	3.57E+05	25,505	16,165	6,825	Yes	0.045
201B	PCWR from Quad D	6	6	3.57E+05	14,576	7,652	4,373	Yes	0.021
202A	PCWS from Quad A	5	5	3.57E+05	17,308	12,620	3,606	Yes	0.035
202B	PCWS from Quad D	6	6	3.57E+05	46,968	25,505	5,900	Yes	0.073
203A	Deion Water Sleeve from Quad A	7	7	3.57E+05	18,834	6,519	8,330	Yes	0.018
203B	Hot Drain Sleeve from Quad B	7	7	3.57E+05	19,760	5,748	7,544	Yes	0.016
Rx 135A	Pit Drain	6	6	3.57E+05	28,898	27,453	1,084	Yes	0.077
1.45A	CA-RT Vent line to pit	7	7	3.85E+05	29,701	20,562	4,950	Yes	0.054
1.45B	CA-RT Vent line to pit	4	4	3.85E+05	13,360	9,043	3,161	Yes	0.024
Reactor Building -15 ft elevation									
Rx-125	1st floor drains	127	127	3.57E+05	126,166	5,697	2,091	Yes	0.016
Rx-121	VSP sewer pipe with 2" pipe inside	66	66	3.85E+05	23,121	13,062	3,787	Yes	0.035
Rx-124	Rx-15 Hot Cold Drain (RBCO-1)	215	215	3.85E+05	65,941	7,509	4,747	Yes	0.020
Rx-134	DR Drain Line	165	165	11,000	5,599	1,617	1,034	Yes	0.147
Reactor-Bowl									
CRT-1	Control Rod Tube	3	3	3.85E+05	30,262	12,861	15,888	Yes	0.034
CRT-2	Control Rod Tube	3	3	3.85E+05	51,054	20,574	26,289	Yes	0.055
CRT-3	Control Rod Tube	3	3	3.85E+05	69,208	24,089	39,001	Yes	0.063
CRT-4	Control Rod Tube	3	3	3.85E+05	46,497	17,532	25,154	Yes	0.046
CRT-5	Control Rod Tube	3	3	3.85E+05	31,767	12,248	17,223	Yes	0.032
CRT-6	Control Rod Tube	3	3	3.85E+05	32,904	12,243	17,982	Yes	0.032
CRT-7	Control Rod Tube	3	3	3.85E+05	62,322	23,323	34,029	Yes	0.061

Table 7, Embedded Piping Survey Results for Co-60 Surrogate Piping

EP ID #	EP Description	Pipe Length (ft)	# of N	DCGL [1] ($dpm/100\ cm^2$)	Maximum Activity ($dpm/100\ cm^2$)	Mean Activity ($dpm/100\ cm^2$)	Standard Deviation ($dpm/100\ cm^2$)	Average Activity <DCGL	EP Dose (mrem/yr.)
CRT-8	Control Rod Tube	3	3	3.85E+05	30,029	11,699	15,989	Yes	0.030
CRT-9	Control Rod Tube	3	3	3.85E+05	21,695	14,512	11,599	Yes	0.040
CRT-10	Control Rod Tube	3	3	3.85E+05	30,633	13,019	16,082	Yes	0.034
IT-11	Instrument tube	3	3	3.85E+05	17,249	7,499	8,624	Yes	0.020
IT-12	Instrument tube	3	3	3.85E+05	7,800	6,240	1,560	Yes	0.016
IT-13	Instrument tube	3	3	3.85E+05	24,050	14,086	10,078	Yes	0.037
IT-14	Instrument tube	3	3	3.85E+05	50,050	22,159	24,452	Yes	0.058
VD-1	Vessel Drain	6	6	3.85E+05	99,003	61,711	22,615	Yes	0.162
Reactor Office And Laboratory Building									
ROLB-102	ROLB Floor Drains	343	343	1.13E+06	51,380	22,310	9,014	Yes	0.022
ROLB-111	Oil Storage Drain	27	27	1.13E+06	346,705	207,888	97,578	Yes	0.185

Table 7 Notes:

1. The DCGL is equivalent to the Embedded Pipe dose goal of 1 mrem/yr, as stated in Section 3.3 of the PBRF FSSP.

Table 8, Embedded Piping Survey Results for Cs-137 Surrogate Piping

EP ID #	EP Description	Pipe Length (ft)	# of N	DCGL [1] (dpm/100 cm^2)	Maximum Activity (dpm/100 cm^2)	Mean Activity (dpm/100 cm^2)	Standard Deviation (dpm/100 cm^2)	Average Activity <DCGL	EP Dose (mrem/yr.)
Pump Room 22 on -25 Foot Elevation of Reactor Building									
Rx-084	Trench drain to sump	6	6	1.94E+06	11,624	9,687	1,937	Yes	0.005
HDS Valve Box, HDS & Off Gas									
1.61	Canal K to valve pit	52	52	3.57E+05	155,402	55,156	27,882	Yes	0.155
1.62	Canal K vent to valve pit	55	55	3.57E+05	144,585	16,588	21,147	Yes	0.047
1.63	Canal J to valve box	10	10	3.57E+05	279,596	99,749	6,977	Yes	0.277
1.83	HDS Floor drains	58	58	1.54E+06	27,951	6,604	3,686	Yes	0.004
1.84	Off Gas Hot Drain	23	23	1.54E+06	3,532	2,457	2,457	Yes	0.002
1.91	HDS to valve pit.	30	30	1.94E+06	60,834	10,849	10,461	Yes	0.006
1.92	Overflow from HDS	8	8	1.54E+06	23,344	6,297	6,911	Yes	0.004
1.93	HDS Vent	24	24	1.54E+06	18,258	10,899	1,078	Yes	0.002
HL-111	Canal J Vent	3	3	3.57E+05	8,538	7,244	2,069	Yes	0.028
Reactor Building -15 ft elevation									
CPT-16	CPT Trough drain	21	21	4.16E+05	11, 006	7,568	1,896	Yes	0.019
SAN-12	North RB	16	16	1.54E+06	7,771	4,591	1,555	Yes	0.003
SAN-13	North RB	13	13	1.54E+06	6,101	4,477	1,535	Yes	0.003
Hot Pipe Tunnel									
HPT102	Pit Floor Drain	23	23	1.54E+06	5,682	2,671	1,103	Yes	0.002
HPT-104	HPT Floor Drains (FD-1 thru FD-8)	273	273	1.94E+06	40,784	9,749	7,696	Yes	0.005
HPT-105	HL Off Gas Drains	25	25	1.94E+06	26,431	13,629	4,601	Yes	0.007
Reactor Office And Laboratory Building									
ROLB-109	Elevator Shaft Drain	3	3	1.13E+06	4,270	3,202	1,068	Yes	0.003
Fan House									
FH-102	Floor Drain	113	113	1.94E+06	356,886	41,949	52,694	Yes	0.022
FH-103	Drain to Resin Pit	15	15	1.94E+06	10,404	6,309	2,429	Yes	0.003
FH-111	Chase Drain	2	2	1.94E+06	57,282	52,236	3,945	Yes	0.027
Waste Handling Building									
WHB-111 1 thru 6	Evap/Laundry Supply and Drains	180	180	2.16E+06	92,966	38,469	8,581	Yes	0.018

Table 8 Notes:

1. The DCGL is equivalent to the Embedded Pipe dose goal of 1 mrem/yr, as stated in Section 3.3 of the PBRF FSSP.

5.3 Quality Control

The quality of piping radiological survey measurements was assured by the diligent application of numerous quality control protocols delineated in the implementing procedures and review criteria for EP field activities, detector quality control documents and survey assessment. All activities are directed by procedures, and all procedures used are PBRF approved procedures.

All instrument and detector calibrations are performed by qualified off-site vendor(s) calibrating with standards traceable to the National Institute of Standards and Technology, derived from accepted values natural physical constants or derived by the ratio-type of calibration techniques.

After calibration and prior to use, detector quality control charts are developed for each detector. These charts establish an expected detector response to a radioactive source standard and background radiation. The acceptable range for satisfactory performance is plus or minus 20% for the established source and background count rates. Satisfactory checks against these source and background radiation values are performed prior to and after any efficiency determinations or field survey measurements. These checks bound measurement data and assure its accuracy.

Efficiency determinations are performed using certified sources traceable to the National Institute of Standards and Technology. Drawings accompany all efficiency determinations which specify the in-situ geometry, detectors, radioactive sources and all other pertinent specifics allowing accurate reproduction of efficiency determinations at future dates.

The survey technician is required to verify the detector-sled-pipe size and nuclide of concern prior to acquiring survey data. All field survey documentation captures the date, time, access location, physical location within the facility, and identies the pipe run being surveyed.

5.4 ALARA Evaluation

It is shown that residual contamination in the EP 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 is presumed that it had been reduced to levels that are ALARA. Therefore, the licensee does not need to conduct an explicit analysis to meet the ALARA requirement."[6]

[6] This guidance was initially published in Draft Regulatory Guide DG-4006, but has been reissued in NUREG-1757 Volume 2, Appendix N [USNRC 2006].

Comparison of EP survey results to NRC generic soil screening levels is not applicable. However, the highest dose attributed to any of the EP identified in this report is 1.366 mRem/yr associated with EP 1.12, which is the 24 inch diameter Primary Coolant Supply line. The dose from all other EP dose is less than this value and most of the piping is significantly below this value. The PBRF dose goal for EP was 1 mrem/yr. However, in accordance with Section 3.3 of the PBRF FSSP, different dose goals could be applied in different areas as long as the residual contamination on the structure surface in the survey unit containing the given EP is sufficiently low to allow for the selected dose goal. The dose attributed to EP, as identified in Table 7 and Table 8 of this report, is added to the dose of any structural surface survey units which coincide with EP in Appendix C of this report. As presented in Appendix C, the combined dose of all EP and structure survey units is < 25 mrem/yr.[7]

The dose attributed to EP at PBRF from the EP surveys is ALARA since the EP survey results indicate the dose from 165 EP surveys is less than or equal to the dose goal of 1 mrem/yr as identified in the FSSP, except for EP 1.11 and EP 1.12. The dose attributed to these two piping runs is 1.009 mrem/yr for EP 1.11 and 1.366 mrem/yr for EP 1.12. However the modified dose goal (2 mrem/yr) when combined with the coinciding structural survey unit dose estimate is significantly less than 25 mrem/yr. The addition of EP dose did not result in any structure survey unit's total dose reaching the 22.5 mrem/yr threshold for additional review in accordance with section 3.5 of the FSSP.

The cost of removing the piping is high and far more costly than justified by the Nuclear Regulatory Commission (NRC) $2000/person-rem ALARA standard. The operational phase of removing the Primary Cooling Loop was estimated to consume fifty-nine (59) weeks of schedule duration at an estimated cost of eight million to ten million dollars ($8,000,000-$10,000,000). The addition of removing the embedded Quadrant and Canal piping would have further increased that cost by approximately one million to one million, two hundred fifty thousand dollars (~$1,000,000-$1,250,000). In total, the estimated costs associated with removing the PBRF's EP systems would have ranged, more or less, from nine million dollars to eleven million, two hundred fifty thousand dollars ($9,000,000-$11,250,000).

Once the preliminary estimates of costs associated with the removal of the PBRF embedded systems were thoroughly evaluated, it was decided that the more prudent and logical course of action would be that of surveying the EP conduits, decontaminating the same as necessary to either meet the DCGL values or ALARA, and subsequently leave the EP in place.

5.5 EPA Trigger Values

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). Concentrations of individual radionuclides, identified as "trigger levels" for further review and consultation between the agencies, are published in the MOU. However, no soil

[7] As stated in the PBRF FSSP [NASA 2007], the goal of the decommissioning project is to release the facility for unrestricted use in compliance with the criteria in US NRC 10CFR20 Subpart E. The principal criterion is that the dose to future site occupants will be less than 25 mrem/yr. 10CFR20 Subpart E also requires that residual contamination be reduced to levels as low as reasonably achievable (ALARA).

survey units are included in the survey of the EP. It is also noted that groundwater is not within the scope of the EP survey effort. Therefore, comparison with EPA Trigger Levels is not applicable to EP survey measurement results.[8]

5.6 Conclusions

The results presented above demonstrate that the EP satisfies all FSS Plan commitments and meets the release criteria in 10CFR20 Subpart E. The principal conclusions are:

- Radiation surveys were conducted on 167 runs of EP.
- The highest dose associated with any EP survey is 1.366 mrem/yr from EP 1.12, which is a 24 inch diameter Primary Loop Coolant line.
- The dose attributed to 165 out of 167 EP surveys, was < 1 mRem/yr. Most of the EP dose for each piping run is < 0.10 mRem/yr.
- The highest combined structure and EP dose is 6.84 mrem/yr, this dose is only 27% of the allowed dose of 25 mrem/yr to be in compliance with the release criterion.
- The EP surveys identified in this report meet the ALARA principle identified by the NRC.
- Therefore, the PBRF piping defined as EP, and discussed in this Attachment, meets the criteria for unrestricted release

[8] 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. Since these trigger levels are only applicable to the PBRF for residual soil and water concentrations, they do not apply to the Embedded Piping results provided in this attachment.

6.0 References

NASA 2007 NASA Safety and Mission Assurance Directorate, *Final Status Survey Plan for the Plum Brook Reactor Facility,* Revision 1, February 2007.

NASA 2007a NASA Safety and Mission Assurance Directorate, *Decommissioning Plan for the Plum Brook Reactor Facility*, Revision 6, July 2007.

PBRF 2006 Plum Brook Reactor Facility Technical Basis Document, *Calculation of PBRF Embedded Piping DCGLs with Revised Conceptual Dose Model,* PBRF-TBD-06-001, Revision 0, March 2006.

PBRF 2006a Plum Brook Reactor Facility Technical Basis Document, *Evaluation of Radionuclide Profiles in Embedded and Buried Piping at the Plum Brook Reactor Facility,* PBRF-TBD-06-003, Revision 0, January 2006.

PBRF 2006b Plum Brook Reactor Facility Technical Basis Document, *Activity Ratios of Radionuclides in Embedded and Buried Piping,* PBRF-TBD-06-004, Revision 0, October 2006.

PBRF 2005 PBRF-WEP-05-006, *Decontamination & Radiological Survey of Embedded and Buried Pipng Systems.*

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*, NUREG-1757, Vol. 1, Rev.2, September 2006.

USEPA 2002 Memorandum of Understanding, US Environmental Protection Agency and US Nuclear Regulatory Commission, *Consultation and Finality on Decommissioning and Decontamination of Contaminated Sites*, October 9, 2002.

7.0 Appendices

Appendix A – Exhibits

Appendix B – Embedded Piping Penetration Location Maps

Appendix C – Structural Survey Unit/Embedded Piping Dose Tables

Appendix D – Primary Cooling Piping, EP 1.11 & EP 1.12.

