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Radiochemical Processing Laboratory High-Level Vault Characterization Report

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October 2007



Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

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Summary

The High Level Vaults (HLV) consists of three underground concrete vaults containing seven tanks. The tanks were used to support a variety of radiochemical processes conducted in the High Level Radiochemistry Facility (HLRF) hot cells. The HLRF is located adjacent to the east wall of the 325 Building, which also is known as the Radiochemical Processing Facility (RPL).

Initial radiological and chemical conditions and video documentation of the interior of the HLV were obtained by disassembling the HLV high efficiency particulate air (HEPA) filter housings and inserting remote monitoring equipment through the openings. The radiological dose rates obtained near the filter housing inlets ranged from less than the minimum detectable amount (MDA) to 150 mRem/hr. The results indicated that the HLV access cover block could be safely removed.

The weather barrier covering the HLV cover blocks was removed and discarded. To extend the working surface, a two-foot strip of concrete was installed around the perimeter of the HLV. Reinforced plastic sheeting was secured over the cover blocks to prevent rainwater incursion into the HLV.

A work structure (containment) was erected over the HLV so the vault could be accessed while maintaining a radiologically controlled environment over the work area. The containment was installed so that both the key cover block and the inlet HEPA filter were enclosed. Positioning the containment in this manner was instrumental in maintaining proper air flow when removing and replacing the vault cover blocks. The vaults were exhausted via the RPL Radioactive Exhaust Ventilation System, and the existing system design and configuration was adequate to exhaust the containment and the vault being accessed.

A portable gantry hoist erected inside the containment was used to remove the HLV key access cover block. A remotely operated vehicle (ROV), hand-held reach tools, and associated sampling equipment were inserted into each HLV via an open access cover block. The ROV was equipped with a robotic arm that was used to transport and maneuver radiological survey and characterization sampling equipment through the interior of the HLV. Hand-held extension tools manipulated through the HLV access openings were also used to obtain radiological dose rates and characterization samples.

Characterization samples consisted of several removable contamination smears from the surfaces of the HLV walls and tanks, liquid obtained from the HLV sump trenches, and samples of debris (soil) from the HLV floor. Samples were submitted to the analytical laboratory and analyzed for total alpha (TA), total beta (TB), alpha energy analysis (AEA), gamma energy analysis (GEA), and beryllium by inductively coupled plasma (ICP) spectrophotometry. The analytical results indicated that the radiological characteristics were consistent within each HLV, and no beryllium was detected in the characterization samples.

The dose data obtained during characterization activities indicate the maximum dose rates on the tanks are approximately 160 mRem/hr in B-Vault, approximately 300 mRem/hr in C-Vault, and up to approximately 1800 mRem/hr in A-Vault. Based on the historical processes that were performed in these tanks, dose rates of several Rem/hr were expected in B- and C-Vaults and tens of Rem/hr were expected in A-Vault. The much lower than expected dose rates indicate that tank rinses conducted in the late 1970s at the conclusion of the Nuclear Waste Vitrification Program were extremely effective in minimizing process hold-up within the tanks. Consequently, future decontamination and decommissioning of these

vaults and vessels may be less challenging than previously believed. The results of this characterization effort will be used as a basis for planning and implementing the second phase of work, which is to perform a similar characterization of the contents of each tank.

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Abbreviations/Acronyms

AEA	alpha energy analysis
GEA	gamma energy analysis
HEPA	high efficiency particulate air
HLRF	High Level Radiochemical Facility
HLV	High Level Vault
ICP	inductively coupled plasma
LMFBR	Liquid Metal Fast Breeder Reactor
MDA	minimum detectable amount
NWVP	Nuclear Waste Vitrification Project
PT	Process Tanks
PUREX	Plutonium-Uranium Extraction
RPL	Radiochemical Process Laboratory
ROV	remotely operated vehicle
SFO	Shielded Facility Operations
TA	total alpha
TB	total beta
WESF	Waste Encapsulation and Storage Facility

1.0 Introduction

In July and August 2007, RPL Transition Project staff safely performed field work to remotely characterize the A, B, and C HLVs in the RPL. This report documents the methods and equipment used to collect radiological and chemical characterization samples and summarizes the analytical results.

The HLV characterization effort was conducted to support closure of the facility. The primary purpose for accessing the HLV was to establish the radiological conditions (e.g., dose rates, removable contamination levels, the types and distribution of radioisotopes, etc.) within each HLV. Remote extension tools, closed-circuit television systems, and an ROV equipped with a manipulator arm (i.e., robot) were used to perform dose rate measurements in several areas of the vaults and on the empty tanks contained within each vault. In addition, removable radiological contamination swipes of the interior surfaces of each vault and exterior surfaces of the tanks and characterization samples for chemical constituents of interest, such as beryllium, were obtained and analyzed. The results were to be used as a basis for planning and implementing the second phase of work for performing a similar characterization campaign for the interior of each tank.

The characterization efforts were conducted in accordance with the High Level Vault Characterization Plan, procedure number SFO-229, *Process Tank Vault Characterization via Access Block Removal*, a sampling instruction specific to each HLV, and a job specific Radiological Work Permit. The characterization efforts were primarily conducted by the Shielded Facility Operations Team and Engineering Mechanics Group with support from the Electronics and Measurement Systems Group, RPL Radiological Control Organization, and RPL Facilities Operations.

2.0 Background

The HLV is a complex of three separate vaults and seven tanks designed to contain radioactively contaminated process and waste solutions generated by the 324 and 325 Buildings in the Hanford Site 300 Area. An overhead view is provided below in Figure 2.1. A description of the vaults and tanks are summarized in Table 2.1.

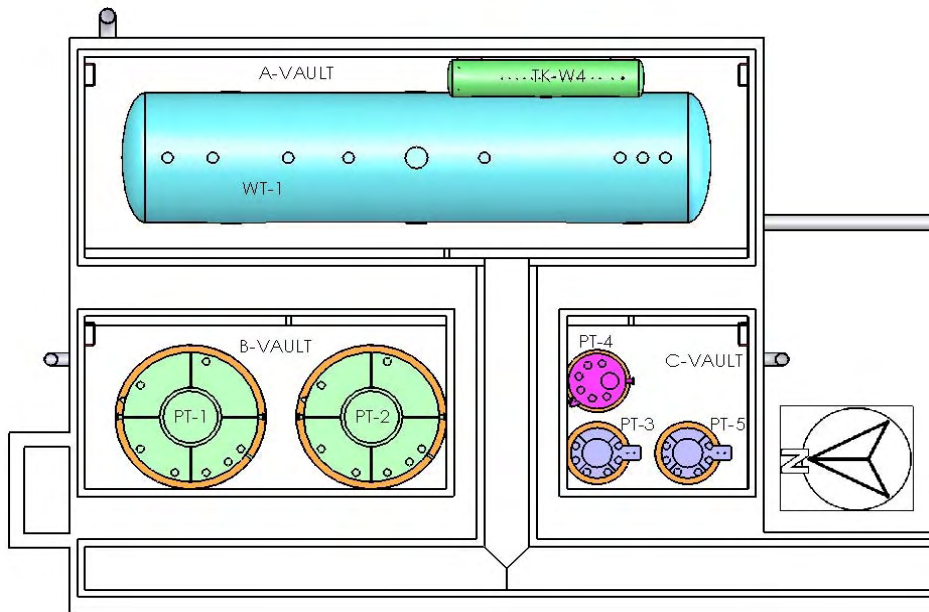


Figure 2.1. Overhead View of HLV

Table 2.1. HLV and Tank Summary

Vault	Tank	Capacity (gal)	Dimensions	Orientation	Description	Function
A	W-4	4,000	3' x 2.6' OD	Horizontal	Stainless steel	Transfer solutions between 324 and 325 Buildings
	WT-1	17,500	39.2' x 9' OD	Horizontal	Carbon steel, partial stainless steel liner	Central collection point for 325 Building radioactive liquid waste, discharge to 340 Building
B	PT-1	3,900	8.7' x 9' OD	Vertical	Carbon steel, partial stainless steel liner	Interim storage of radioactive waste liquids
	PT-2	3,900	8.7' x 9' OD	Vertical	Carbon steel, partial stainless steel liner	Interim storage of radioactive waste liquids
C	PT-3	270	4' x 3.5' OD	Vertical	Carbon steel, partial stainless steel liner	Interim storage of radioactive waste liquids
	PT-4	404	6' x 3.5' OD	Vertical	Carbon steel, partial stainless steel liner	Interim storage of radioactive waste liquids
	PT-5	270	4' x 3.5' OD	Vertical	Carbon steel, partial stainless steel liner	Interim storage of radioactive waste liquids

Source: PNNL 1996

2.1 Physical Description

The HLV consists of three below-grade concrete vaults. Each vault has a stainless steel floor tray that extends one foot or more up the wall. Each floor tray has a trench along one side, and a sump positioned in the middle of the trench. The floor and trench are sloped slightly to direct any water infiltrating the vaults to the sumps. Each sump is equipped with a level monitoring gauge and a system for removing liquid. The top of the HLV is covered by concrete blocks approximately two feet thick. The concrete blocks are protected by a weather barrier constructed of insulated roofing material.

The tanks in the HLV vary in size and differ significantly in construction details. Additional physical details are available from Hanford drawings H-3-9321, H-3-43197, H-3-43311, and H-3-43312.

All of the HLV tanks were equipped with liquid monitoring devices and a variety of lines for adding material to or removing material from the tanks. The primary method for adding or removing materials was by steam jets. Steam jets also were the principal method for moving liquids to and from the 324 Building. The steam supply used to operate these jets was terminated in the early 1990s. The PT tanks contain agitators that were functional in 1978, but may no longer work.

2.2 History

The 325 building, also known as the RPL, was constructed in the Hanford Site 300 Area during the early 1950s to provide for research and development activities necessary to support exiting processes and explore process improvements. To augment the expanding missions of the 325 Building, an annex designated 325-A was constructed in the latter part of the 1950s. The 325-A annex, now known as the High Level Radiochemical Facility (HLRF), is composed of three interconnected, heavily shielded hot cells; an operating gallery; a high-bay, cask-handling area; a truck lock; and supporting laboratory, office, and decontamination areas.

In 1961, the HLRF footprint was expanded by the addition of the HLV, which was constructed immediately adjacent to and below grade on the east side of the HLRF. The HLRF and HLV were originally built for fission product recovery demonstrations, with a pre-construction emphasis on cerium recovery.

The early missions in HLRF were segregated by hot cell. In A-Cell, campaigns were conducted for the extraction and purification of Sr-90, Pm-147, Cm-244, and Am-241 from high-level waste solutions. Feed materials for these efforts were 1WW (i.e., the first cycle) waste from PUREX and waste derived from fuel from the Shippingport Atomic Power Station in Pennsylvania. A number of these missions are discussed in reports published by Pacific Northwest National Laboratory (PNNL) (Van Tuyl 1983 PNNL 1996).

The primary mission for B-Cell was development of the process flow sheet used by B Plant to extract high-heat isotopes from Hanford tank waste, and the encapsulation chemistry used by Waste Encapsulation and Storage Facility (WESF) to generate the CsCl and SrF₂ capsules.

Missions for C-Cell included molten salt electro-deposition of UO₂ and PuO₂, recovery of Pu-238 from irradiated Np/Al targets, and solvent degradation tests from Liquid Metal Fast Breeder Reactor (LMFBR) fuel processing,

The HLV supported these HLRF missions to varying extents. In many cases, the tanks in the HLV were used as part of the flow sheets for these recovery processes. In all cases, tank WT-1 was used to collect and dispose of radioactive liquid wastes generated by these efforts.

By 1977, the last of the radioisotope recovery programs was discontinued to free up the HLRF for Nuclear Waste Vitrification Project (NWVP). As part of the construction efforts preceding NWVP, two pipelines were constructed to connect the 324 and 325 Buildings. One of these pipelines connected HLV tank W4 with Tank 106 the 324 Building.

Commercial reactor fuel was cut up and dissolved in the 324 Building, and the dissolver solutions were sent to the 325 Building for extraction of plutonium and uranium. The resulting waste solution from the solvent extraction process was returned to the 324 Building, via HLV tank W-4, for use as a feed to an in-can melter. A total of three metric tons of reactor fuel was processed during the NWVP. The project was eventually placed in a standby mode by the U.S. Department of Energy in 1980. The NWVP is discussed in reports published by PNNL (Wheelwright et al. 1979, 1996).

Based on the facility history described above, it was expected that the HLV tanks would contain liquid waste or liquid waste residuals with substantial activation and mixed fission product content. Minor transuranic content also was expected in all the tanks. HLV tank WT-1, which is much larger than the other tanks and saw far more frequent use, was expected to contain substantially more radioactive material than the other tanks.

3.0 Equipment and Materials

The primary purpose for accessing the HLV was to establish the radiological conditions (e.g., dose rates, removable contamination levels, and the types and distribution of radioisotopes located on the surfaces of the HLV and tanks). To accomplish these objectives, an ROV and extended reach tools was used to transport and maneuver sampling and monitoring equipment within each HLV. A summary description of the types of equipment used during the HLV characterization process is presented in Sections 3.1 to 0. Detailed equipment descriptions are provided in Appendix C.

3.1 Remotely Operated Vehicle

The Allen-Vanguard Mark II remotely operated vehicle (ROV) shown in Figure 3.1 was selected for use in the HLV characterization effort.



Figure 3.1. ROV and Associated Sampling Equipment

The tracked crawler unit is approximately 36-inches long, 17-inches wide and 22-inches high with the manipulator fully stowed. It has a 38-inch reach, 3 cameras, and 3 lights. Command signals are transmitted to the vehicle and video signals returned to the control station via a copper-wire tether. It is powered by a field-replaceable, on-board battery which that allows for mission times of several hours. Field life of the battery depends on the level of vehicle activity. As most characterization activities occurred over several days, a low current battery charge maintainer was used to recharge the on-board battery overnight when the vehicle was not in use.

3.2 ROV Control Station

The ROV control station shown in Figure 3.2 was provided by the manufacturer and included a laptop computer which that displayed vehicle status and controls and the current video image from the vehicle.



Figure 3.2. ROV Control Station

3.3 Sampling Equipment

Removable contamination smears were obtained within the vault using metal billet-type samplers (Figure 3.3). A rapid prototyped ABS plastic sample tray suspended from a U-bolt was used to transport the sample billets (Figure 3.4).



Figure 3.3. Billet Sampler



Figure 3.4. Sample Tray

A sampling end-effector consisting of an electro-magnet gripper and a hook was carried in the ROV manipulator arm gripper (Figure 3.5). The electromagnet was powered by a built-in tool power circuit on the ROV.



Figure 3.5. End Effector

3.4 Extended Reach Tools

The ROV robotic arm had a limited reach of approximately 3 feet above the floor of each HLV. Therefore, a set of long-reach tools was developed to acquire samples within each vault at higher elevations. These tools allowed the ROV robotic arm to sample the underside of the cover blocks, the tops of some of the tanks, and the vault walls near the access point.

A sample head for the poles is shown in Figure 3.6. This sample head served as both a dosimeter holder and a smear sample media mounting location.



Figure 3.6. Sampling Tool

3.5 Radiological Dose Rate Measurements

The DMC 2000 series electronic dosimeter equipped with the CTM 2000 transmitter for remote data logging was used to obtain beta/gamma radiation dose information within the HLV (Figure 3.7). The radiation dose measurements were transmitted via radio signals to the control station and recorded.

3.6 Overview Camera Platform

An overview video camera, lighting system, and dosimeter communications antenna were mounted to a support platform that was suspended through the vault access opening.

The platform-mounted lighting system provided improved overall lighting within the HLV, resulting in improved image quality. The accompanying video camera provided an overview of ROV operations, which is an important aid to the operator of the ROV. The camera system was a Sony SNC-RZ30N network camera (Figure 3.8) that



Figure 3.7. DMC 2000 Series Electronic Dosimeter

was enclosed in a Sony-provided sealed dome enclosure. This is a pan/tilt/zoom camera with a web interface for control of the camera.

3.7 Control Station

Controls for the various systems were located in a trailer approximately 150 feet from the vault access points. These controls included those for the ROV, the pan/tilt lighting system, the pan/tilt/zoom camera system and the dosimeter data collection. A video display for the overview camera was also provided at the control station, and video signals from both the overview camera and the ROV were recorded on VHS tape. It was possible to capture the displayed image and save it to the laptop hard drive, and images were captured during deployments. The pan/tilt lighting system was controlled and powered by a small hand-held joystick unit located at the control station.



Figure 3.8. Sony Camera

A second computer at the control station location provided control of the pan/tilt/zoom overview camera system. Digital image display and capture for this camera was provided by this interface, as were other camera control parameters (focus, aperture, etc.). The images captured using these systems were also retained on the computer hard drive.

This second computer was also connected to the dosimeter base station; this allowed it to record the dosimeter data as it was reported.

A flat panel display at the control station displayed the analog image from the overview camera; this signal was also recorded using a VHS VCR. A second VHS VCR was connected to an analog output on the ROV control station to record the video signal from the ROV.

3.8 Work Structure

A portable work structure (containment) was used during the characterization activities (Figure 3.9). The primary purpose of the containment was to provide radiological contamination control and protection to staff, and sampling equipment and instrumentation from inclement weather. Wind and snow loading were considered in the design. Ventilation for the greenhouse was provided by the HLV open cover block.



Figure 3.9. Containment Installed over HLV

The vaults were exhausted via the RPL Radioactive Exhaust Ventilation System, and the existing system design and configuration was adequate to exhaust the containment and the vault being accessed.

4.0 Approach

Initial radiological and chemical conditions and video documentation of the interior of the HLV were obtained by disassembling the HLV HEPA filter housings and inserting remote monitoring equipment through the openings. The radiological dose rates obtained near the filter housing inlets ranged from less than the MDA to 150 mRem/hr. The results indicated that the HLV access cover block could be safely removed.

The weather barrier covering the HLV cover blocks was removed and discarded. To extend the working surface, a 2-foot strip of concrete was installed around the perimeter of the HLV. Reinforced plastic sheeting was secured over the cover blocks to prevent rainwater incursion into the HLV. Shortly after removing the weather barrier, heavy rains resulted in the accumulation of approximately 2 gallons of water in each HLV. The water has since evaporated.