Plum Brook Reactor Facility

Final Status Survey Report

Attachment 9

Embedded Piping

Revision 0

Appendix A

Exhibits

List of Exhibits

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Exhibit 1, Video Inspection of Embedded Piping in Reactor Building

Exhibit 2, HEPA Ventilation Unit

Exhibit 3, Tanks to Capture Hydrolazer Water

Exhibit 4, Setting up for Cleaning of Embedded Piping

Exhibit 5, Cleaning the Embedded Piping

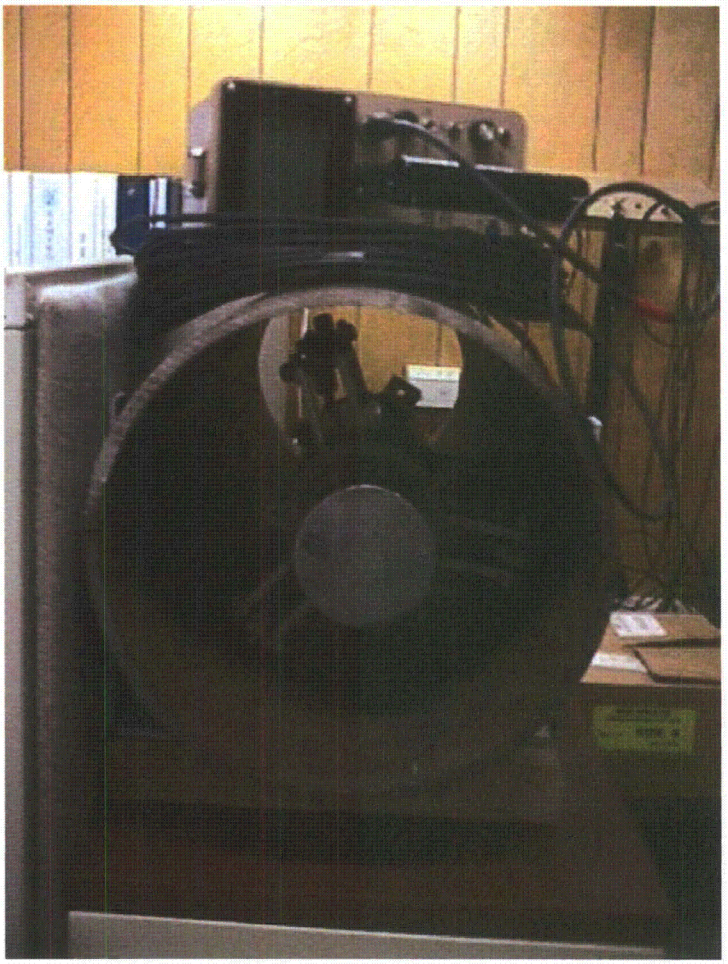
Exhibit 6, NLB Hydrolazer Unit

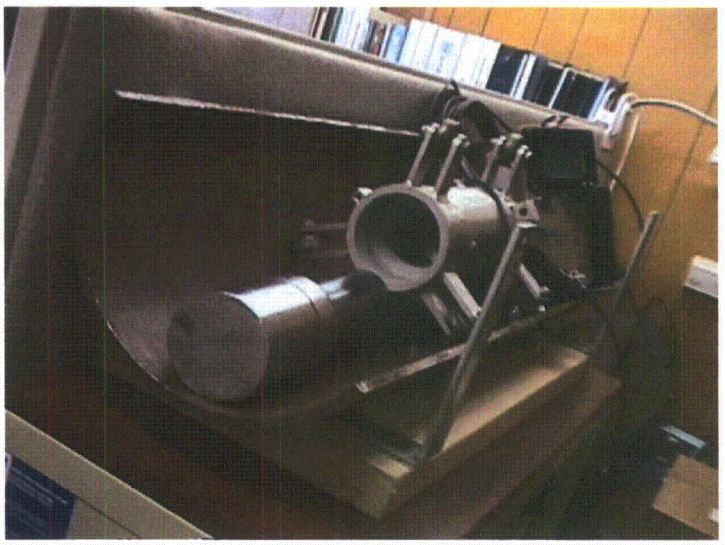
Exhibit 7, Embedded Pipe Survey Sled

Exhibit 8, Embedded Pipe Cleaning

Exhibit 9, Embedded Piping Survey

Exhibit 10, Detector-Sled-Pipe and Cable Set-up





Plum Brook Reactor Facility

Final Status Survey Report

Attachment 9

Embedded Piping

Revision 0

Appendix B

Embedded Piping Penetration Location Maps

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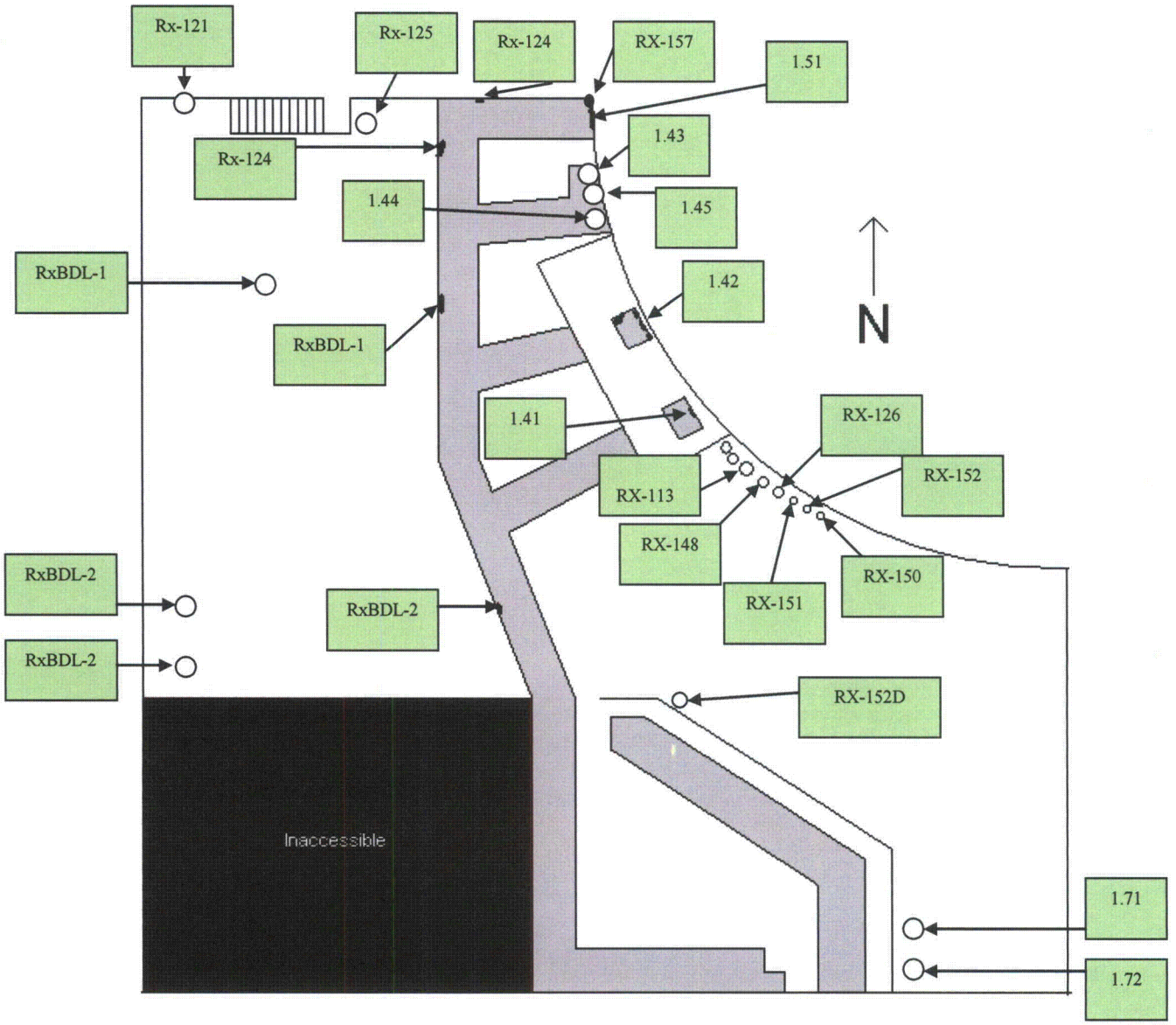
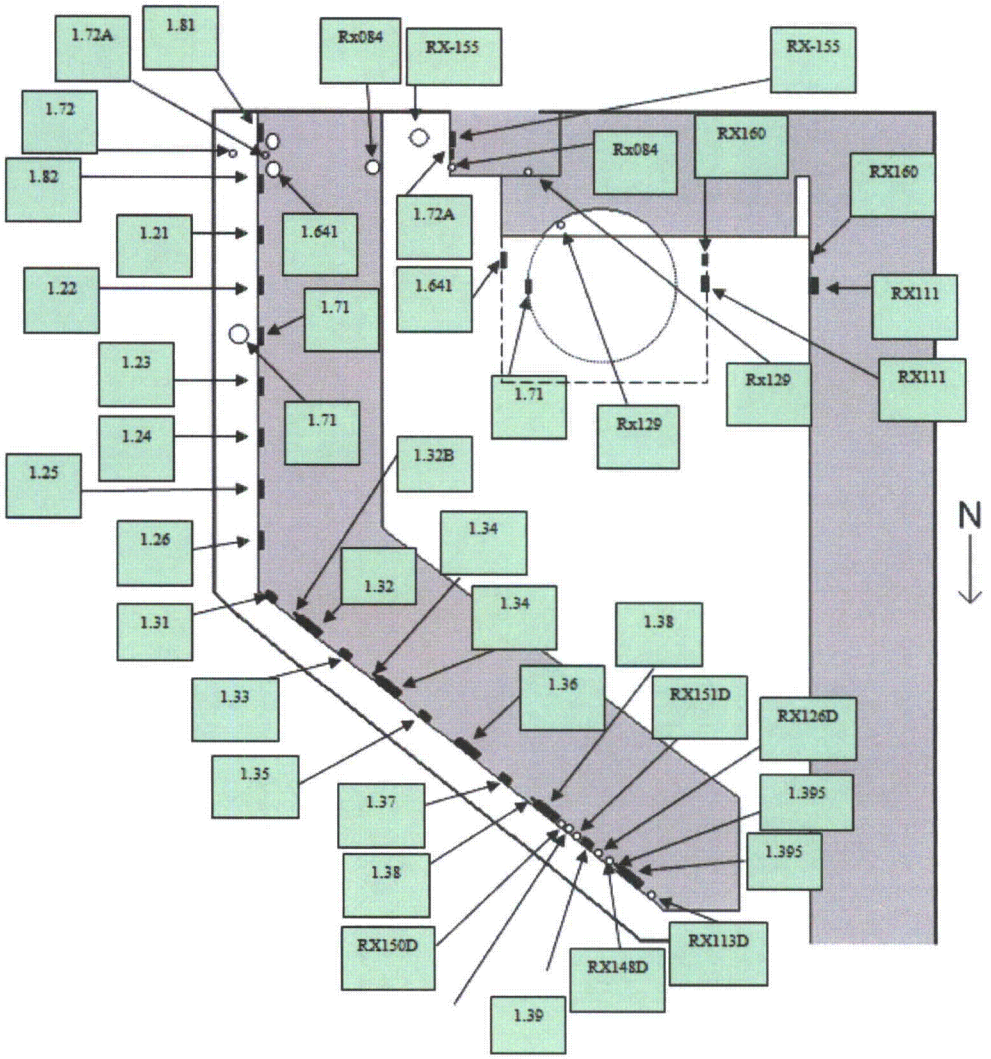
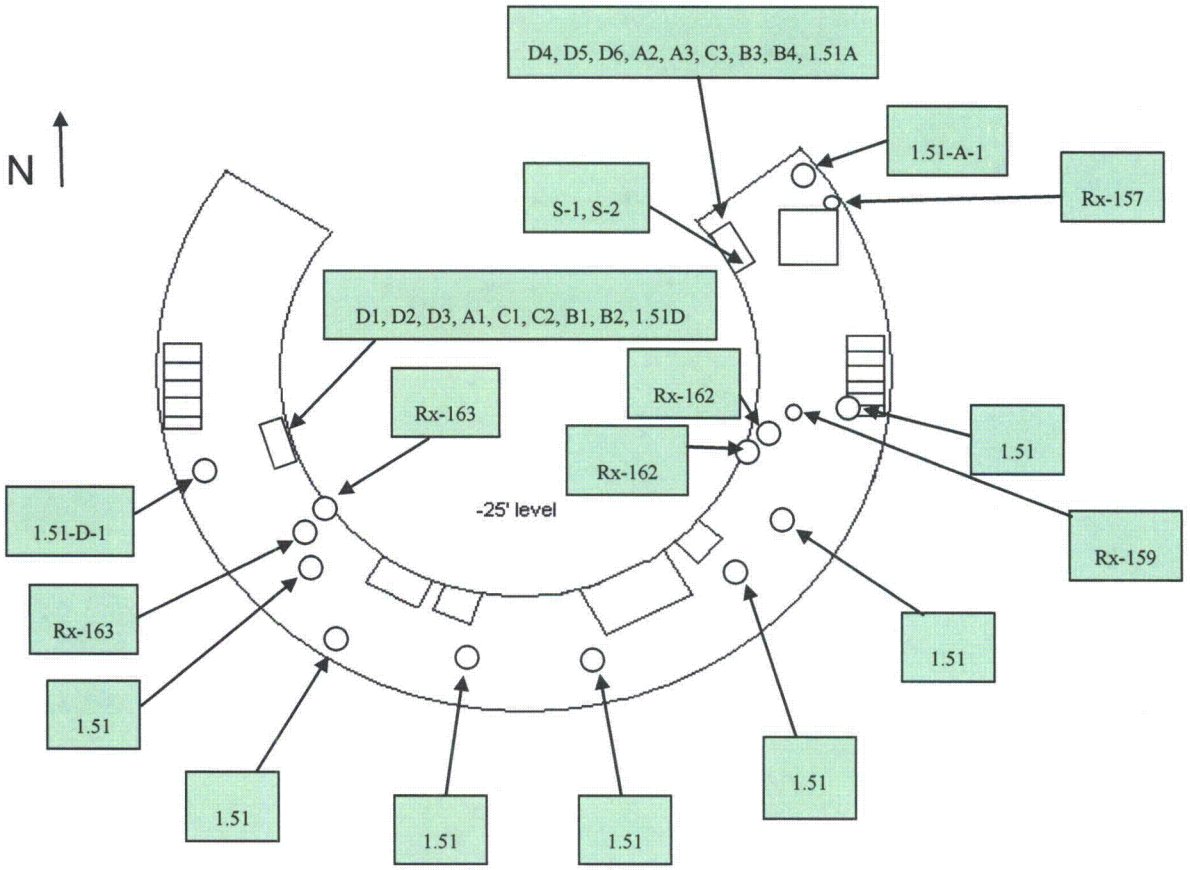
Map 1, Drain Trench on Reactor Building -25 Foot Elevation



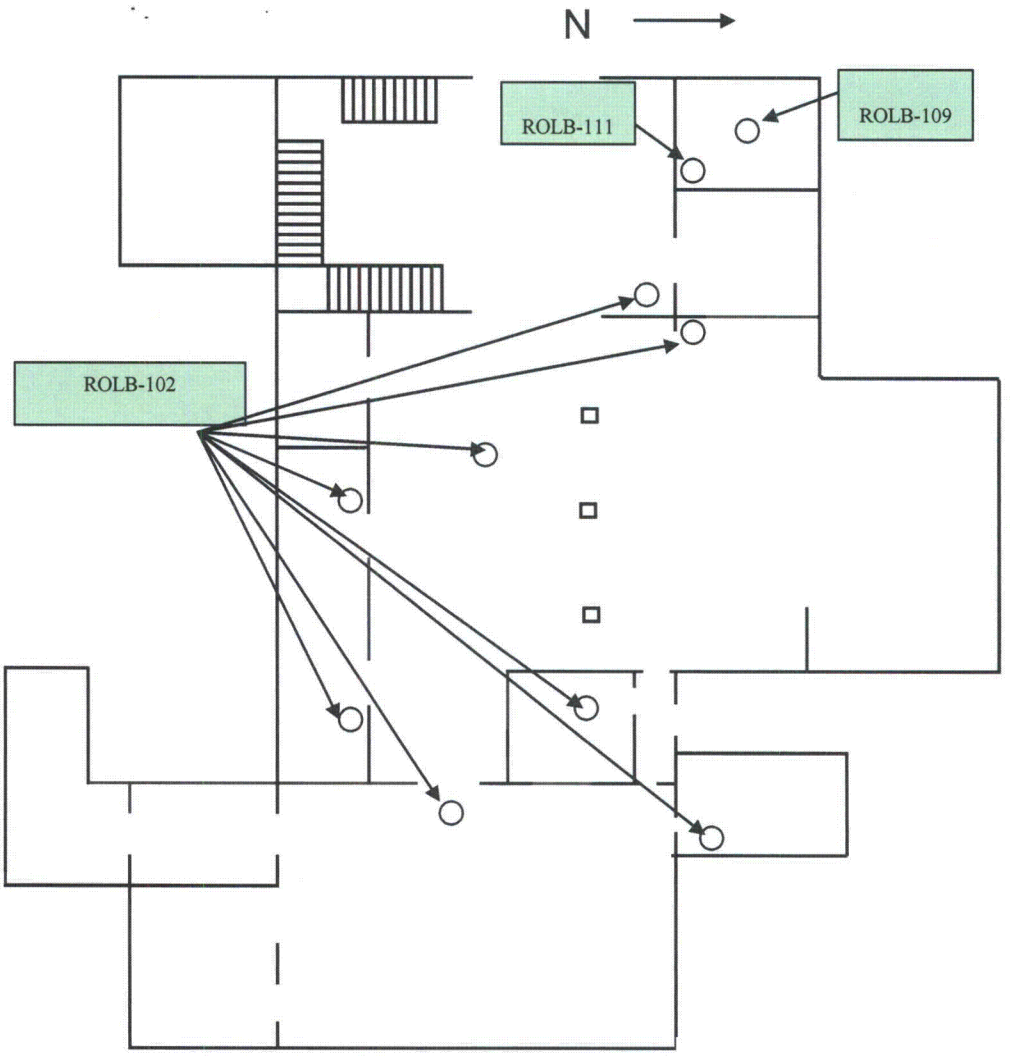
Map 2, Pump Room on Reactor Building -25 Foot Elevation