Figure 4.1. Vault Access Cover Block Removal



Figure 4.2. Sampling Equipment Installed in Vault

remote dose reading using extended reach instrumentation over the opening. Then thorough characterization sampling and video documentation of each HLV was performed. The ROV, hand-held reach tools, and associated sampling equipment were inserted into the HLV via an open access cover block (Figures 4.1, 4.2, and 4.3). The ROV was equipped with a robotic arm that was used to transport and maneuver radiological survey and characterization sampling equipment around the interior of the HLV. Hand-held extension tools manipulated through the HLV access openings were also used to obtain radiological dose rates and characterization samples.

A work structure (containment) was erected over the HLV so the vault could be accessed while maintaining a radiologically controlled environment over the work area. The containment was installed so that both the key cover block and the inlet HEPA filter were enclosed. Positioning the containment in this manner was instrumental in maintaining proper air flow when removing and replacing the vault cover blocks.

A portable gantry hoist was erected inside the containment and used to remove the HLV key access cover block. Radiological conditions of the vault were obtained via air sampling and



Figure 4.3. ROV Being Lowered into the Vault

future use, and the containment was discarded. A new weather-proof barrier was installed over the HLV cover blocks.

Log keeping and video documentation were maintained throughout the characterization activities. After characterization samples were obtained, the key cover block was replaced and the containment relocated to the next HLV. The same containment was used for all three vaults because there was no loss of contamination during the characterization activities. C-Vault was characterized first, followed by B-Vault, and then A-Vault.

Upon completion of the characterization activities, the ROV was packaged and stored for

5.0 Sampling Processes and Results

Sampling instructions were developed for each HLV. These instructions provided directions for obtaining radiological and chemical characterization samples from the interior of each HLV and the exteriors of the tanks housed in each HLV. The sampling instructions included sampling location maps and tables for recording sample data. The maps were used as a guide to identify the general areas where the characterization samples could be obtained.

Prior to installing the sampling equipment, the HLV sampling maps were reviewed, and sampling methods and ROV access limitations discussed. The orange-colored portions of Figures 5.1, 5.2 and 5.3 identify the areas accessible to the ROV.

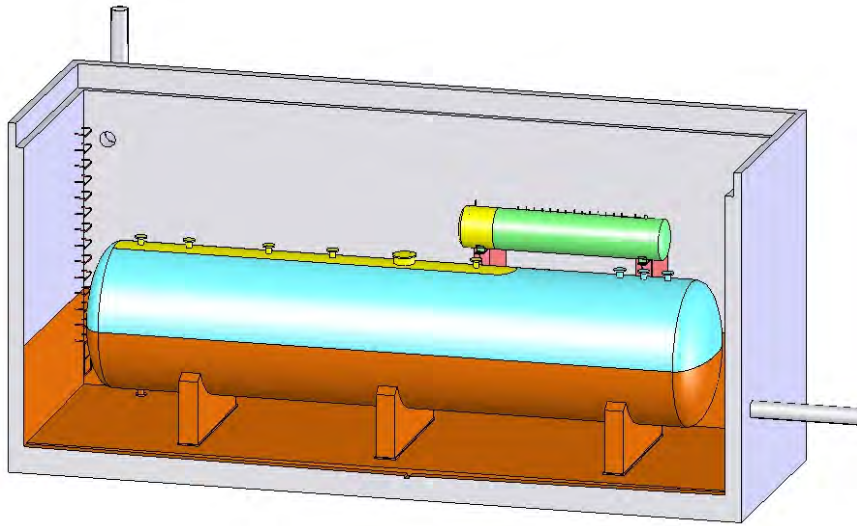


Figure 5.1. Schematic of A-Vault

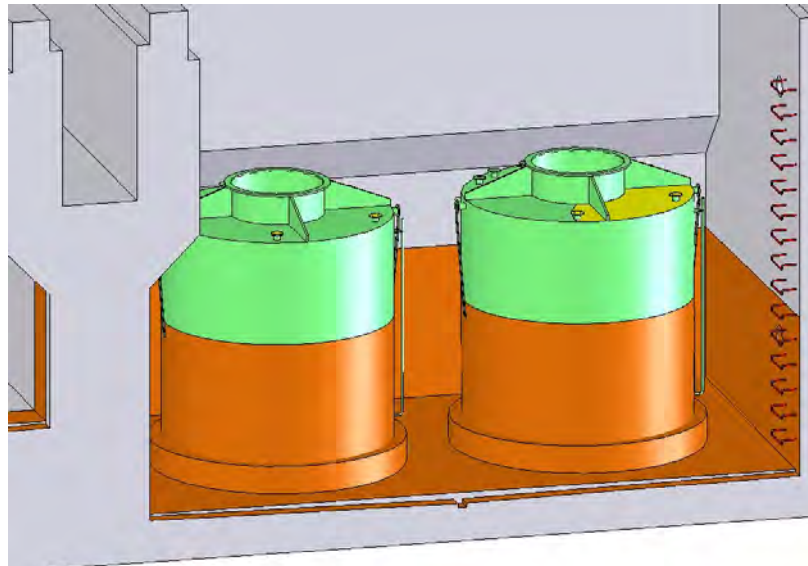


Figure 5.2. Schematic of B-Vault

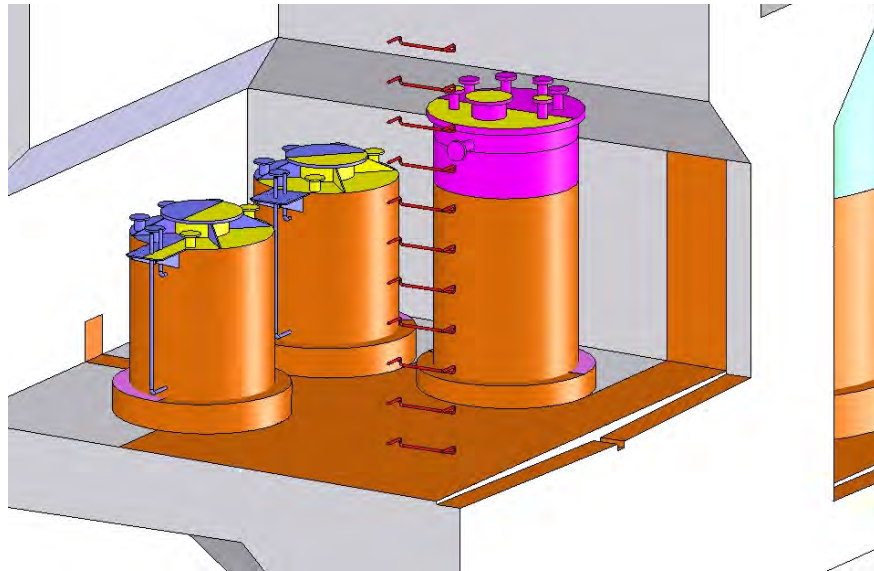


Figure 5.3. Schematic of C-Vault

The sample data tables were used in conjunction with the sample location maps to record the actual sample location and height, identification number, dose rate, time of sampling, and type of sample obtained. Samples were collected using both the ROV and hand-held reach tools. The ROV was used to obtain dose rates, removable contamination smears, liquid samples, and samples of solid particulate (debris). Hand-held reach tools were used for dose rate measurements and obtaining removable contamination smear samples. Only the areas easily accessible through the cover block were sampled using hand-held reach tools.

5.1 Radiological Dose Sampling

Radiological dose rates were obtained in several areas of the vaults and on the empty tanks contained within each vault. Dose rates were taken via a dosimeter which was mounted to the back of the ROV body approximately 15 inches above the floor. The dose rate measurements were transmitted by radio signal to the antenna located on the overview platform, then to the data logging base station at the control station, and finally to a computer for data recording. When the ROV was stopped to obtain smear, liquid, or debris samples, the dose rate and approximate ROV location were manually recorded in the data log. Table 5.1 contains a range of the radiological dose rate measurements obtained in each vault.

Table 5.1. Radiological Dose Rate Measurements

	A-Vault	B-Vault	C-Vault
Approximate Dose Rate* (mRem/hr)	150 to 1800	6 to 160	39 to 300

General area dose rates within each vault are shown in the following drawings. Appendix A contains detailed dose rate and sampling information. The alpha-numeric references in the Figures 5.4, 5.5, and 5-6 correspond to smear sample locations that may be reviewed in Appendix A.

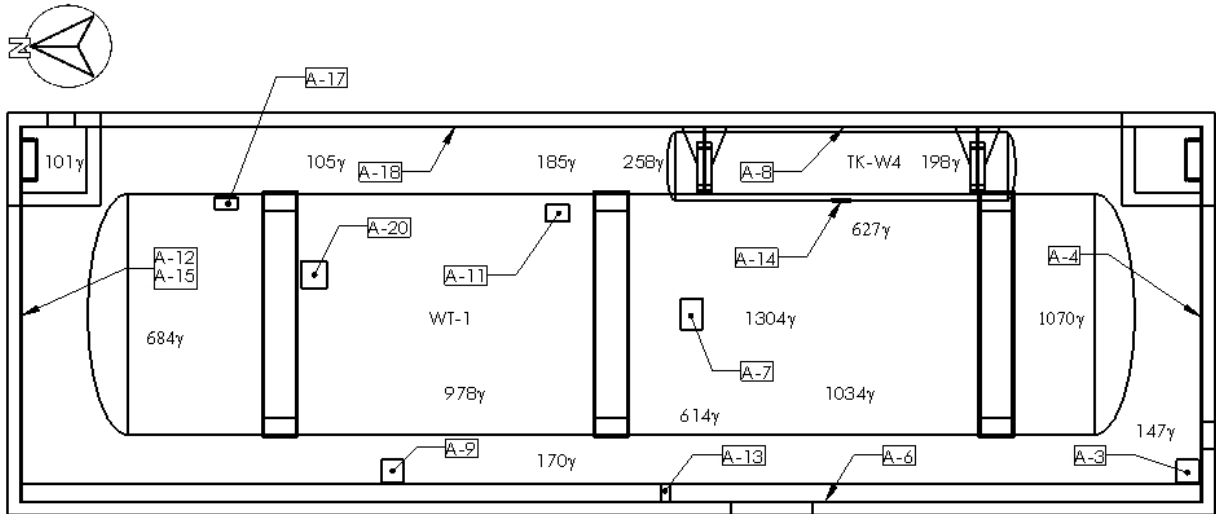


Figure 5.4. Drawing of A-Vault

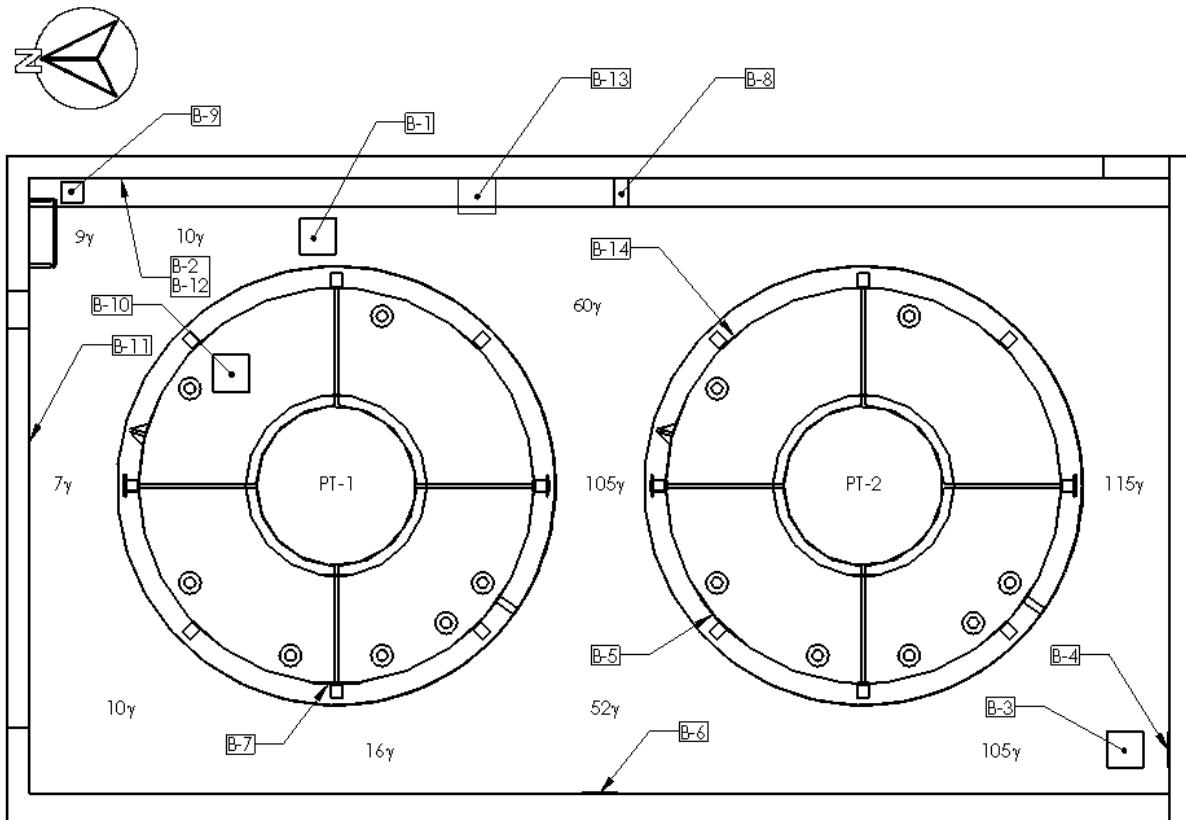


Figure 5.5. Drawing of B-Vault

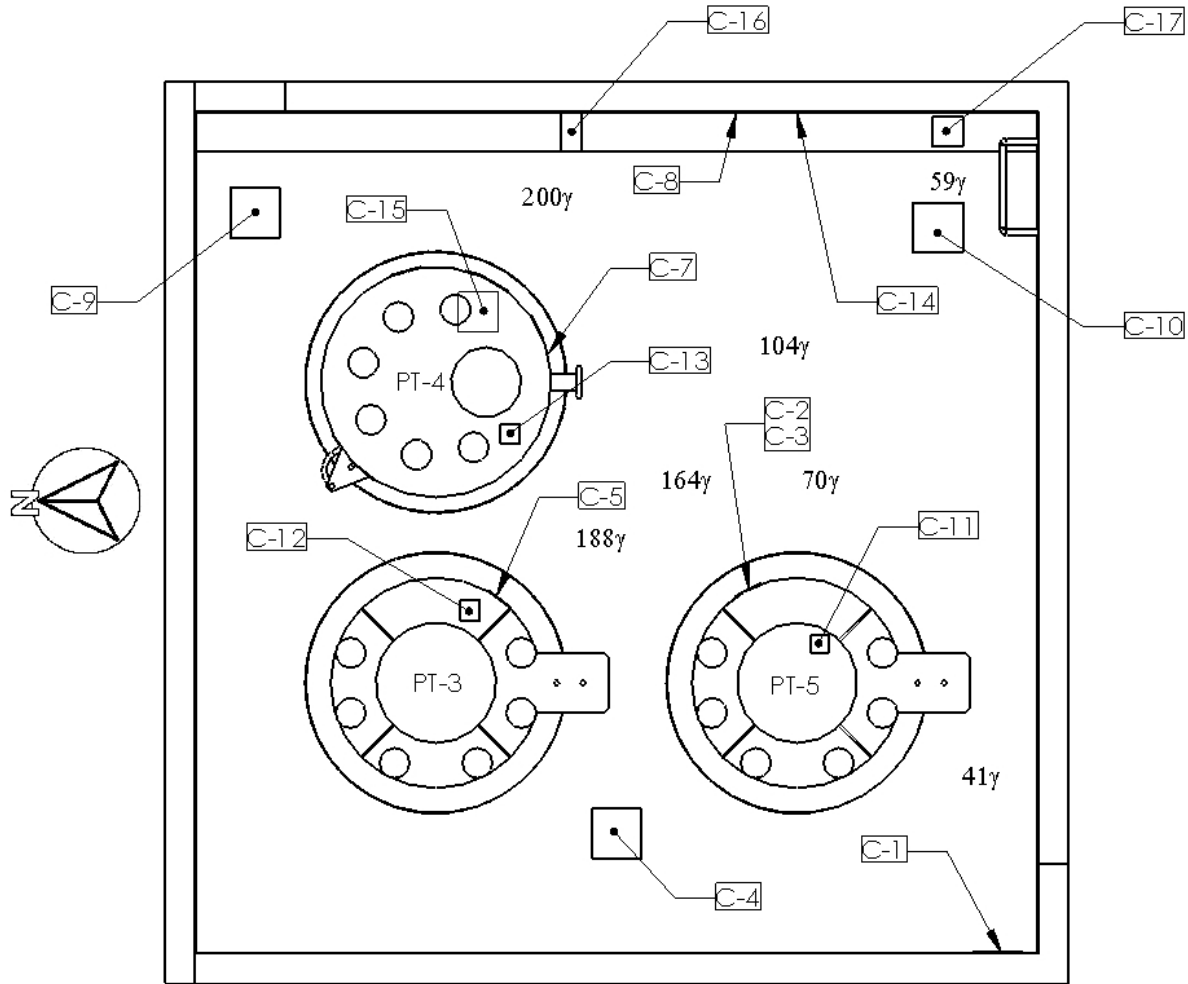


Figure 5.6. Drawing of C-Vault

5.2 Smear Sampling

A sample tray containing eight metal samplers was lowered into the HLV via the open cover block and placed on the floor of the HLV. The sample tray was picked up by the ROV using the hook on the end-effector and transported to sampling locations within the HLV. Once at the sample location, the operator would place the sample tray on the floor, position the electromagnet over the selected metal sampler, activate the electromagnet using the remote tool circuit on the ROV control station, and remove the metal sampler from the sample tray. The metal sampler, with smear media attached, was moved to the sampling, placed against the target surface, moved back and forth in an area measuring approximately 100 cm², and then returned to the sample tray. This process was repeated for all eight metal samplers.

Smear samples were also obtained utilizing an extended reach tool lowered into the HLV and manipulated through the open cover block. The end of the extended reach tool was equipped with a small plastic sampler designed with multiple protrusions which were used as attachment points for smear media. The plastic sampler was lowered into the HLV, placed against the target surface, and then moved back and forth.