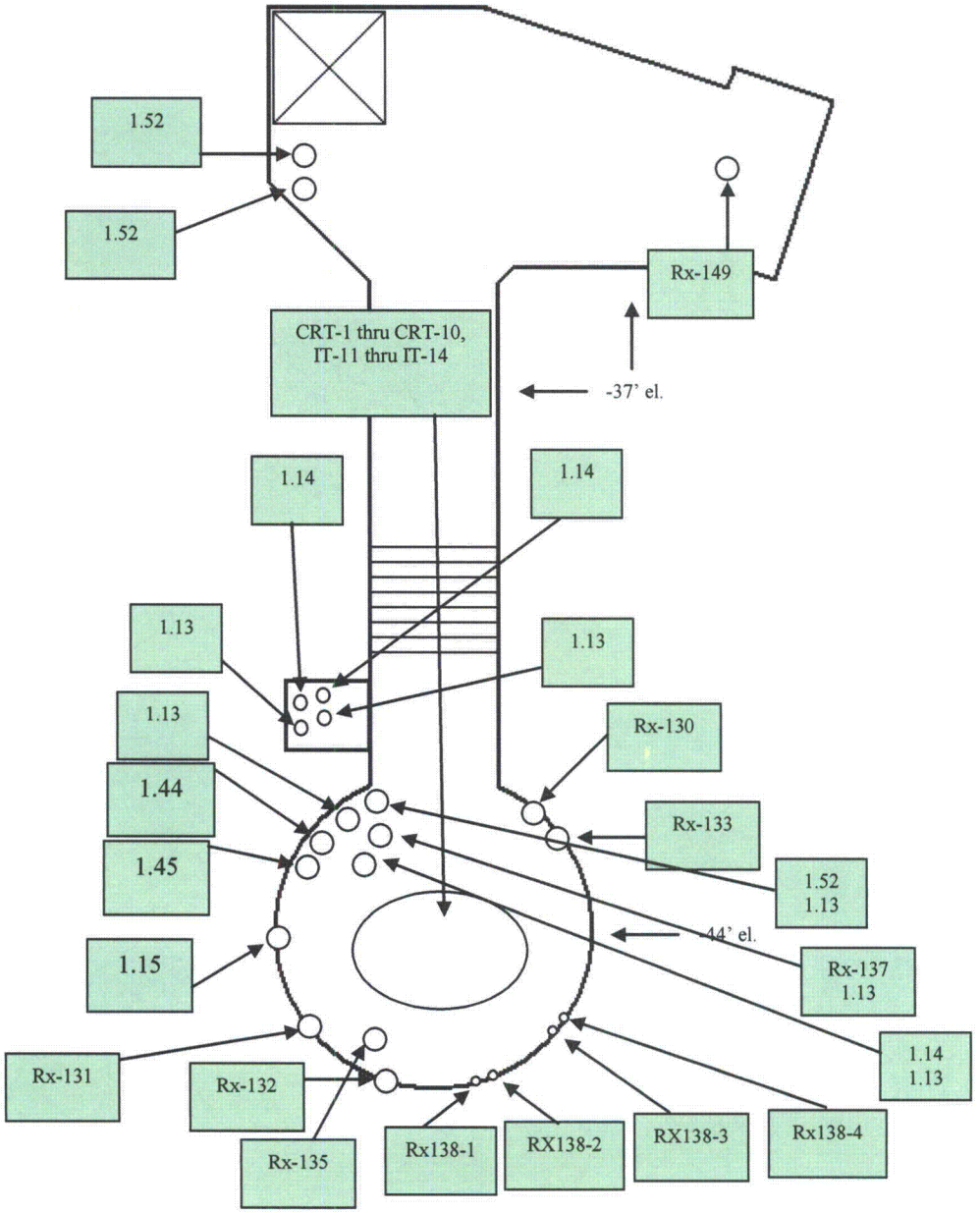
Map 3, CV -25 Foot Elevation



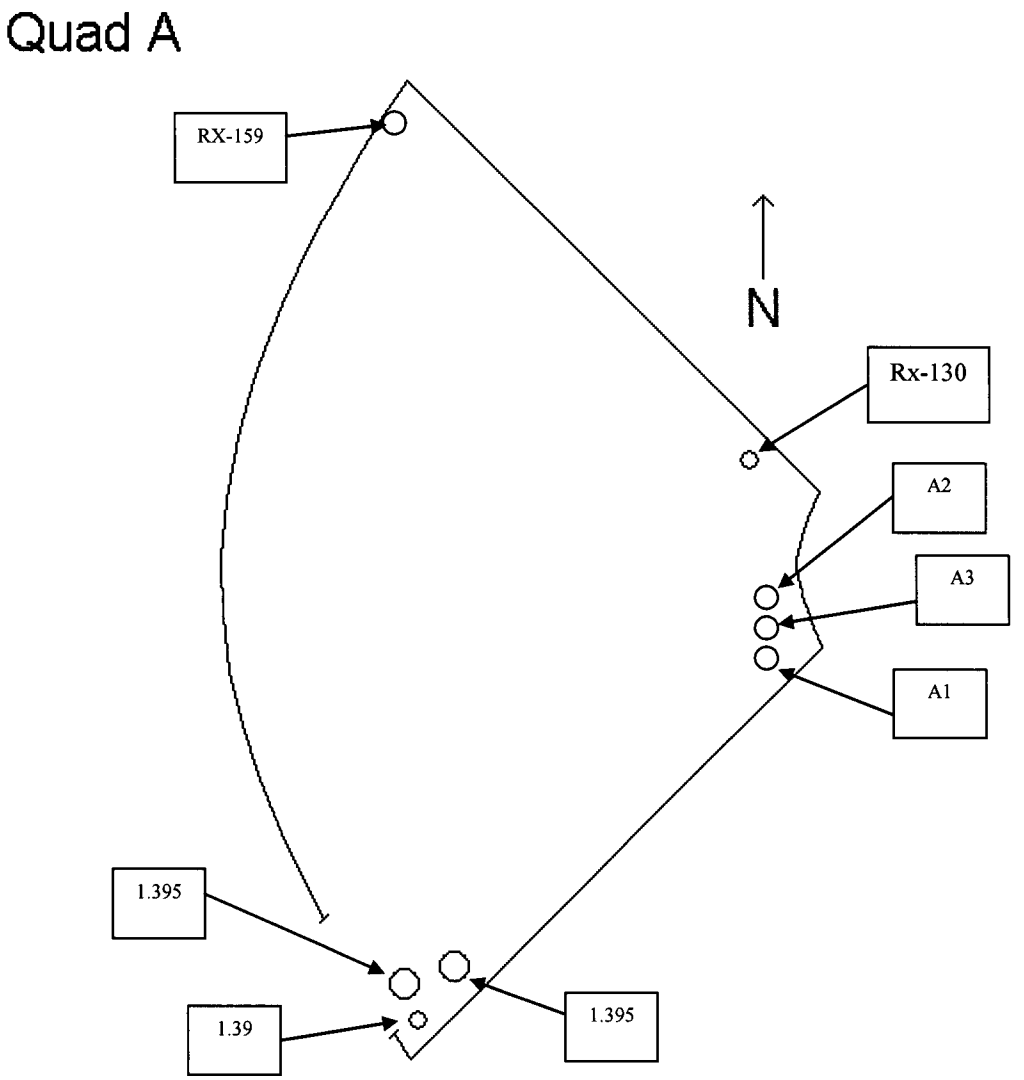
Map 4, ROLB -15 Foot Elevation



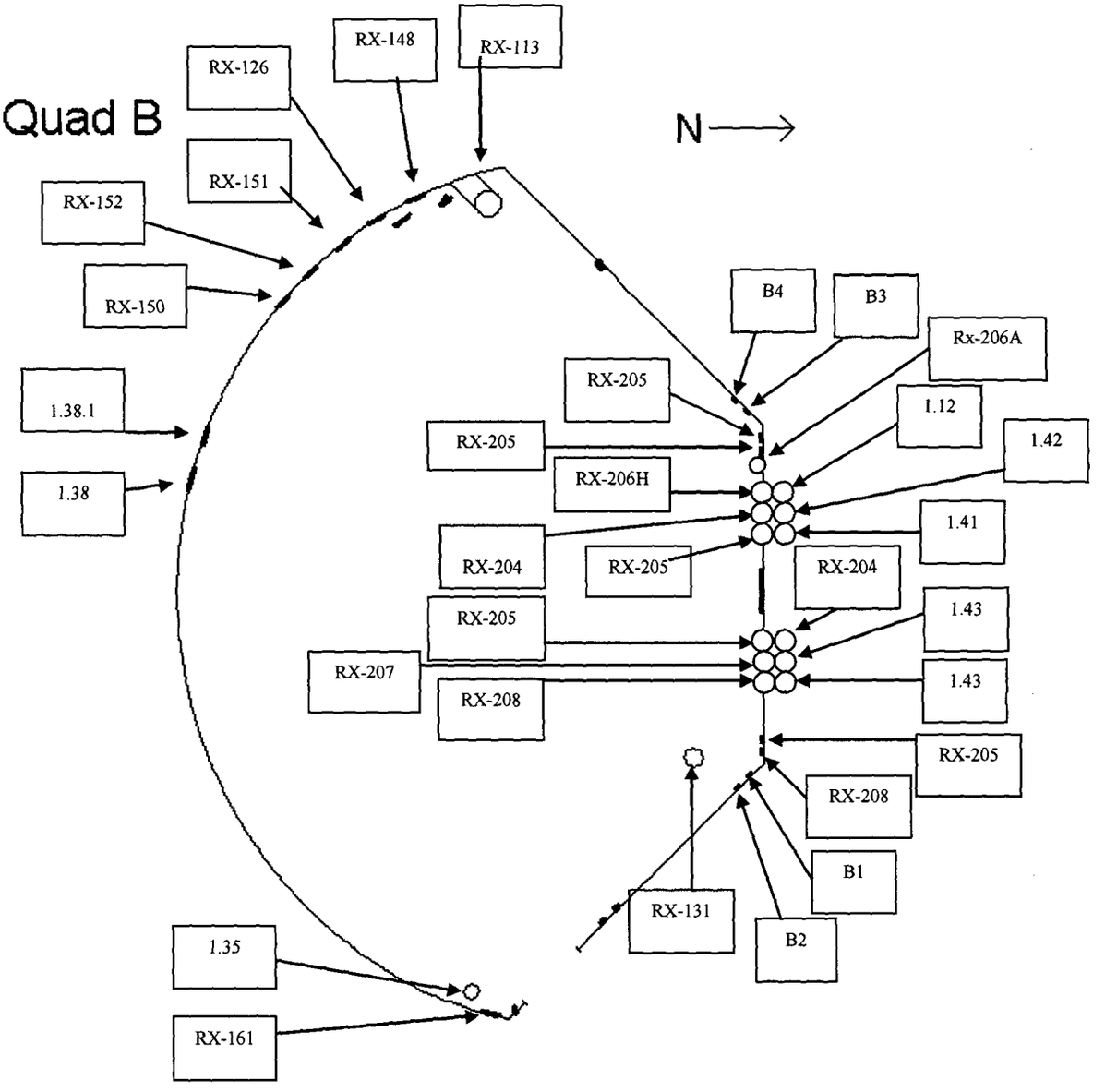
Map 5, CV, Sub Pile & Corridor



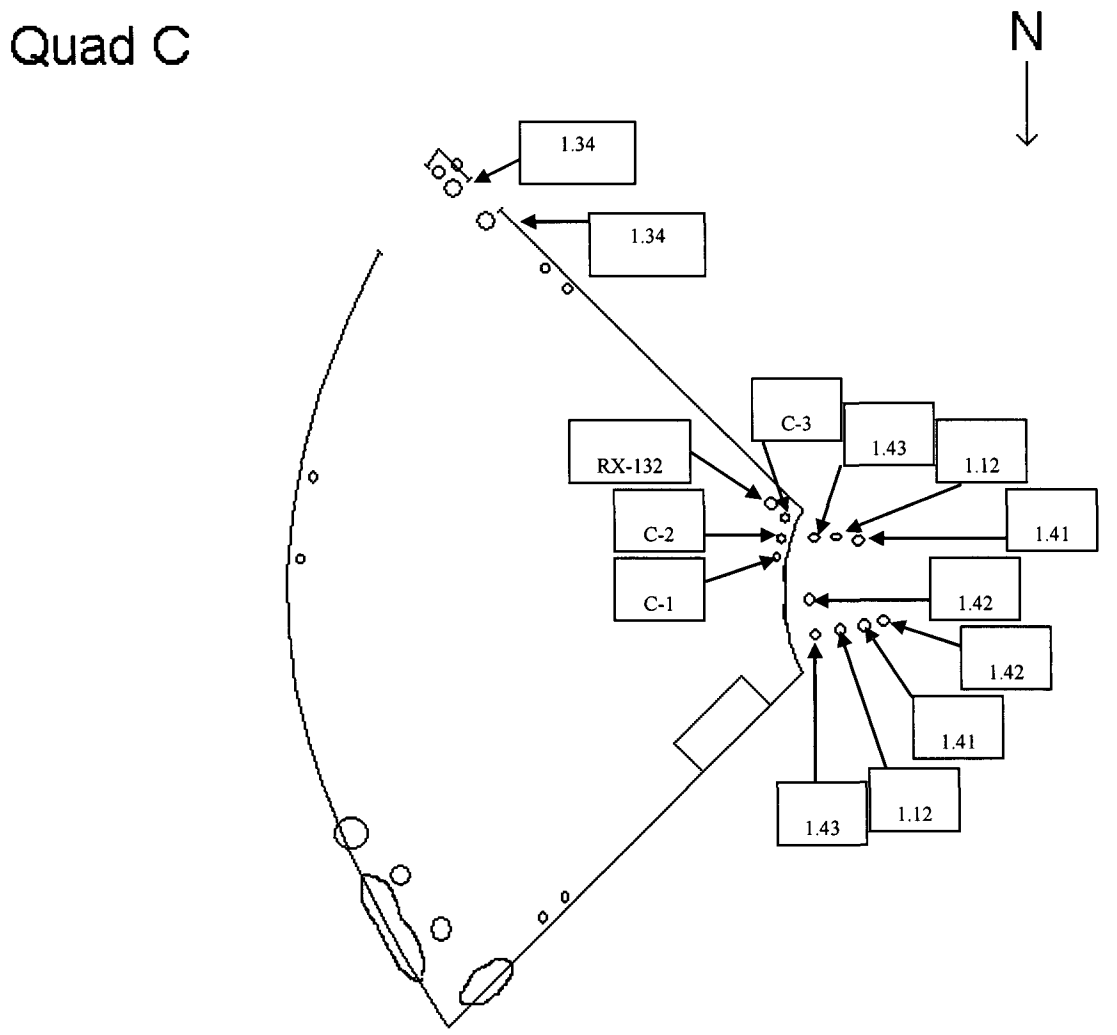
Map 6, Quad A



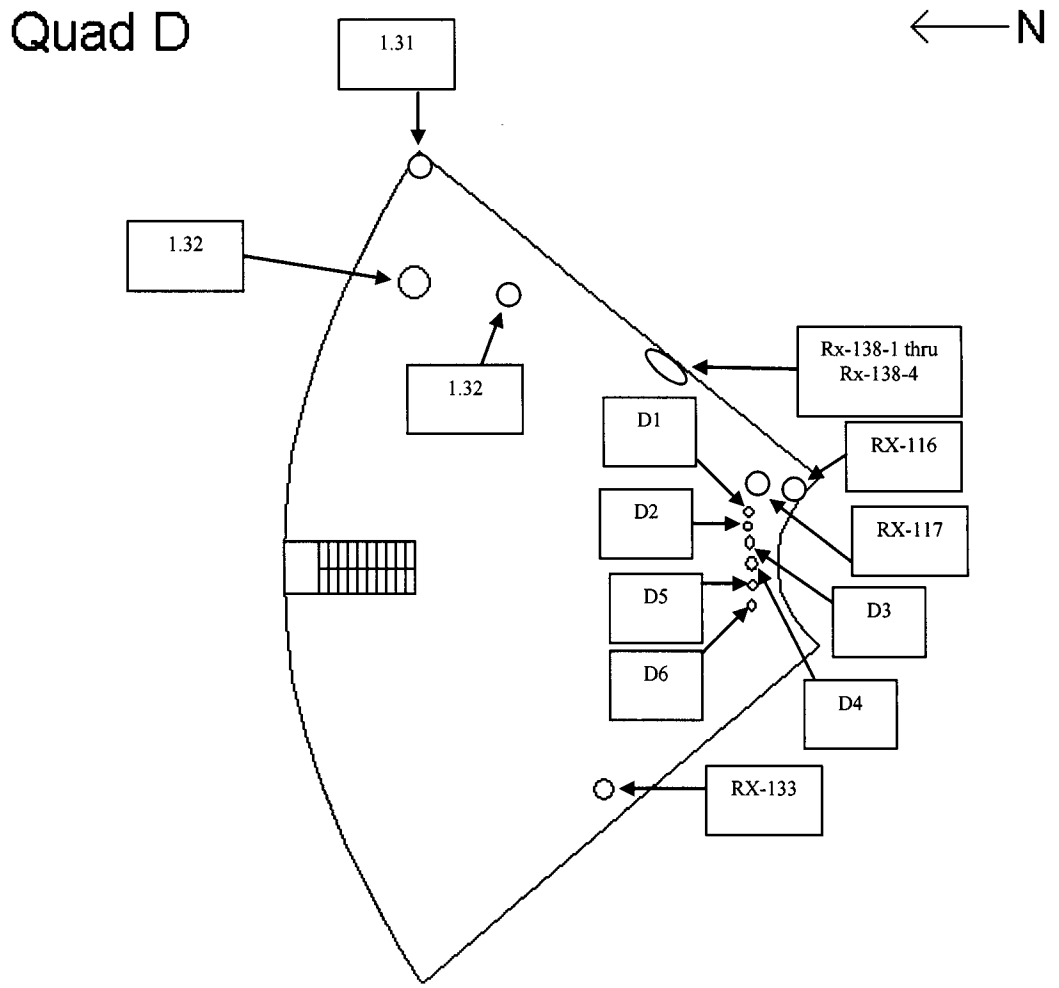
Map 7, Quad B


Quad B
N
RX-126
RX-148
RX-113
RX-151
RX-152
RX-150
1.38.1
1.38
B4
B3
Rx-206A
RX-205
1.12
1.42
RX-205
RX-206H
1.41
RX-204
RX-205
RX-204
RX-205
1.43
RX-207
RX-208
1.43
RX-205
RX-208
B1
RX-131
B2
1.35
RX-161

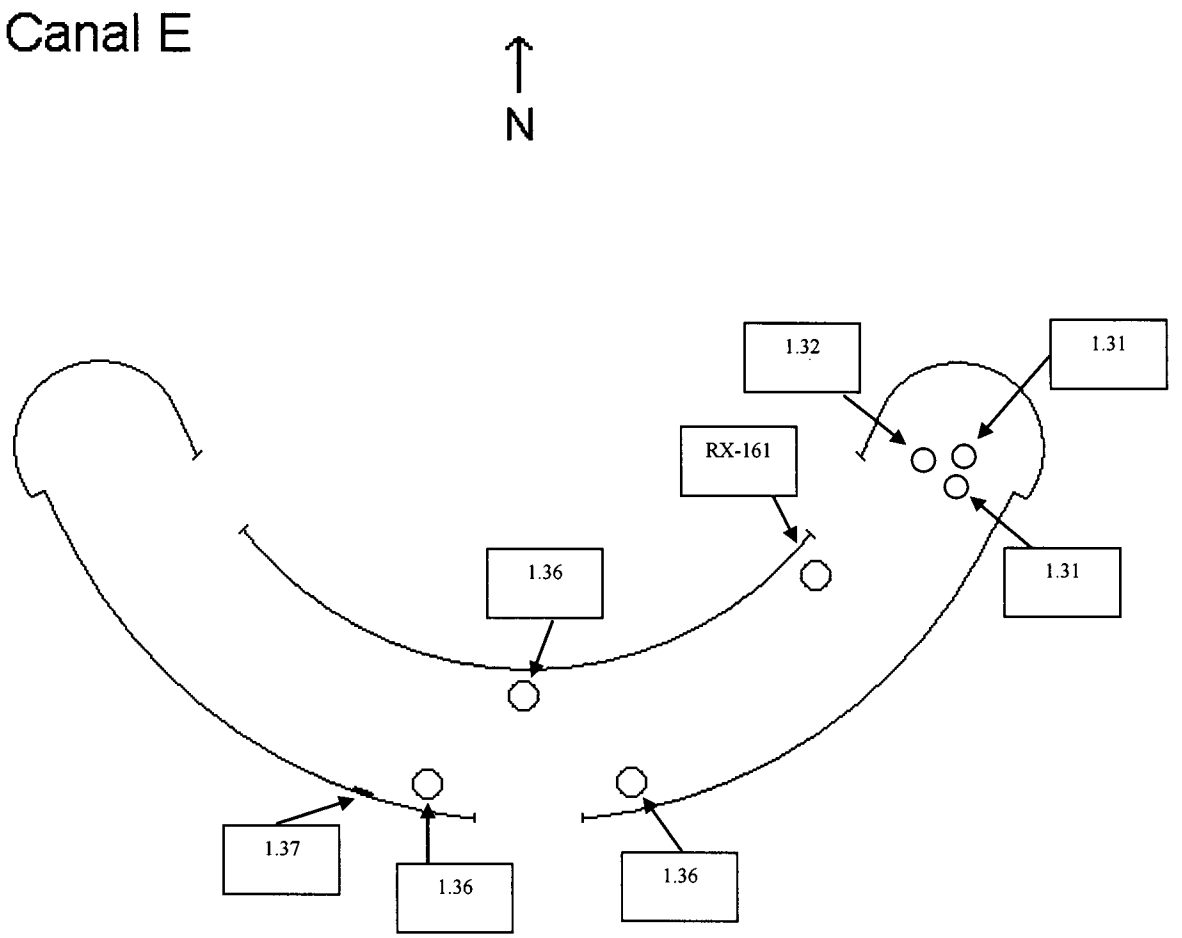
Map 8, Quad C



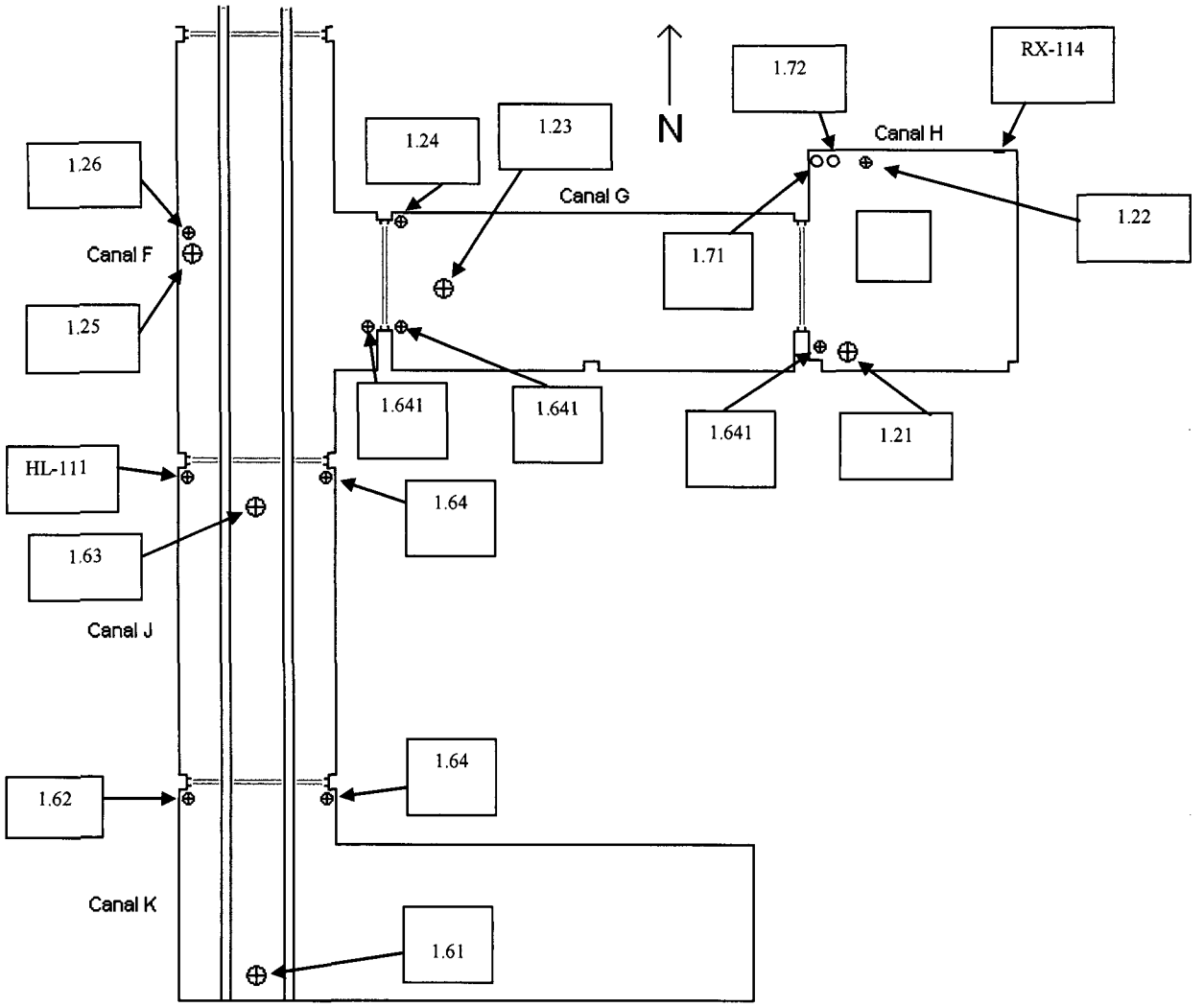
Map 9, Quad D


Quad D
N
1.31
1.32
1.32
Rx-138-1 thru
Rx-138-4
D1
RX-116
D2
RX-117
D5
D3
D6
D4
RX-133