In most cases, the operator could determine, via video camera, a clean area on the target surface after the samples were taken. The sampling information was recorded on the sampling data table, location map, and field logs at the time of sampling. Once the samples were collected, they were retrieved from the HLV through the open cover block (Figures 5.7 and 5.8) and transported to a radiological fumehood within the facility.



Figure 5.7. Sample Tray Retrieval from HLV



Figure 5.8. Extended Reach Sampling Tool Retrieval from HLV

Prior to submittal to the analytical laboratory, the smear samples were visually examined for the presence of debris and surveyed using hand held radiological instrumentation. The smears with debris present and exhibiting radiological contamination above room background levels were packaged individually and submitted to the laboratory for GEA screening. The smears with no debris and no measured radiological contamination above room background were combined into a single container, one for each HLV, and also submitted to the laboratory for GEA screening. Appendix A contains a list of sampling locations and corresponding sample identification numbers.

The GEA screening results indicated that the contamination levels were within a factor of ten between sampling locations within each HLV. Based on this information, all of the smears were combined into a single container, one for each vault, and submitted to the laboratory for TA, TB, AEA, GEA, and beryllium by ICP spectrophotometry. Surface area of smear samples should be considered when reviewing the analytical results. Table 5.2 provides the surface area of the consolidated smear surface area.

Table 5.2. Smear Consolidation Information

Analytical Sample ID#	Sample Location	Surface Area of Consolidated Smears
07-01806	A Vault	1300 cm ²
07-01807	B Vault	1100 cm ²
07-01808	C Vault	1300 cm ²

The total alpha, total beta and GEA analyses provided information for a broad range of radioisotopes. The primary radioactive contaminants on the smears are shown in Table 5.3. The results for beryllium analysis are also shown in Table 5.3. The detailed analytical results are presented in Appendix B.

Table 5.3. Primary Contaminants on Smears

Analytical Results Per 100 cm ²	A-Vault	B-Vault	C-Vault
TA	9.31E-07	4.05E-06	2.08E-05
TB	4.86E-06	7.70E-06	1.00E-05
Range of Cs137 (GEA)	6.84E-05 to 4.37E-03	9.41E-05 to 3.50E-02	3.21E-05 to 7.80E-02
Beryllium (ICP)	Non-detectable	Non-detectable	Non-detectable

5.3 Liquid Samples

Liquid samples were obtained using a 250-mL plastic bottle with a screw cap. These bottles were prepared for use by drilling a vent hole in the cap and an inlet hole in the side of the bottle about 2 cm from the bottom of the bottle. The hole in the side was marked with an indelible black pen for ready identification by the operator. To acquire a liquid sample, one of these bottles was placed in a small metal can equipped with a wire lifting bail. The bottle and metal can were lowered into the vault and placed on the floor. The ROV transported the metal can/bottle to the sampling location. With the aid of video cameras, the bottle was removed from the can, submerged in liquid, returned to the can, and then retrieved from the HLV through the open cover block. The liquid sampler is shown in Figure 5.9.



Figure 5.9. Liquid Sampler

The liquid samples were submitted directly to the laboratory and analyzed for TA, TB, AEA, and ICP analyses. The results indicated that the characteristics of the contamination in the liquid samples were consistent with the contamination on the smear samples. The total alpha, total beta and GEA analyses provided information for a broad range of radioisotopes. The primary radioactive contaminants are shown in Table 5.4. The results for beryllium analysis are also shown in Table 5.4. The detailed analytical results are presented in Appendix B.

Table 5.4. Primary Constituents

Analytical Results for Liquid Samples Per Milliliter	A-Vault	B-Vault	C-Vault
TA	Less than detectable	Less than detectable	1.07E+01
TB	2.00E-03	2.50.E-01	1.60E+0 (average)
Cs137 (GEA)	5.73E-04	3.16E-02	3.41E-01 (highest)
Beryllium (ICP)	Non-detectable	Non-detectable	Non-detectable

5.4 Debris Samples

Debris (soil) samples were obtained utilizing a small metal shop-made scoop (Figure 5.10). The scoop was designed with an opening in which to capture a small amount of floor debris. The scoop was transported to the sampling location and dragged across the HLV floor until the cavity was filled with soil. The metal scoop was transported and manipulated similarly to the liquid bottle sampler.



Figure 5.10. Debris Sampler

A soil sample was not obtained from A-Vault because there was insufficient sampling material present in the HLV. The soil samples from B and C-Vault were submitted directly to the laboratory and analyzed for TA, TB, AEA, GEA, and ICP spectrophotometry. The results indicated that the characteristics of the contamination in the soil samples were consistent with the contamination on the smear samples. The TA, TB, and GEA analyses provided information for a broad range of radioisotopes. The primary radioactive contaminants are shown in Table 5.5. The results for beryllium analysis are also shown in Table 5.5. The detailed analytical results are presented in Appendix B.

Table 5.5. Primary Contaminants in Soil

Analytical Results for Solid Samples Per Gram	A-Vault	B-Vault	C-Vault
TA	Sample not obtained	4.63E-02	2.16E-01
TB		1.06E+0	3.07E+0
Cs137 (GEA)		2.44E-01	8.87E-01
Beryllium (ICP)		Non-detectable	Non-detectable

6.0 Conclusions

The analytical results from the characterization samples indicated that the radiological characteristics were consistent within each HLW, and no beryllium was detected. The dose data obtained during characterization activities indicates the approximate maximum dose rates on the tanks are 160 mRem/hr in B-Vault, 300 mRem/hr in C-Vault, and up to 1800 mRem/hr in A-Vault. Based on the historical processes that utilized these tanks, dose rates of several Rem/hr were expected in B- and C-Vaults and tens of Rem/hr were expected in A-Vault. The much lower than expected dose rates indicate that tank rinses conducted in the late 1970s, at the conclusion of the Nuclear Waste Vitrification Program, were extremely effective in minimizing process hold-up within the tanks. Consequently, future decontamination and decommissioning of these vaults and vessels may be less challenging than previously believed. The results of this characterization effort will be used as a basis for planning and implementing the second phase of work which is to perform a similar characterization of the contents of each tank.

7.0 Acknowledgements

The following staff members are acknowledged for their key contributions to the HLV characterization effort:

Shielded Facility Operations Team

Steve Halstead – Field Work Supervisor
Victor Saucedo – Hot Cell Technician
Tim Smith – Hot Cell Technician
Johnny Trevino – Hot Cell Technician
Christopher Francy – Student Intern

Engineering Mechanics Group

Matt Prowant – Student Intern
Rob Stahl – Technician

Electronics and Measurement Systems Group

Kim Lessor – Technician
Rob Stahl – Technician

RPL Radiological Control Organization

Tomas Moreno – Radiological Control Technician
Ron Smidga – Radiological Control Technician
Conan Wade – Radiological Control Technician
John Zeilstra – Radiological Control Technician
Woody Buckner – Radiological Control Engineer

Facilities Operations

Ed Arel – Work Supervisor
Robert Cozad – Millwright
Larry Lang - Millwright
Dennis Smith – Millwright
James Sportelli – Work Supervisor
Dan Wandler – RPL Systems Engineer
Thompson Mechanical - Contractor

8.0 References

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Appendix A

Sampling information, Dose Rates and Corresponding Vault Diagrams

Appendix A

Sampling information, Dose Rates and Corresponding Vault Diagrams

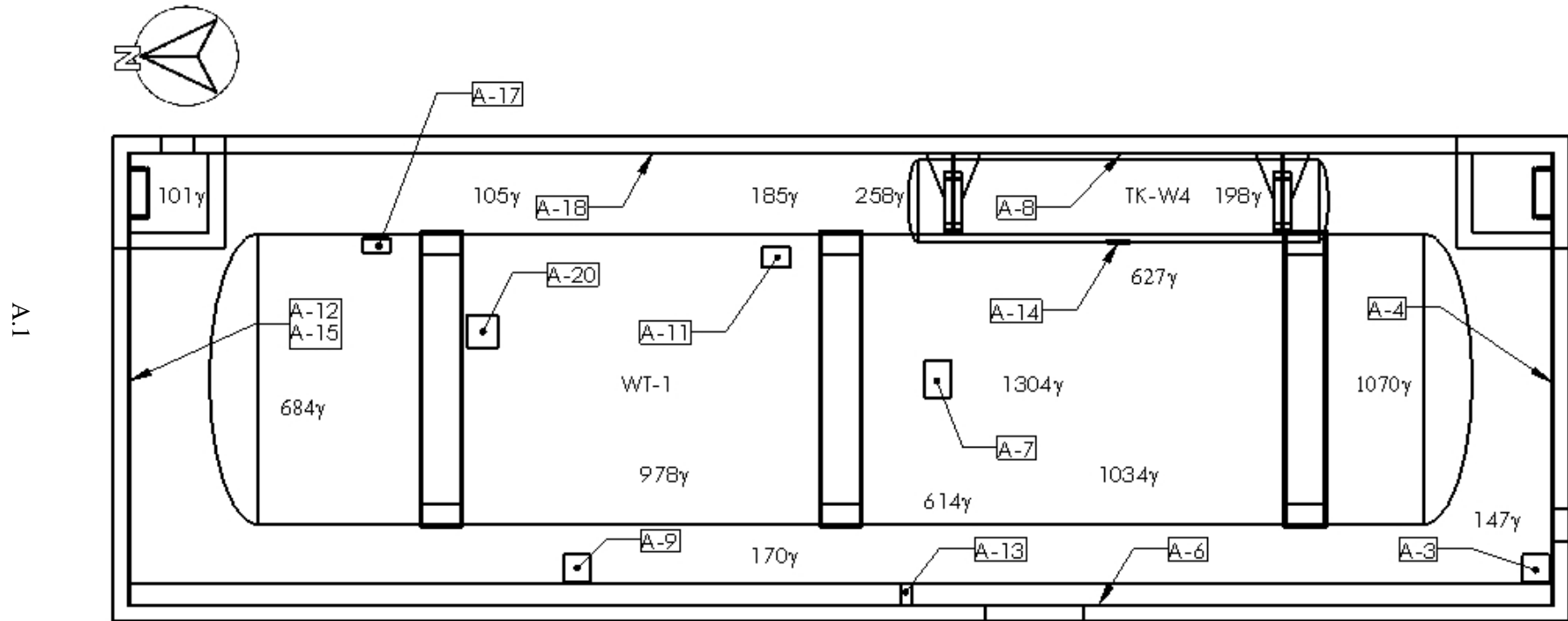


Table A.1. A-Vault Overhead Diagram and Sample Information

Field Sample ID#	Dose rate, smear, or liquid	Approximate Sample Location and Analytical Sample ID#	Approximate Height (feet)	Dose Rate* (mRem/hr)	$\beta\gamma$ dpm/smear area of ~100 cm ²	α dpm/ smear area of ~100 cm ²
A-1	Dose	Parked under north heel of WT-1	--	620	--	--
A-2	Dose	Parked under south end of TK-W4	--	188	--	--
A-3	Smear	Robot smear, floor at southwest corner of vault, near trench. Identified in analytical report as # 07-01722 smear (A-1)	0	150	20,000	700
A-4	Smear	Robot smear, south wall approx center of wall. Smear combined with other smears reading <1000 dpm and submitted to laboratory for analysis. Identified on analytical report as 07-1737.	3	380	1000 (MDA)	<MDA
A-5	Dose	Parked under south heel of WT-1	--	1070	--	--
A-6	Smear	Robot smear, west wall, south of sump midway between center and south WT-1 supports. Smear combined with other smears reading <1000 dpm and submitted to laboratory for analysis. Identified on analytical report as 07-1737.	1.5	1020	<1000 (MDA)	<MDA
A-7	Smear	Robot smear, underside of WT-1 along centerline, approx 2 feet south of center support. Identified in analytical report as 07-01723 smear (A-4)	2	1370	1000	<MDA
A-8	Smear	Robot smear, east wall below TK-W4. Identified in analytical report as 07-01724 smear (A-5).	2.5	600	3000	<MDA
A-9	Smear	Robot smear, floor west of WT-1 along trench, midway between north and center WT-1 supports. Identified in analytical report as 07-01725 smear (A-6).	0	801	20,000	1400
A-10	Dose	Parked west of WT-1, approx 4 feet north of sump	--	169	--	--
A-11	Smear	Robot smear, east side of WT-1 slightly below centerline, approx 1.5 feet north of center WT-1 support. Smear combined with other smears reading <1000 dpm and submitted to laboratory for analysis. Identified on analytical report as 07-1737.	3.5	185	<MDA (1000)	<MDA
A-12	Smear	Robot smear, north wall approx center of wall. Smear not submitted to laboratory for analysis.	2	637	<MDA (1000)	<MDA

A.2

Table A.1. (contd)

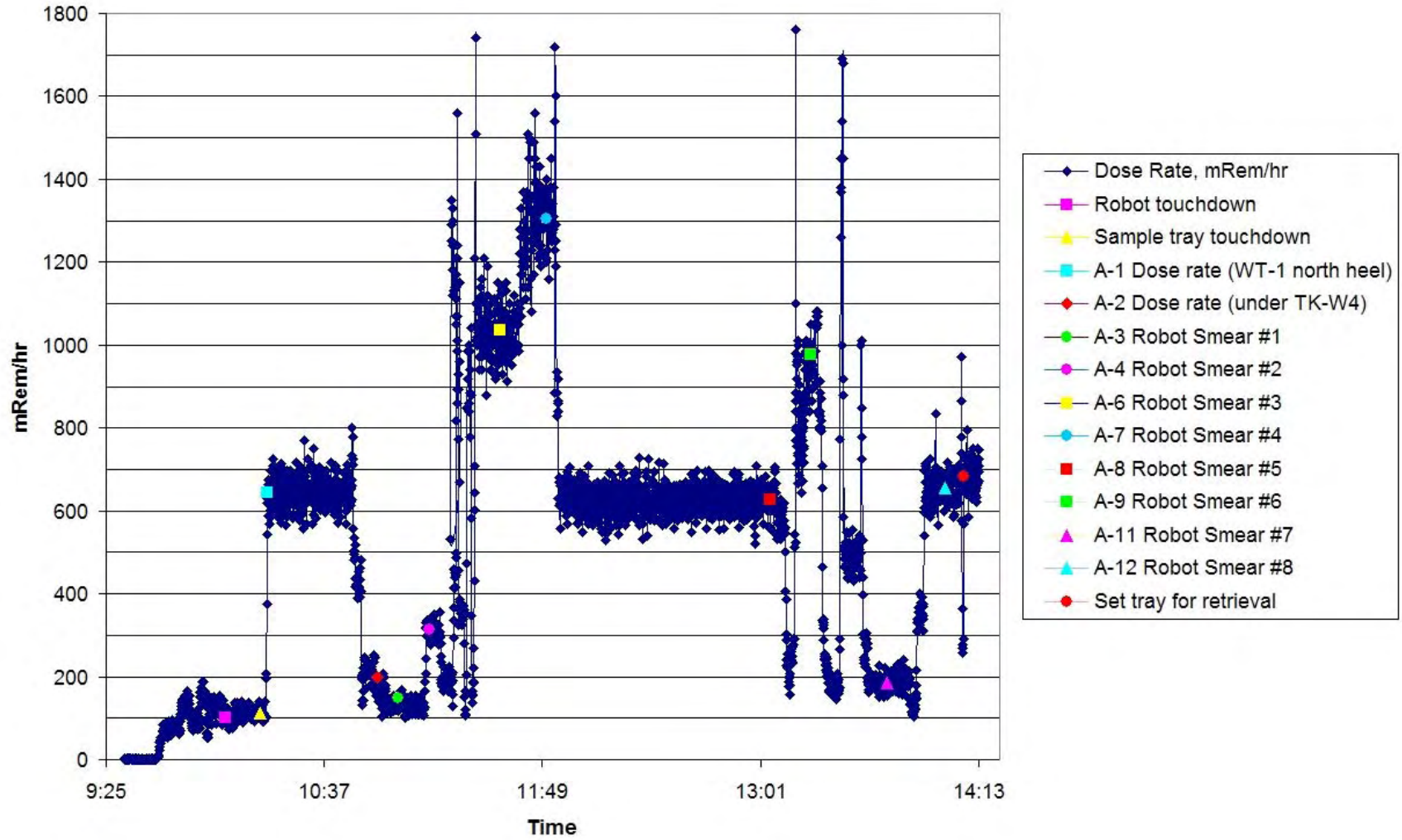
Field Sample ID#	Dose rate, smear, or liquid	Approximate Sample Location and Analytical Sample ID#	Approximate Height (feet)	Dose Rate* (mRem/hr)	$\beta\gamma$ dpm/smear area of ~100 cm ²	α dpm/ smear area of ~100 cm ²
A-13	Liquid	Robot liquid sample center of sump	--	624	--	--
A-14	Smear	Robot smear using extension pole, TK-W4 centered both length and height. Smear combined with other smears reading <1000 dpm and submitted to laboratory for analysis. Identified on analytical report as 07-1737.	12	569 [†]	<MDA (1000)	<MDA
A-15	Smear	Pole smear, north wall approx centered on wall. Smear combined with other smears reading <1000 dpm and submitted to laboratory for analysis. Identified on analytical report as 07-1737.	10	--	<MDA (1000)	<MDA
A-16	Dose	Pole dosimeter reading, north wall approx centered on wall	10	200 [†]	--	--
A-17	Smear	Pole smear, east side of WT-1, above tank centerline, approx 1.5 feet north of WT-1 north support. Identified on analytical report as 07-01726 smear (A-17).	8	310 [†]	<MDA (1000)	700
A-18	Smear	Pole smear, east wall, approx centered between north and center WT-1 supports. Smear combined with other smears reading <1000 dpm and submitted to laboratory for analysis. Identified on analytical report as 07-1737.	10	268 [†]	<MDA (1000)	<MDA
A-19	Dose	--	--	--	--	--
A-20	Smear	Pole smear, underside of cover block, approx 1 foot east of tank centerline, approx 1 foot south of WT-1 north support. Smear combined with other smears reading <1000 dpm and submitted to laboratory for analysis. Identified on analytical report as 07-1737.	17	270 [†]	<MDA (1000)	<MDA

*Unless otherwise noted, all dose rates were recorded on the vehicle, approximately 12 inches above the vault floor, not at the height of the smear.