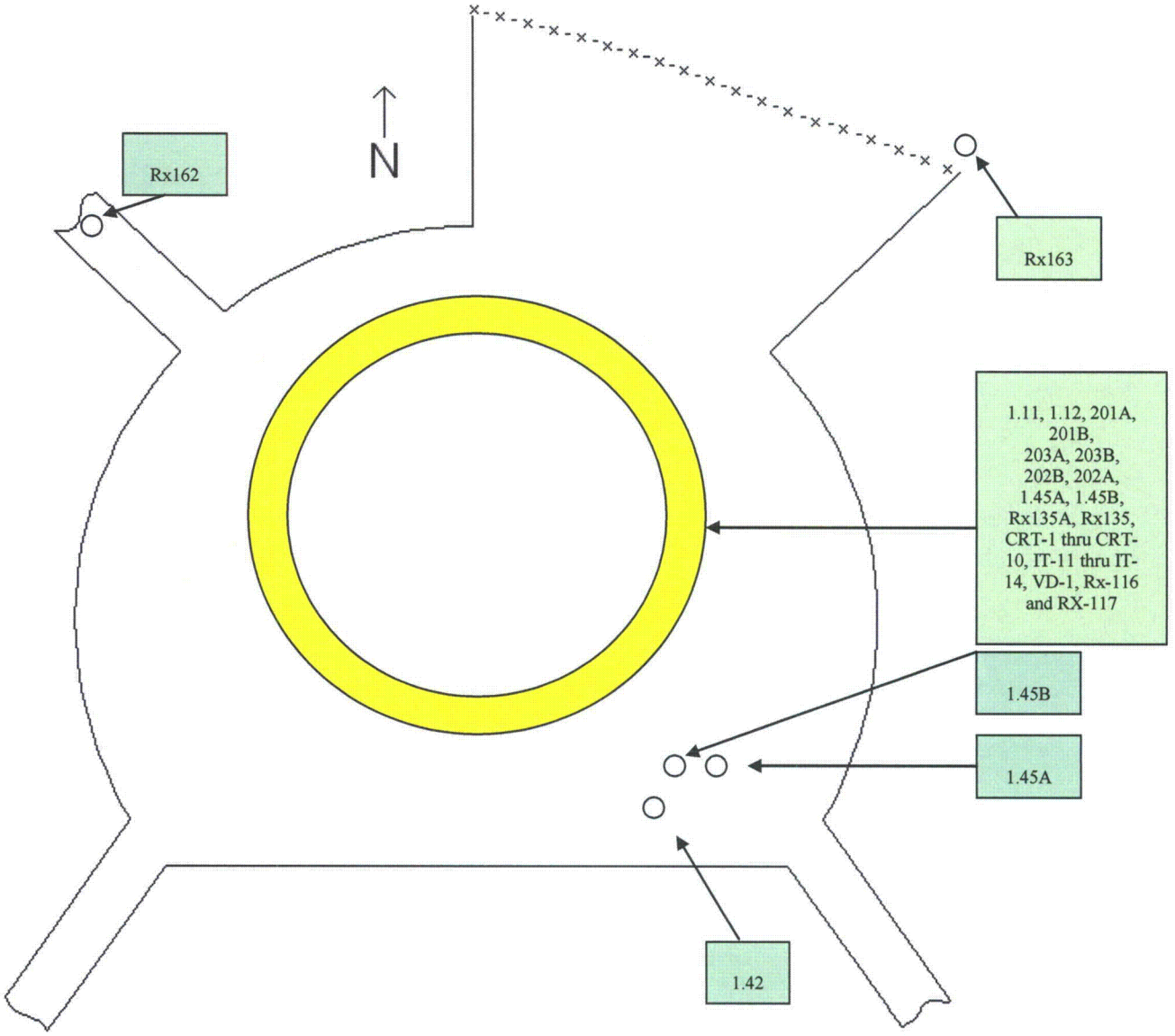
Map 10, Canal E



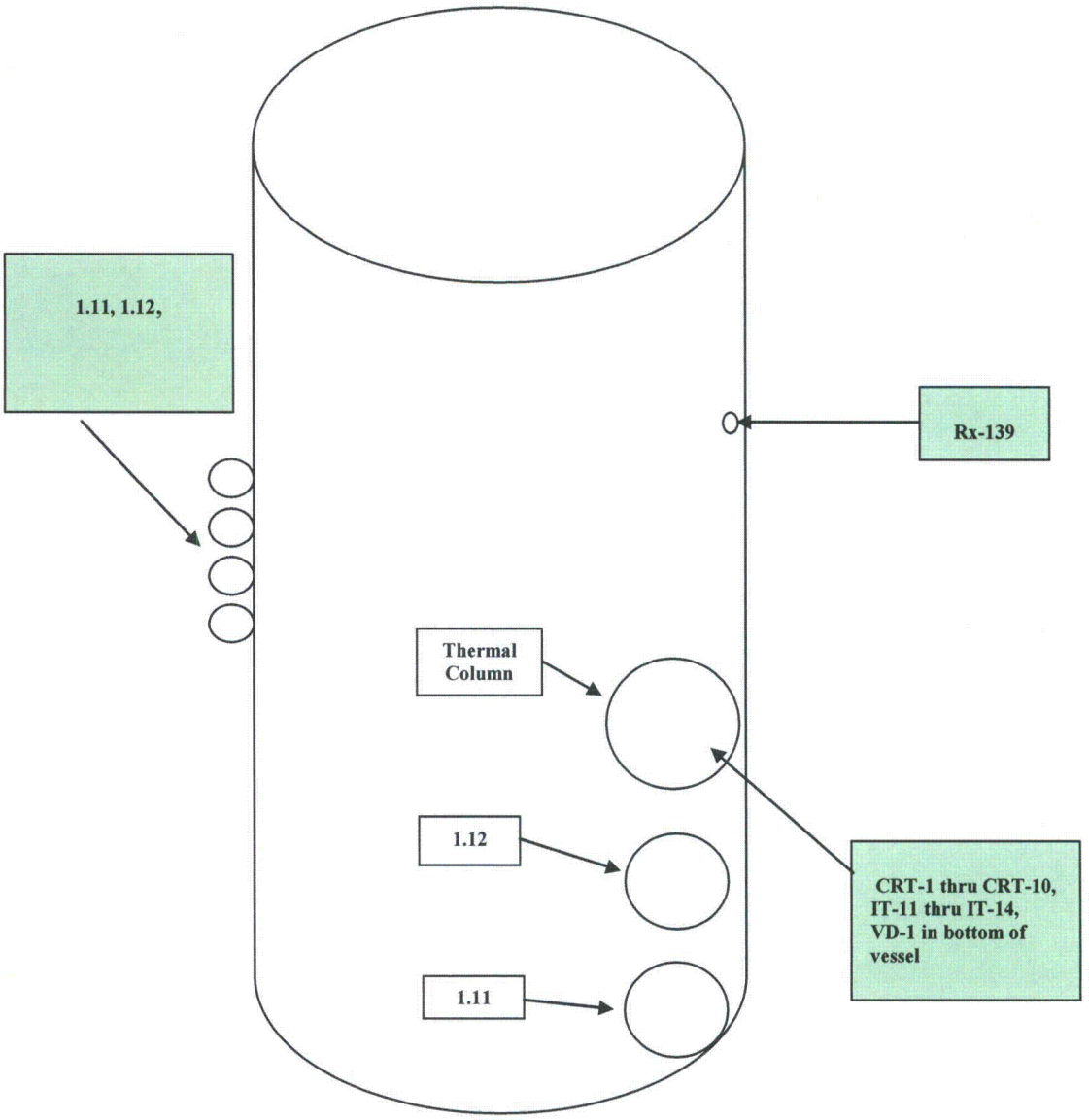
Map 11, Canals F, G, H, J & K



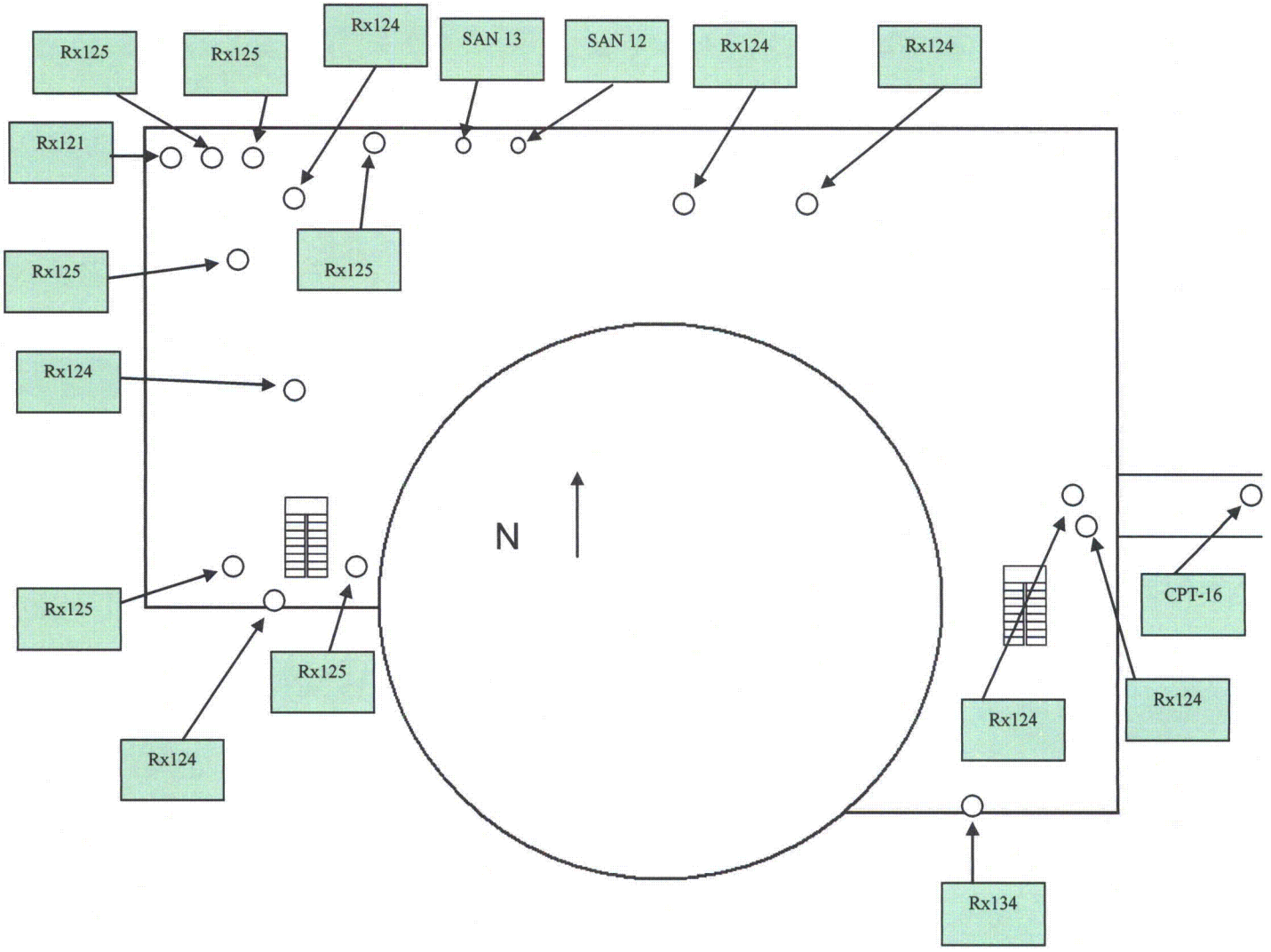
Map 12, Reactor Building Reactor Tank



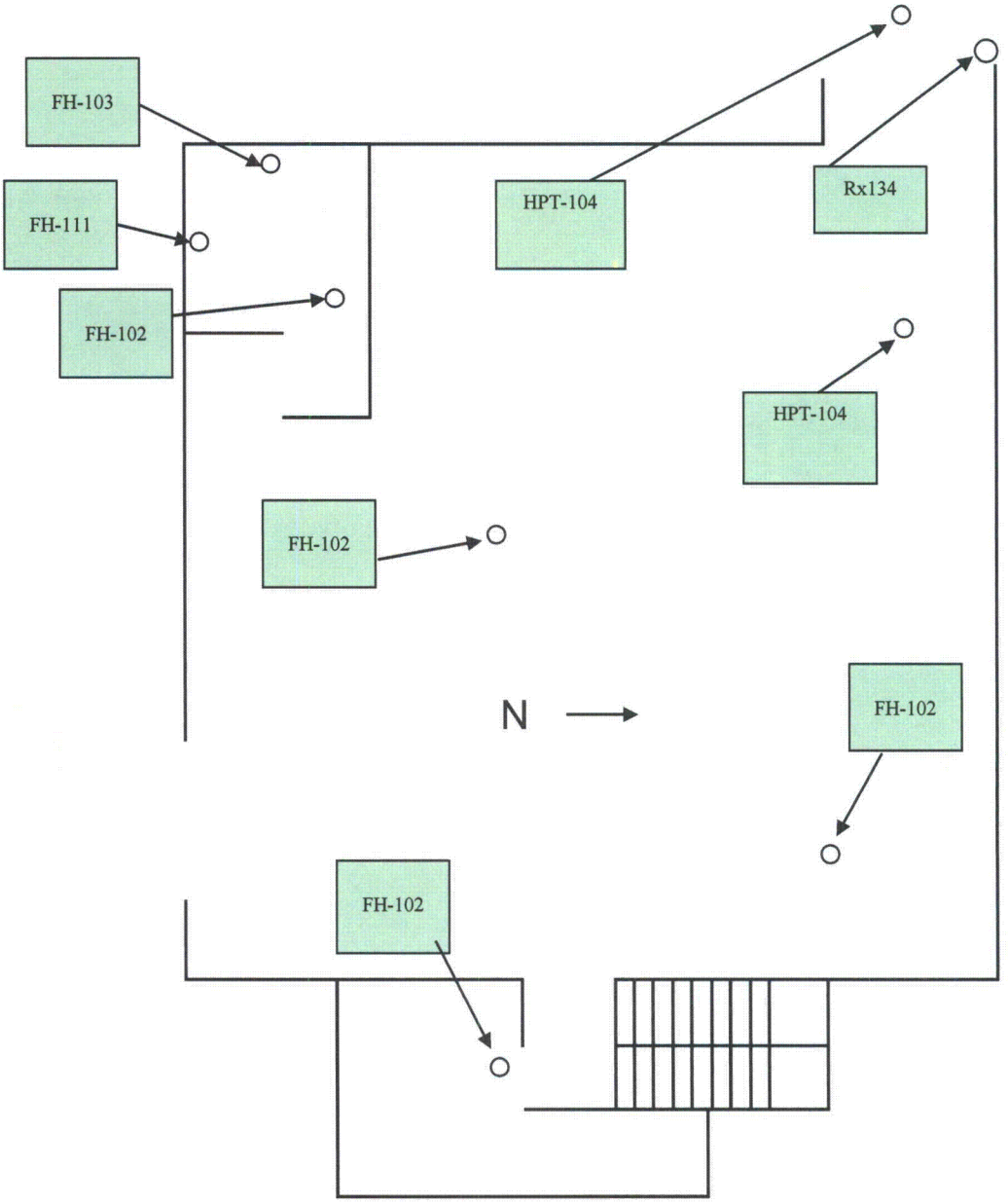
Map 13, Reactor Vessel, -15 Foot Elevation and Vessel Bowl



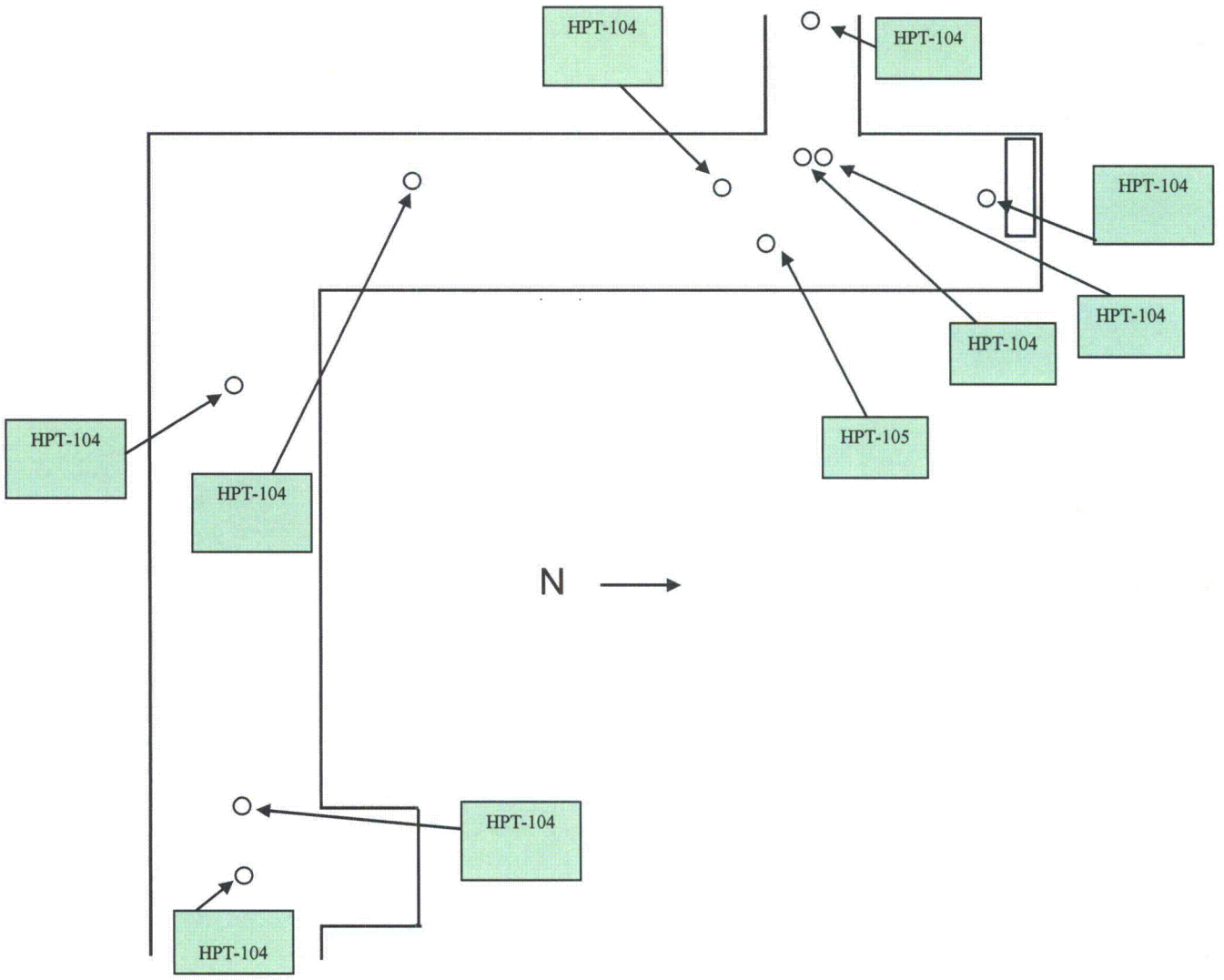
Map 14, Reactor Building -15 Foot Elevation