[†]Dose rate measured at smear location (i.e. on the end of the pole)

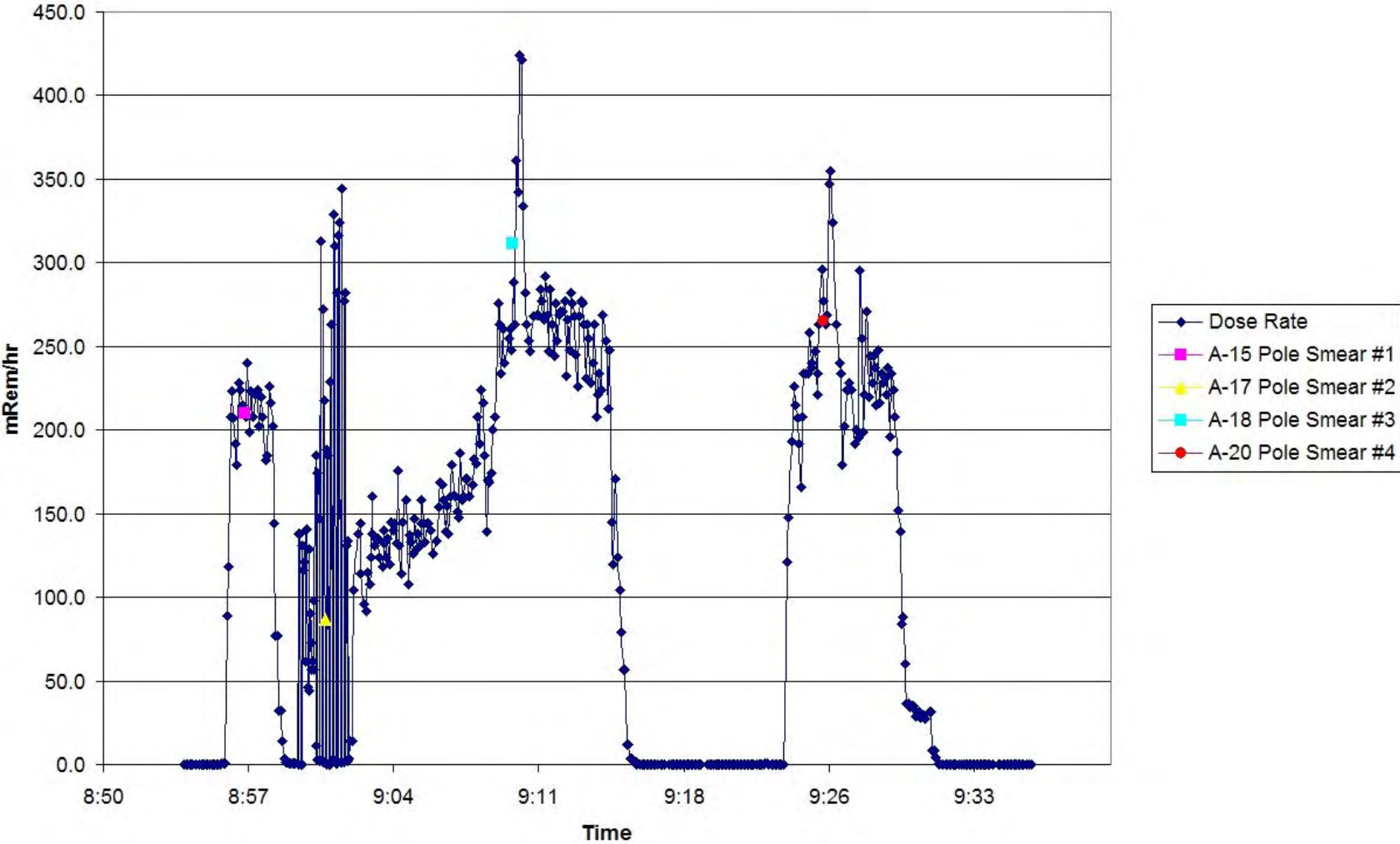
A-Vault 20070815 Vanguard Dose Rate

A.4



A-Vault 20070817 Pole Dose Rates

A.5



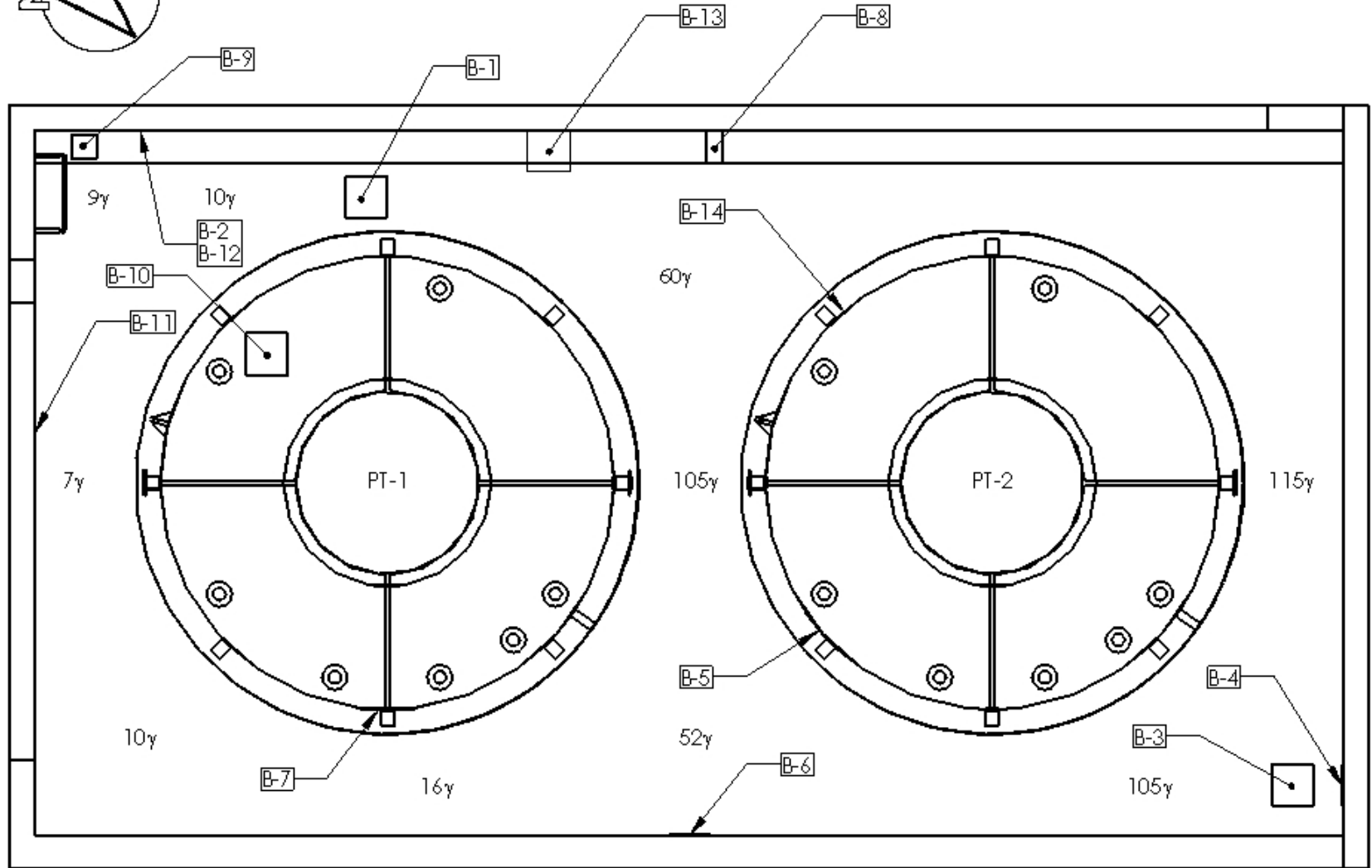
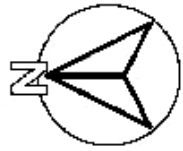


Table A.2. B-Vault Overhead Diagram and Sample Information

Field Sample ID#	Dose rate, smear, or liquid	Approximate Sample Location and Analytical Sample ID#	Approximate Height (feet)	Dose Rate* (mRem/hr)	$\beta\gamma$ dpm/smear of ~100 cm ²	α dpm/smear of ~100 cm ²
B-1	Smear	Robot smear, floor on east side of PT-1. Identified on analytical report as 07-01727 smear (B-1).	0	8	200,000	2100
B-2	Smear	Robot smear, east wall approx 3 feet south of north wall. Identified on analytical report as 07-01728 smear (B-2).	2.5	10	7000	<MDA
B-3	Smear	Robot smear, floor at southwest corner of vault. Identified on analytical report as 07-01729 smear (B-3)	0	101	200,000	280
B-4	Smear	Robot smear, south wall, 1 ft east of west wall. Identified on analytical report as 07-01730 smear (B-4)	1.5	94	1000	<MDA
B-5	Smear	Robot smear, northwest side of tank PT-2. Identified on analytical report as 07-01731 smear (B-5).	1.5	54	1000	<MDA
B-6	Smear	Robot smear, west wall, half way between tanks Identified on analytical report as 07-01732 smear (B-7).	2	61	10,000	<MDA
B-7	Smear	Robot smear, west side of PT-1. Smear not submitted to the laboratory for analysis.	2.5	14	<MDA (1000)	<MDA
B-8	Liquid	Robot liquid sample center of sump	--	61	--	--
B-9	Debris	Robot debris sample, east trench, 2 feet south of north wall	0	6	--	--
B-10	Smear	Pole smear, top of PT-1, northeast quadrant. Identified on the analytical report as 07-1733 smear (B-10)	10	8 [†]	8000	<MDA
B-11	Smear	Pole smear, north wall, approx center of wall. Identified on the analytical report as 07-1734 smear (B-11).	9	7 [†]	5000	<MDA
B-12	Smear	Pole smear, east wall, approx 3 feet south of north wall Identified on the analytical report as 07-1735 smear (B-12).	13	12 [†]	8000	<MDA
B-13	Smear	Pole smear, underside of cover block along east wall, approx 10 feet south of north wall Identified on the analytical report as 07-1736 smear (B-13).	16	22 [†]	5000	<MDA
B-14	Smear	Pole smear, northeast side of PT-2. Smear not retrieved, lost in vault.	9	94 [†]	--	--

*Unless otherwise noted, all dose rates were recorded on the vehicle, approximately 12 inches above the vault floor, not at the height of the smear.