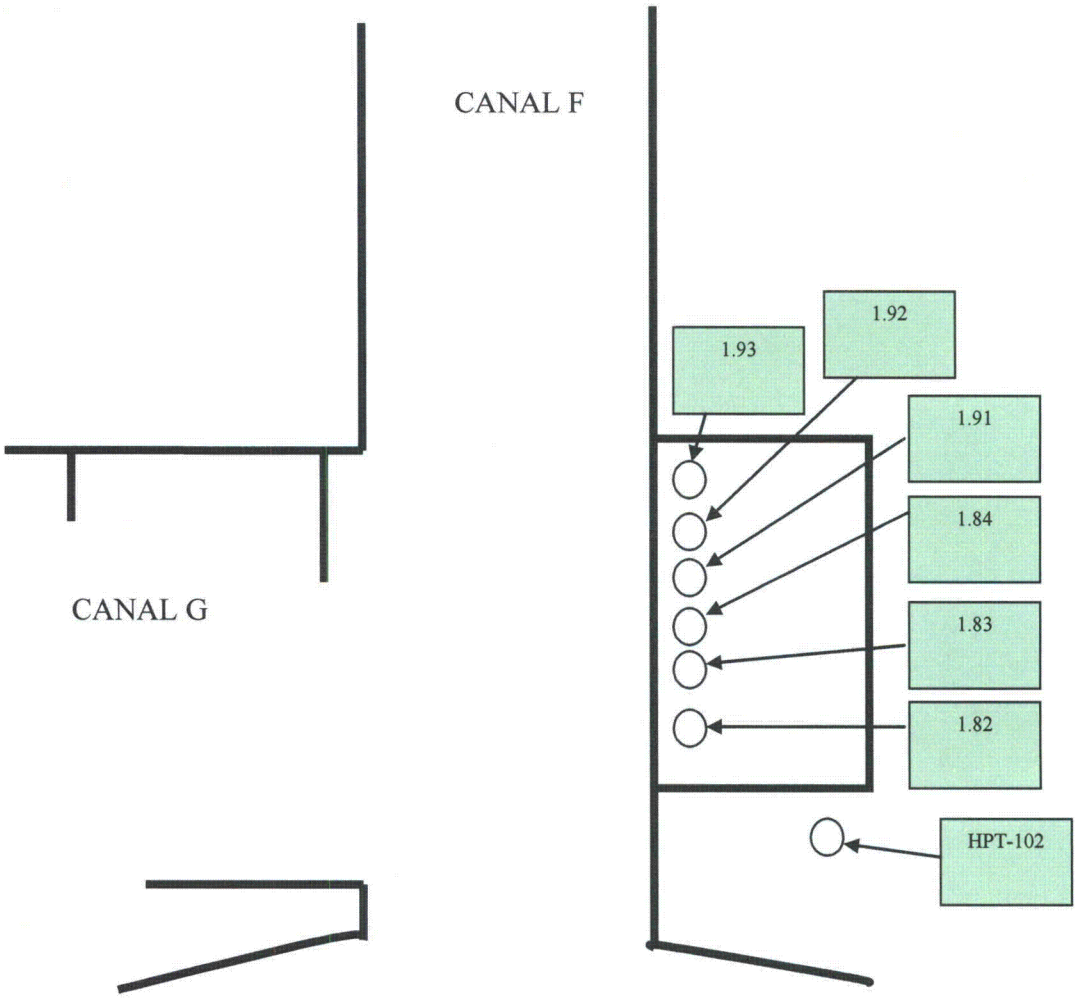
Map 15, Fan House -15 Foot Elevation



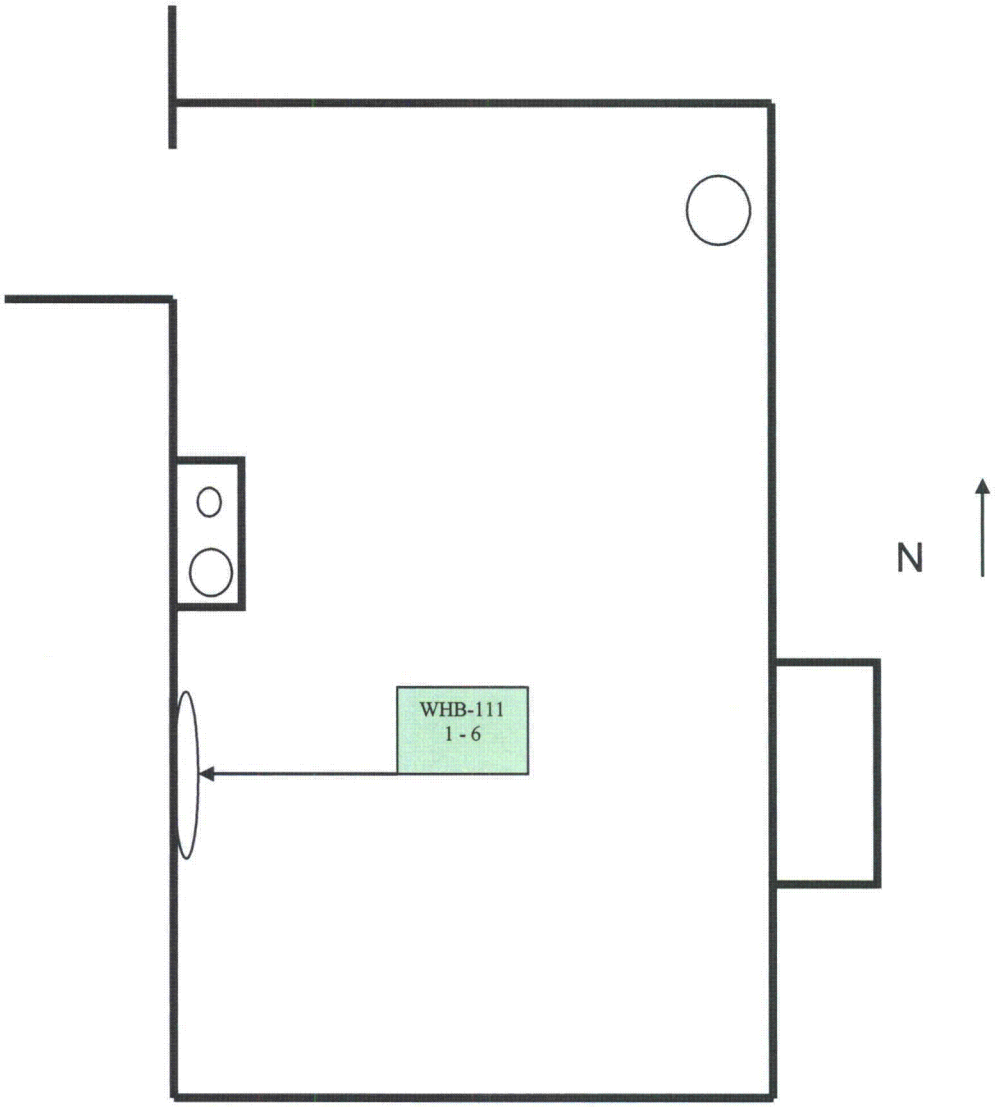
Map 16, Hot Pipe Tunnel



Map 17, HDS Valve Box



Map 18, Waste Handling Building



Plum Brook Reactor Facility

Final Status Survey Report

Attachment 9

Embedded Piping

Revision 0

Appendix C

Structural Survey Unit/Embedded Piping Dose Tables

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PBRF FSSR Attachment 9, Appendix C, Table 1

Structural Survey Units with Embedded Pipe Present	EP Contributing Highest mrem/yr to Structural SU	Location	Highest Structural SU mrem/yr Value	Highest EP mrem/yr Value	Highest Possible Combined mrem/yr Value
FSSR, Att. 1, Rev. 1					
RO-3-1	ROLB-111	Area Way	1.03	0.19	1.22
RO-3-2	ROLB-111	Vestibule, Men's Room, Cold Test Area	1.03	0.19	1.22
RO-3-3	ROLB-111	Cold Test Area	1.03	0.19	1.22
RO-3-4	ROLB-111	Cold Test Area and Vault	1.03	0.19	1.22
RO-3-5	ROLB-111	Sump Room, Sumps, Elevator Sump	1.03	0.19	1.22
FSSR, Att. 2, Rev. 1					
SE-3-1	CPT-16	Cold Pipe Tunnel - Floor Section 1 Fl	6.82	0.02	6.84
SE-3-2	CPT-16	Cold Pipe Tunnel - Floor Section 2 Fl	6.82	0.02	6.84
SE-3-3	CPT-16	Cold Pipe Tunnel - Floor Section 3 Fl	6.82	0.02	6.84
SE-3-4	CPT-16	Cold Pipe Tunnel - Floor Section 4 Fl	6.82	0.02	6.84
SE-3-5	CPT-16	Cold Pipe Tunnel - Floor Section 5 Fl	6.82	0.02	6.84
SE-3-6	CPT-16	Cold Pipe Tunnel - Floor Section 6 Fl	6.82	0.02	6.84
SE-3-7	CPT-16	Cold Pipe Tunnel - Floor Section 7 Fl	6.82	0.02	6.84
SE-3-8	CPT-16	Cold Pipe Tunnel - Floor Section 8 Fl	6.82	0.02	6.84
SE-3-9	CPT-16	Cold Pipe Tunnel - North Wall Section 1 Lw	6.82	0.02	6.84
SE-3-10	CPT-16	Cold Pipe Tunnel - North Wall Section 2 Lw	6.82	0.02	6.84
SE-3-11	CPT-16	Cold Pipe Tunnel - North Wall Section 3 Lw	6.82	0.02	6.84
SE-3-12	CPT-16	Cold Pipe Tunnel - North Wall Section 4 Lw	6.82	0.02	6.84
SE-3-13	CPT-16	Cold Pipe Tunnel - North Wall Section 5 Lw	6.82	0.02	6.84
SE-3-14	CPT-16	Cold Pipe Tunnel - South Wall Section 1 Lw	6.82	0.02	6.84
SE-3-15	CPT-16	Cold Pipe Tunnel - South Wall Section 2 Lw	6.82	0.02	6.84
SE-3-16	CPT-16	Cold Pipe Tunnel - South Wall Section 3 Lw	6.82	0.02	6.84
SE-3-17	CPT-16	Cold Pipe Tunnel - South Wall Section 4 Lw	6.82	0.02	6.84

PBRF FSSR Attachment 9, Appendix C, Table 1

Structural Survey Units with Embedded Pipe Present	EP Contributing Highest mrem/yr to Structural SU	Location	Highest Structural SU mrem/yr Value	Highest EP mrem/yr Value	Highest Possible Combined mrem/yr Value
FSSR, Att. 2, Rev. 1					
SE-3-18	CPT-16	Cold Pipe Tunnel - South Wall Section 5 Lw	6.82	0.02	6.84
SE-3-19	CPT-16	CPT - Ceiling Section 1Ceiling	6.82	0.02	6.84
SE-3-20	CPT-16	CPT - Ceiling Section 2 Ceiling	6.82	0.02	6.84
SE-3-21	CPT-16	CPT - Ceiling Section 3 Ceiling	6.82	0.02	6.84
SE-3-22	CPT-16	CPT - Ceiling Section 4 Ceiling	6.82	0.02	6.84
SE-3-23	CPT-16	CPT - Ceiling Section 5 Ceiling	6.82	0.02	6.84
SE-3-24	CPT-16	CPT - Ceiling Section 6 Ceiling	6.82	0.02	6.84
SE-3-25	CPT-16	CPT - Ceiling Section 7 Ceiling	6.82	0.02	6.84
SE-3-26	CPT-16	CPT - Cooling Tower Basin Tunnel Floor	6.82	0.02	6.84
SE-3-27	CPT-16	CPT - CTB Tunnel S&W Walls Lw	6.82	0.02	6.84
SE-3-28	CPT-16	CPT - CTB Tunnel N&E Walls Lw	6.82	0.02	6.84
SE-3-29	CPT-16	CPT - CTB Tunnel Ceiling	6.82	0.02	6.84
SE-3-30	CPT-16	CPT - Connecting Tunnel Fl	6.82	0.02	6.84
SE-3-31	CPT-16	CPT - Connecting Tunnel Lw	6.82	0.02	6.84
SE-3-32	CPT-16	Basement Class 2 Areas Fl	1.20	0.02	1.22
FSSR, Att. 3, Rev. 1					
FH-2-1	FH-111	Basement – Floor – Section 1	2.54	0.03	2.57
FH-2-2	FH-111	Basement – Floor – Section 2	2.54	0.03	2.57
FH-2-3	FH-111	Basement – Floor – Section 3	2.54	0.03	2.57
FH-2-4	FH-111	Basement – Floor – Section 4	2.54	0.03	2.57
FH-2-5	FH-111	Basement – Floor – Section 5	2.54	0.03	2.57
FH-2-6	FH-111	Basement – Floor – Stairs & Valve Pit	2.54	0.03	2.57

PBRF FSSR Attachment 9, Appendix C, Table 1

Structural Survey Units with Embedded Pipe Present	EP Contributing Highest mrem/yr to Structural SU	Location	Highest Structural SU mrem/yr Value	Highest EP mrem/yr Value	Highest Possible Combined mrem/yr Value
FSSR, Att. 6, Rev. 1					
WH-3-2	WHB-111 1 thru 6	WHB Basement Trench – Concrete Edges	0.36	0.02	0.38
WH-3-11	WHB-111 1 thru 6	WHB Basement Floor - Section 1	0.36	0.02	0.38
WH-3-12	WHB-111 1 thru 6	WHB Basement Floor - Section 2	0.36	0.02	0.38
WH-3-13	WHB-111 1 thru 6	WHB Basement Floor Section 3 & Sumps	0.36	0.02	0.38
FSSR, Att. 8					
HL-3-1	HPT-104	HPT - Floor – Section 1 & Sump	0.89	0.01	0.90
HL-3-2	HPT-104	HPT - Floor – Section 2	0.89	0.01	0.90
HL-3-3	HPT-104	HPT - Floor – Section 3	0.89	0.01	0.90
HL-3-4	HPT-104	HPT - Floor – Section 4	0.89	0.01	0.90
HL-3-5	HPT-104	HPT - Floor – Section 5	0.89	0.01	0.90
HL-3-6	HPT-104	HPT - Corrugated Pipe Tunnel – Section 1	0.89	0.01	0.90
HL-3-7	HPT-104	HPT - Corrugated Pipe Tunnel – Section 2	0.89	0.01	0.90
HL-3-8	HPT-104	HPT - Corrugated Pipe Tunnel – Section 3	0.89	0.01	0.90
HL-3-9	HPT-104	HPT - Walls – Section 1	0.89	0.01	0.90
HL-3-10	HPT-104	HPT - Walls – Section 2	0.89	0.01	0.90
HL-3-11	HPT-104	HPT - Walls – Section 3	0.89	0.01	0.90
HL-3-12	HPT-104	HPT - Walls – Section 4	0.89	0.01	0.90
HL-3-13	HPT-104	HPT - Walls – Section 5	0.89	0.01	0.90
HL-3-14	HPT-104	HPT - Walls – Section 6	0.89	0.01	0.90
HL-3-15	HPT-104	HPT - Ceiling – Section 1	0.89	0.01	0.90
HL-3-16	HPT-104	HPT - Ceiling – Section 2	0.89	0.01	0.90
HL-3-17	HPT-104	HPT - Ceiling – Section 3	0.89	0.01	0.90
HL-3-18	HPT-104	HPT - Ceiling – Section 4	0.89	0.01	0.90

PBRF FSSR Attachment 9, Appendix C, Table 1

Structural Survey Units with Embedded Pipe Present	EP Contributing Highest mrem/yr to Structural SU	Location	Highest Structural SU mrem/yr Value	Highest EP mrem/yr Value	Highest Possible Combined mrem/yr Value
FSSR, Att. 8					
HL-3-19	HPT-104	HPT - Ceiling – Vents & Penetrations	0.89	0.01	0.90
HL-3-21	HPT-104	HPT - Floor – edges of removed section	0.89	0.01	0.90
HL-4-1	HPT-105	Off-Gas - Floor, 6'6" Walkway, North Wall	1.58	0.01	1.59
HL-4-2	HPT-105	Off-Gas – North & East Walls	1.58	0.01	1.59
HL-4-3	HPT-105	Off-Gas - South & West Walls	1.58	0.01	1.59
HL-4-4	HPT-105	HDS - Beam	0.74	0.01	0.75
HL-4-5	HPT-105	HDS – Floor – West section	1.58	0.01	1.59
HL-4-6	HPT-105	HDS – Floor – East section	1.58	0.01	1.59
HL-4-7	HPT-105	HDS – North Wall & Observation Window	0.74	0.01	0.75
HL-4-8	HPT-105	HDS – West Wall	0.74	0.01	0.75
HL-4-9	HPT-105	HDS – East Wall below beam	1.58	0.01	1.59
HL-4-10	HPT-105	HDS – South Wall & East Wall above beam	0.74	0.01	0.75
HL-4-11	HPT-105	Interim Storage – Floor and Pit	1.58	0.01	1.59
HL-4-12	HPT-105	Interim Storage – East & West Walls	0.74	0.01	0.75
HL-4-13	HPT-105	Interim Storage – North & South Walls and	0.74	0.01	0.75
HL-4-14	1.61	Canal K - Floor	0.53	0.16	0.69
HL-4-15	1.61	Canal K - North Wall	0.53	0.16	0.69
HL-4-16	1.61	Canal K - East Wall & South Wall	0.53	0.16	0.69
HL-4-17	1.61	Canal K - West Wall & South Wall	0.53	0.16	0.69
HL-4-18	1.63	Canal J - Floor	0.58	0.28	0.86
HL-4-18	1.63	Canal J - Floor	0.58	0.28	0.86
HL-4-19	1.63	Canal J - West Wall - North Section	0.58	0.28	0.86
HL-4-20	1.63	Canal J - East Wall - North Section	0.58	0.28	0.86

PBRF FSSR Attachment 9, Appendix C, Table 1

Structural Survey Units with Embedded Pipe Present	EP Contributing Highest mrem/yr to Structural SU	Location	Highest Structural SU mrem/yr Value	Highest EP mrem/yr Value	Highest Possible Combined mrem/yr Value
FSSR, Att. 8					
HL-4-21	1.63	Canal J - E & W Walls - South Section	0.58	0.28	0.86
FSSR, Att. 11					
CV-3-1	RX-135	Sub-Pile Room - Floor and Liner Floor	1.63	0.16	1.79
CV-3-2	RX-135	Sub-Pile Room - South Wall, Elevator walls	1.63	0.16	1.79
CV-3-3	RX-135	Sub-Pile Room – Ceiling, North Wall	1.63	0.16	1.79
CV-3-4	EP 1.12	Bio-Shield Lower	0.94	1.37	2.31
CV-3-5	EP 1.12	Bio-Shield Upper	0.94	1.37	2.31
CV-3-6	1.72A	Canal E - West Floor Section and Doorway	0.62	0.04	0.66
CV-3-7	1.72A	Canal E - East Floor Section	0.62	0.04	0.66
CV-3-8	1.72A	Canal E - Wall Section #1	0.62	0.04	0.66
CV-3-9	1.72A	Canal E - Wall Section #2	0.62	0.04	0.66
CV-3-10	1.72A	Canal E - Wall Section #3	0.62	0.04	0.66
CV-3-11	1.72A	Canal E - Wall Section #4	0.62	0.04	0.66
CV-3-12	1.72A	Canal E - Wall Section #5	0.62	0.04	0.66
CV-3-13	1.72A	Canal E - Wall Section #6	0.62	0.04	0.66
CV-3-14	1.72A	Canal E - Ceiling	0.62	0.04	0.66
CV-3-15	RX-139	CV -25' Reactor Annulus - West Floor	0.55	0.13	0.68
CV-3-16	RX-139	CV -25' Reactor Annulus - North Floor	0.55	0.13	0.68
CV-3-17	RX-139	CV -25' Reactor Annulus - East Floor	0.55	0.13	0.68
CV-3-18	RX-139	CV -25' Reactor Annulus - Cave	0.55	0.13	0.68
CV-3-19	RX-139	CV -25' Reactor Annulus - East Platform	0.55	0.13	0.68
CV-3-20	RX-139	CV -25' Reactor Annulus - West Stairs	0.55	0.13	0.68
CV-3-21	RX-139	CV -25' Reactor Annulus - East Stairs	0.55	0.13	0.68

PBRF FSSR Attachment 9, Appendix C, Table 1

Structural Survey Units with Embedded Pipe Present	EP Contributing Highest mrem/yr to Structural SU	Location	Highest Structural SU mrem/yr Value	Highest EP mrem/yr Value	Highest Possible Combined mrem/yr Value
FSSR, Att. 11					
CV-3-22	RX-139	CV -25' Reactor Annulus - West End Wall	0.55	0.13	0.68
CV-3-23	RX-139	CV -25' Reactor Annulus/Inner Wall Sect. #2	0.55	0.13	0.68
CV-3-24	RX-139	CV -25' Reactor Annulus/Inner Wall Sect. #3	0.55	0.13	0.68
CV-3-25	RX-139	CV -25' Reactor Annulus/Inner Wall Sect. #4	0.55	0.13	0.68
CV-3-26	RX-139	CV -25' Reactor Annulus/Outer Wall Sect. #1	0.55	0.13	0.68
CV-3-27	RX-139	CV -25' Reactor Annulus/Outer Wall Sect. #2	0.55	0.13	0.68
CV-3-28	RX-139	CV -25' Reactor Annulus/Outer Wall Sect. #3	0.55	0.13	0.68
CV-3-29	RX-139	CV -25' Reactor Annulus/Outer Wall Sect. #4	0.55	0.13	0.68
CV-3-30	RX-139	CV -25' Reactor Annulus/Outer Wall Sect. #5	0.55	0.13	0.68
CV-3-31	RX-139	CV -25' Reactor Annulus/West Ceiling	0.55	0.13	0.68
CV-3-32	RX-139	CV -25' Reactor Annulus/East Ceiling	0.55	0.13	0.68
CV-3-33	EP 1.12	Quads B & D	0.05	1.37	1.42
CV-3-34	EP 1.12	Quads B & D	0.05	1.37	1.42
CV-3-35	EP 1.12	Quads B & D	0.05	1.37	1.42
CV-3-36	EP 1.12	Quads B & D	0.05	1.37	1.42
CV-3-37	EP 1.12	Quads B & D	0.05	1.37	1.42
CV-3-38	EP 1.12	Quads B & D	0.05	1.37	1.42
CV-3-39	EP 1.12	Quads B & D	0.05	1.37	1.42
CV-3-40	EP 1.12	Quads B & D	0.05	1.37	1.42
CV-3-41	1.43 A + B	CV -25' - Quad A - Floor	1.87	0.26	2.13
CV-3-42	1.43 A + B	CV -25' - Quad A – N Wall, Reactor, & S Wall	1.87	0.26	2.13
CV-3-43	1.43 A + B	CV -25' - Quad A - South Wall & Canal E Doorway	1.87	0.26	2.13
CV-3-44	1.43 A + B	CV -25' - Quad A - West Wall	1.87	0.26	2.13

PBRF FSSR Attachment 9, Appendix C, Table 1

Structural Survey Units with Embedded Pipe Present	EP Contributing Highest mrem/yr to Structural SU	Location	Highest Structural SU mrem/yr Value	Highest EP mrem/yr Value	Highest Possible Combined mrem/yr Value
FSSR, Att. 11					
CV-3-45	1.43 A + B	CV -25' - Quad C - Floor	1.87	0.26	2.13
CV-3-46	1.43 A + B	CV -25' - Quad C – N Wall, Rx Wall, & S Wall	1.87	0.26	2.13
CV-3-47	1.43 A + B	CV -25' - Quad C - East Wall	1.87	0.26	2.13
CV-3-48	1.43 A + B	CV -25' - Quad C - S Wall & Canal E Door	1.87	0.26	2.13
FSSR, Att. 12					
RB-3-3	RX-134	RB -15' - Floor Section #1	0.94	0.15	1.09
RB-3-4	RX-134	RB -15' - Floor Section #2	0.94	0.15	1.09
RB-3-5	RX-134	RB -15' - Floor Section #3	0.94	0.15	1.09
RB-3-6	RX-134	RB -15' - Floor Section #4	0.94	0.15	1.09
RB-3-7	RX-134	RB -15' - Floor Section #5	0.94	0.15	1.09
RB-3-8	RX-134	RB -15' - Floor Section #6	0.94	0.15	1.09
RB-3-9	RX-134	RB -15' - Floor Section #7	0.94	0.15	1.09
RB-3-10	RX-134	RB -15' - Floor Section #8	0.94	0.15	1.09
RB-3-11	RX-134	RB -15' - Floor Section #9	0.94	0.15	1.09
RB-3-12	RX-134	RB -15' - Floor Section #10	0.94	0.15	1.09
RB-3-13	RX-134	RB -15' - East Stairway	0.94	0.15	1.09
RB-3-14	RX-134	RB -15' - West Stairway	0.94	0.15	1.09
RB-3-15	RX-134	RB -15' - Wall Section #1	0.94	0.15	1.09
RB-3-16	RX-134	RB -15' - Wall Section #2	0.94	0.15	1.09
RB-3-17	RX-134	RB -15' - Wall Section #3	0.94	0.15	1.09
RB-3-18	RX-134	RB -15' - Wall Section #4	0.94	0.15	1.09
RB-3-19	RX-134	RB -15' - Wall Section #5	0.94	0.15	1.09
RB-3-20	RX-134	RB -15' - Wall Section #6	0.94	0.15	1.09

PBRF FSSR Attachment 9, Appendix C, Table 1

Structural Survey Units with Embedded Pipe Present	EP Contributing Highest mrem/yr to Structural SU	Location	Highest Structural SU mrem/yr Value	Highest EP mrem/yr Value	Highest Possible Combined mrem/yr Value
FSSR, Att. 12					
RB-3-21	RX-134	RB -15' - Wall Section #7	0.94	0.15	1.09
RB-3-22	RX-134	RB -15' - Wall Section #8	0.94	0.15	1.09
RB-3-23	RX-134	RB -15' - ATS Tunnel Entrance	0.94	0.15	1.09
RB-3-24	RX-134	RB -15' - Ceiling Section #1	0.94	0.15	1.09
RB-3-39	RX-134	RB -15' - West Columns	0.94	0.15	1.09
RB-4-1	1.36	Canal F - Floor including F-J and F-H doorway	0.65	0.03	0.68
RB-4-2	1.36	Canal F - West & North Walls	0.65	0.03	0.68
RB-4-3	1.36	Canal F - East Wall & F-J doorway sides	0.65	0.03	0.68
RB-4-4	1.36	Canal F - Catwalk steel & undersides	0.65	0.03	0.68
RB-4-5	1.36	Canal G - Floor & G-H doorway	0.65	0.03	0.68
RB-4-6	1.36	Canal G - North Wall	0.65	0.03	0.68
RB-4-7	1.36	Canal G - E & W Walls, & S Wall lower 4m	0.65	0.03	0.68
RB-4-8	1.36	Canal G - S Wall >4m , G & H walkway	0.65	0.03	0.68
RB-4-9	1.36	Canal H - Floor	0.65	0.03	0.68
RB-4-10	1.36	Canal H - W & N Walls, G-H doorway sides	0.65	0.03	0.68
RB-4-11	1.36	Canal H - S & E Walls	0.65	0.03	0.68
RB-4-12	1.44	RB -25' - Trench bottom & Pit sides	4.92	0.21	5.13
RB-4-13	1.44	RB -25' - Trench sides	4.92	0.21	5.13
RB-4-14	1.44	RB -25' - Floor Section #1 - East Floor	4.92	0.21	5.13
RB-4-15	1.44	RB -25' - Floor Section #2 - SE & South Floor	4.92	0.21	5.13
RB-4-16	1.44	RB -25' - Floor Section #3 - Ctr Floor & Pad	4.92	0.21	5.13
RB-4-17	1.44	RB -25' - Floor Section #4 - N Floor & Strway	4.92	0.21	5.13
RB-4-18	1.44	RB -25' - PR Main Trench Flr & Pipe Chase	4.92	0.21	5.13

PBRF FSSR Attachment 9, Appendix C, Table 1

Structural Survey Units with Embedded Pipe Present	EP Contributing Highest mrem/yr to Structural SU	Location	Highest Structural SU mrem/yr Value	Highest EP mrem/yr Value	Highest Possible Combined mrem/yr Value
FSSR, Att. 12					
RB-4-19	1.44	RB -25' - Pump Room Main Trench Walls	4.92	0.21	5.13
RB-4-20	1.44	RB -25' - Pump Room Floor & Pump Services Trench	4.92	0.21	5.13
RB-4-21	1.44	RB -25' - Wall Section #1	4.92	0.21	5.13
RB-4-22	1.44	RB -25' - Wall Section #2	4.92	0.21	5.13
RB-4-23	1.44	RB -25' - Wall Section #3	4.92	0.21	5.13
RB-4-24	1.44	RB -25' - Wall Section #4	4.92	0.21	5.13
RB-4-25	1.44	RB -25' - Wall Section #5	4.92	0.21	5.13
RB-4-26	1.44	RB -25' - Wall Section #6	4.92	0.21	5.13
RB-4-27	1.44	RB -25' - Wall Section #7	4.92	0.21	5.13
RB-4-28	1.44	RB -25' - Wall Section #8	4.92	0.21	5.13
RB-4-29	1.44	RB -25' - Columns	4.92	0.21	5.13
RB-4-30	1.44	RB -25' - Pump Room - Mezzanine	4.92	0.21	5.13
RB-4-31	1.44	RB -25' - Pump Room - South & West Walls	4.92	0.21	5.13
RB-4-32	1.44	RB -25' - Pump Room - North, Northeast, & East Walls	4.92	0.21	5.13
RB-4-33	1.44	RB -25' - Pump Room - Ceiling	4.92	0.21	5.13
RB-4-34	1.44	RB -25' - Ceiling Section #1	4.92	0.21	5.13
RB-4-35	1.44	RB -25' - Ceiling Section #2	4.92	0.21	5.13
RB-4-36	1.44	RB -25' - Ceiling Section #3	4.92	0.21	5.13
RB-4-37	1.44	RB -25' - Ceiling Section #4	4.92	0.21	5.13
RB-4-38	1.44	RB -25' - Ceiling Section #5	4.92	0.21	5.13
RB-4-39	1.44	RB -25' - Ceiling Section #6	4.92	0.21	5.13
RB-4-40	1.44	RB -25' - Ceiling Section #7	4.92	0.21	5.13
RB-4-41	1.44	RB -25' - Ceiling Section #8	4.92	0.21	5.13

PBRF FSSR Attachment 9, Appendix C, Table 1

Structural Survey Units with Embedded Pipe Present	EP Contributing Highest mrem/yr to Structural SU	Location	Highest Structural SU mrem/yr Value	Highest EP mrem/yr Value	Highest Possible Combined mrem/yr Value
FSSR, Att. 12					
RB-4-42	1.44	RB -25' - Cold Sump	4.92	0.21	5.13
RB-4-43	1.44	RB -25' - PPP Room Sump	4.92	0.21	5.13

Plum Brook Reactor Facility

Final Status Survey Report

Attachment 9

Embedded Piping

Revision 0

Appendix D

Primary Cooling Piping, EP 1.11 & EP 1.12

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1.0 Physical Description of EP 1.11 & EP 1.12

The Primary Coolant Lines are identified in the EP surveys as EP 1.11 and EP 1.12. These lines exist after decommissioning as two 24 inch lines which run from the Primary Pump House Room #4 floor down to the RB -25 ending at the bottom of the reactor vessel tank. The two lines are remnants of the former reactor coolant return line (EP 1.11, hot leg), and the reactor cooling supply line (EP 1.12, cold leg).

The reactor coolant return line (EP 1.11) is the 24" hot leg for the Primary Coolant system. The function of this piping was to convey heated water away from the reactor core. As it exists today EP 1.11 consists of 24" diameter piping that is approximately 146 feet in length.

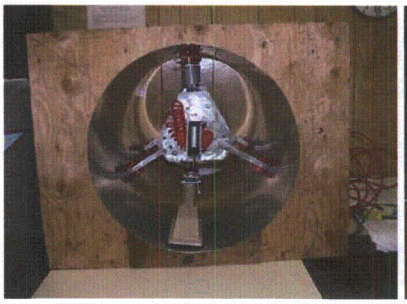
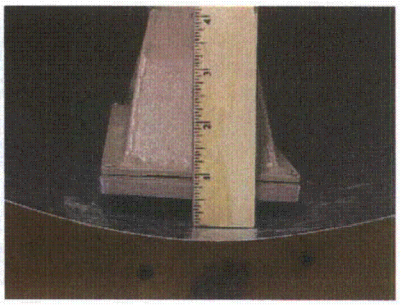
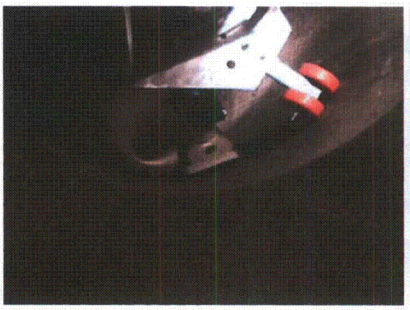
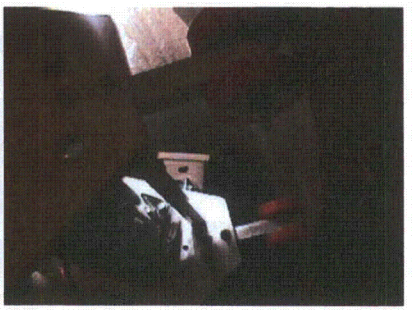
The reactor coolant supply line (EP 1.12) is the 24" cold leg for the Primary Coolant system. The function of this piping was to convey cool water into the reactor core. As it exists today EP 1.12 consists of 24" diameter piping that is approximately 146 feet in length.

The current physical configuration of these piping runs consists of the 24" pipes in a conformal steel support box at the PPH Room 4 which is surrounded by a concrete sarcophagus of at least two feet in thickness for the entire length of the piping until the piping enters the concrete foundations of the Containment Vessel. The piping is completely encased in the Containment Vessel foundation and lies under the grouted section of the reactor vessel tank. There is no access into the sarcophagus from any adjacent survey units, and the steel support box is inaccessible to personnel as it is also concrete filled between the exterior of the 24" piping and the interior of the steel support box. The 24" piping is filled with grout between the PPH Room 4 minus 3 foot elevation to their lower ends at the reactor vessel tank.

2.0 Description of Embedded Pipe Surveys for EP 1.11 & EP 1.12

The 24" pipes were surveyed with beta-gamma scintillating detectors mounted on an in-situ, variable geometry, pipe sled. This sled allows the detectors to traverse elbows and risers while assuring a consistent geometry for each survey measurement. 100% assay by scan survey of all accessible surfaces and static radiological measurements at specified increments are assessed to demonstrate compliance with the EP dose goals. This detector and sled combination was utilized because the largest NaI scintillators in the project inventory were not able to provide sufficient MDA's for the 24" piping survey. Larger scintillating crystal detectors were not available to the project to allow surveys to be accomplished within the constraints of time and schedule.

The sled with detectors utilized for these surveys are illustrated below in both 24"mock-up piping and primary coolant 24" piping.

The detectors were calibrated under the PBRF calibration procedures and the efficiency determinations were performed with NIST traceable, conformable sources using the mock-ups pictured above. The sources were mounted in the mock-up allowing the detector-sled combination to reproduce the in-situ geometry of the 24" primary cooling pipes. Surveys in EP 1.11 and EP 1.12 were performed using detectors optimized to measure beta energies ≥85 keV. This energy is similar to the beta energy for Co-60 (96 keV), assuring the nuclide of concern for DCGL is assessed during data acquisition

When performing piping surveys, the sleds were moved through the piping using flexible conduit rodding, extendable cameras and measuring tapes to control progress through the piping. Scan measurements require a 90 second scan time to survey each section of accessible 24"piping at ≤ 1inch/second and within ½ inch of the piping surface. The gross cpm measurement for each scan is the highest, instantaneous, cpm count rate observed during the 90 second scan. The derived activity from these scan measurements is the most conservative quantity for that section of assessed piping. This conservatism is replicated when determining compliance with the DCGL release criterion. At each static measurement location a one minute static measurement was acquired at four clock positions for each location (12, 3, 6 and 9 o'clock).

Surveys of EP 1.11 & 1.12 were performed on the accessible piping in each piping run (106 feet of EP 1.11 and 87 feet of EP 1.12). 100% of the accessible piping was scanned. The inaccessible piping includes elbows (5 in EP 1.11 and 8 in EP 1.12), weld bead transitions (EP 1.12) and the three feet of piping between the 0' elevation and the -3' elevation in the PPH Room 4. The surveys performed

are representative of the entire pipe lengths and comply with the requirements of Section 7.5 of the FSSP.

The elbows and their approaches are inaccessible to the pipe sled. The upper 3 feet in PPH Room 4 was released to the structural DCGL for both pipe runs and is not grouted. This ungrouted piping was subsequently removed as part of ongoing decommissioning efforts.

Sixteen static survey locations were selected by a random number generator for each piping run (EP 1.11 and EP 1.12). At each accessible location four static measurements were acquired for a total of 44 static measurements in EP 1.11 and 40 static measurement locations in EP 1.12.

3.0 Summary of Remediation & Embedded Pipe Surveys for EP 1.11 & EP 1.12

The 24" primary cooling pipes were remediated using hydrolasing techniques as described in Section 3.6 of this attachment. The hydrolasing apparatus for remediating the piping enabled a consistent application of remediation effort throughout the entire piping run. Several remediation and post-remediation survey evolutions were performed on both EP 1.11 and EP 1.12. There was little to no change in the radiological contamination levels between hydrolasing evolutions remediation was secured and a dose goal of 2 mrem/yr was selected for EP 1.11 and EP 1.12. This selection was based after a review of the safety concerns inherent in hydrolasing operations, the diminished results of additional

hydrolasing, and the residual contamination levels achieved for the structure survey units which coincide with EP 1.11 and EP 1.12.

These piping runs are assessed for compliance with the embedded pipe dose goals attributing all activity derived dose as a 100% Co-60 nuclide distribution. This is the most conservative DCGL for the facility. Background was not subtracted from the survey measurements and the Elevated Measurement Comparison (EMC) was not employed for these survey units. As allowed in the FSSP, Section 3.3, a dose goal of 2 mrem/yr is designated for EP 1.11 and EP 1.12, the coinciding structural survey units were corrected for this dose goal.

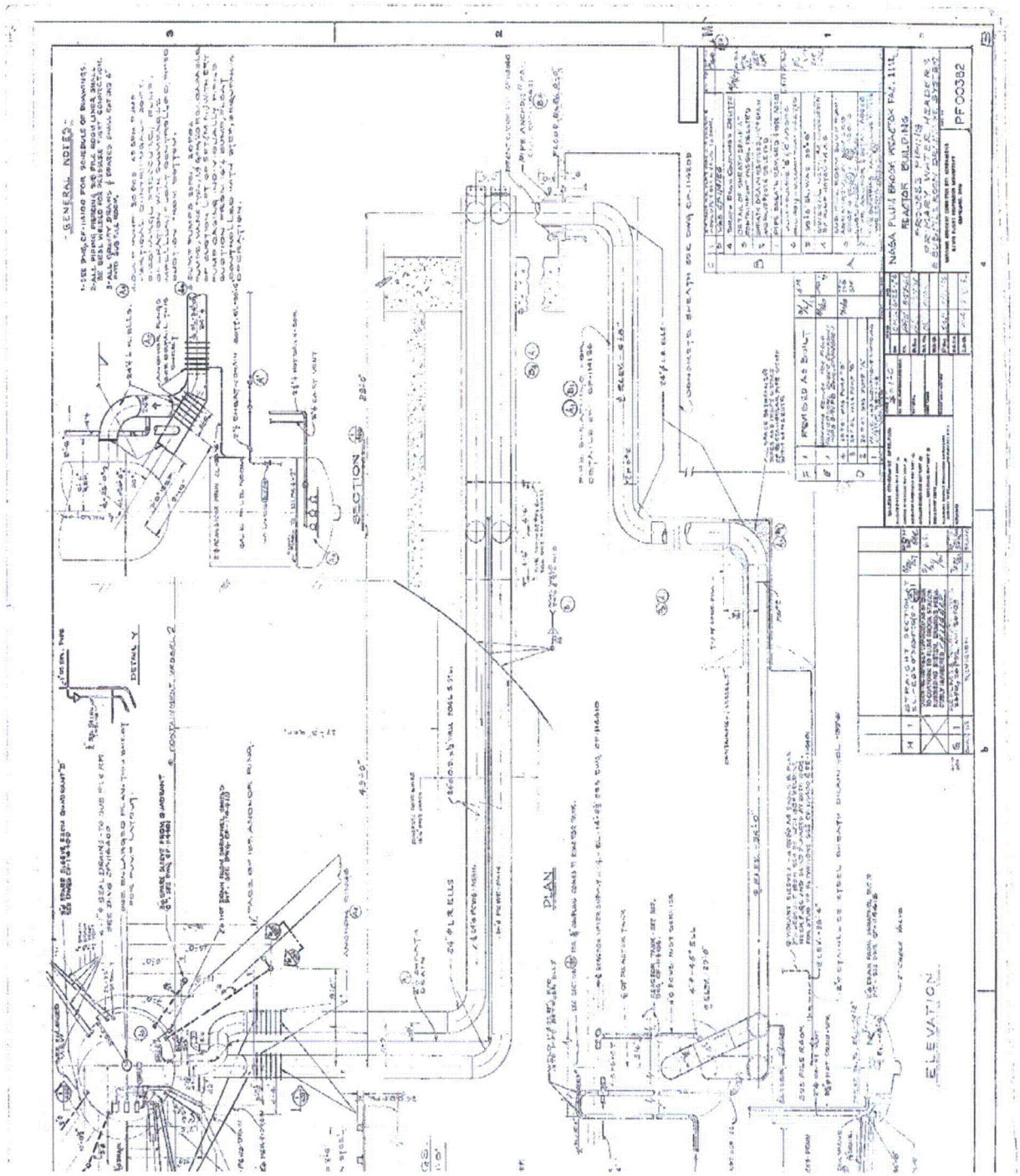
The dose contribution for EP 1.11 is 1.009 mrem/yr, the dose contribution for EP 1.12 is 1.366 mrem/yr for the coinciding structural survey units as detailed below in Table 1. A summary of results is included as Table 2.

Appendix D, Table 1 - Structural Survey Unit/Embedded Piping Dose Table

Structural Survey Units with Embedded Pipe Present	EP Contributing Highest mrem/yr to Structural SU	Location	Highest Structural SU mrem/yr Value	Highest EP mrem/yr Value	Highest Possible Combined mrem/yr Value
FSSR, Att. 11					
CV-3-4	EP 1.12	Bio-Shield Lower	0.94	1.37	2.31
CV-3-5	EP 1.12	Bio-Shield Upper	0.94	1.37	2.31
CV-3-33	EP 1.12	Quads B & D	0.05	1.37	1.42
CV-3-34	EP 1.12	Quads B & D	0.05	1.37	1.42
CV-3-35	EP 1.12	Quads B & D	0.05	1.37	1.42
CV-3-36	EP 1.12	Quads B & D	0.05	1.37	1.42
CV-3-37	EP 1.12	Quads B & D	0.05	1.37	1.42
CV-3-38	EP 1.12	Quads B & D	0.05	1.37	1.42
CV-3-39	EP 1.12	Quads B & D	0.05	1.37	1.42
CV-3-40	EP 1.12	Quads B & D	0.05	1.37	1.42

Appendix D, Table 2 - Embedded Piping Survey Results for EP 1.11 & EP 1.12

EP ID #	EP Description	Pipe Length (ft)	# of N	DCGL [1] (dpm/100 cm^2)	Maximum Activity (dpm/100 cm^2)	Mean Activity (dpm/100 cm^2)	Standard Deviation (dpm/100 cm^2)	Average Activity <DCGL	EP Dose (mrem/yr.)
EP 1.11	24" Hot Leg	146	44	4.816E+05	336,638	243,208	35,638	Yes	1.009
EP 1.12	24" Cold Leg	146	40	4.816+05	466,670	328,933	45,270	Yes	1.366

Table 2 Notes:
Note 1 – DCGL value is based on dose goal of 2 mrem/yr. This value was increased from the initial 1 mrem/yr dose goal to 2 mrem/yr after extensive remediation and authorization from the NASA Project Radiation Safety Officer.

EP 1.11 & EP 1.12 Drawing