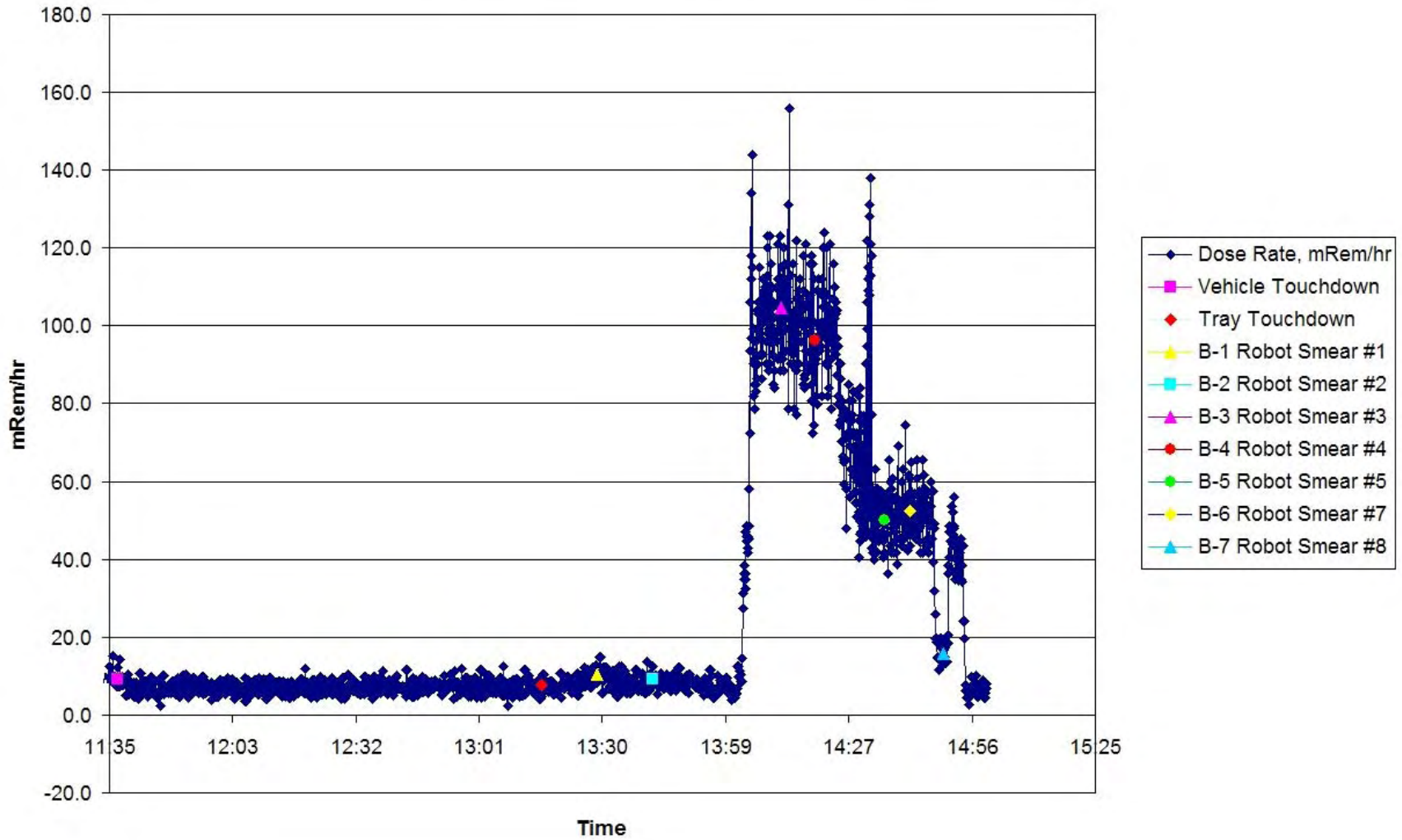
†Dose rate measured at smear location (i.e. on the end of the pole)

NOTE: All dose rates on maps are average dose rates.

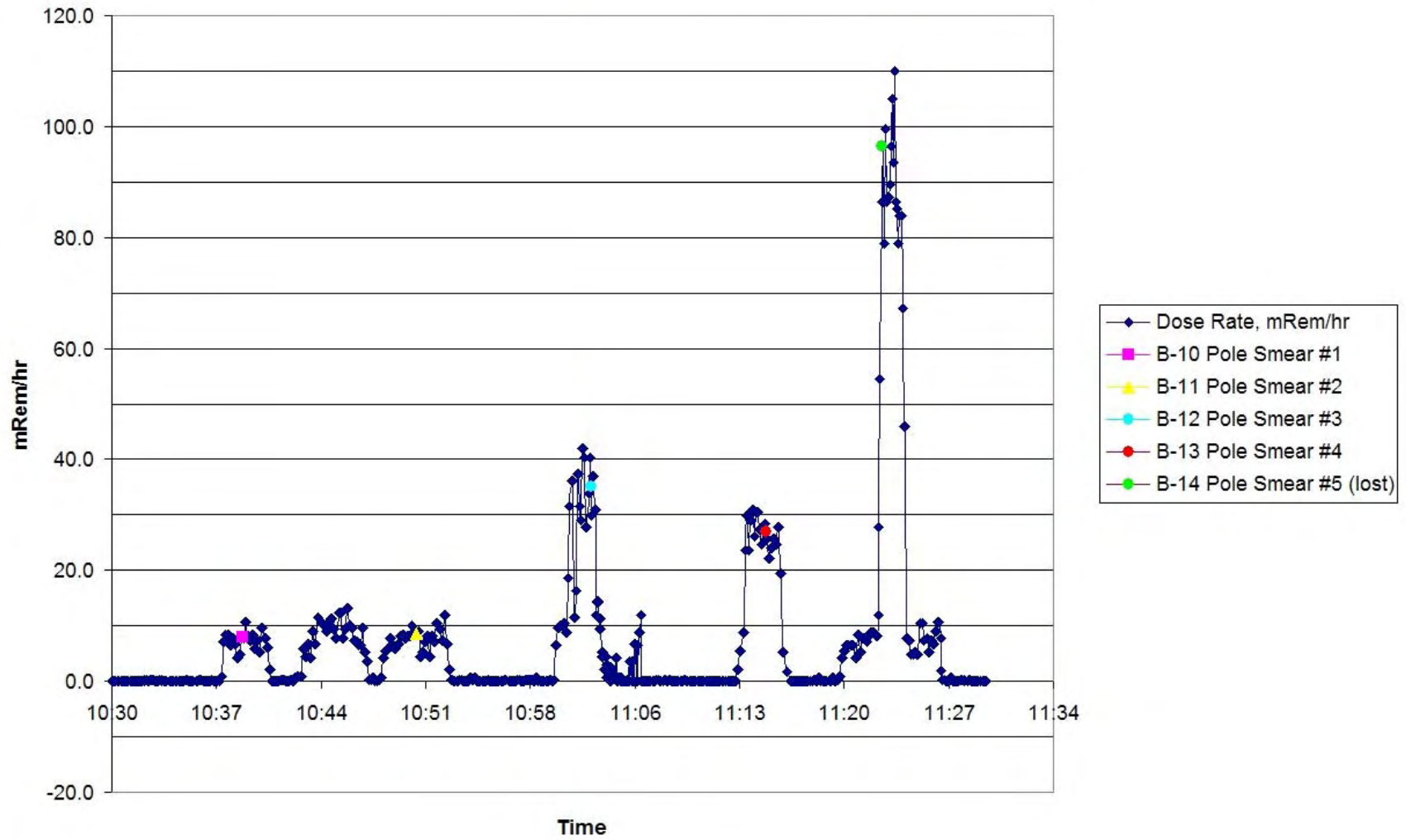
Cover block hidden for drawing clarity.

B-Vault 20070806 Vanguard Dose Rate

A.8



B-Vault 20070807 Pole Dose Rate



A.9

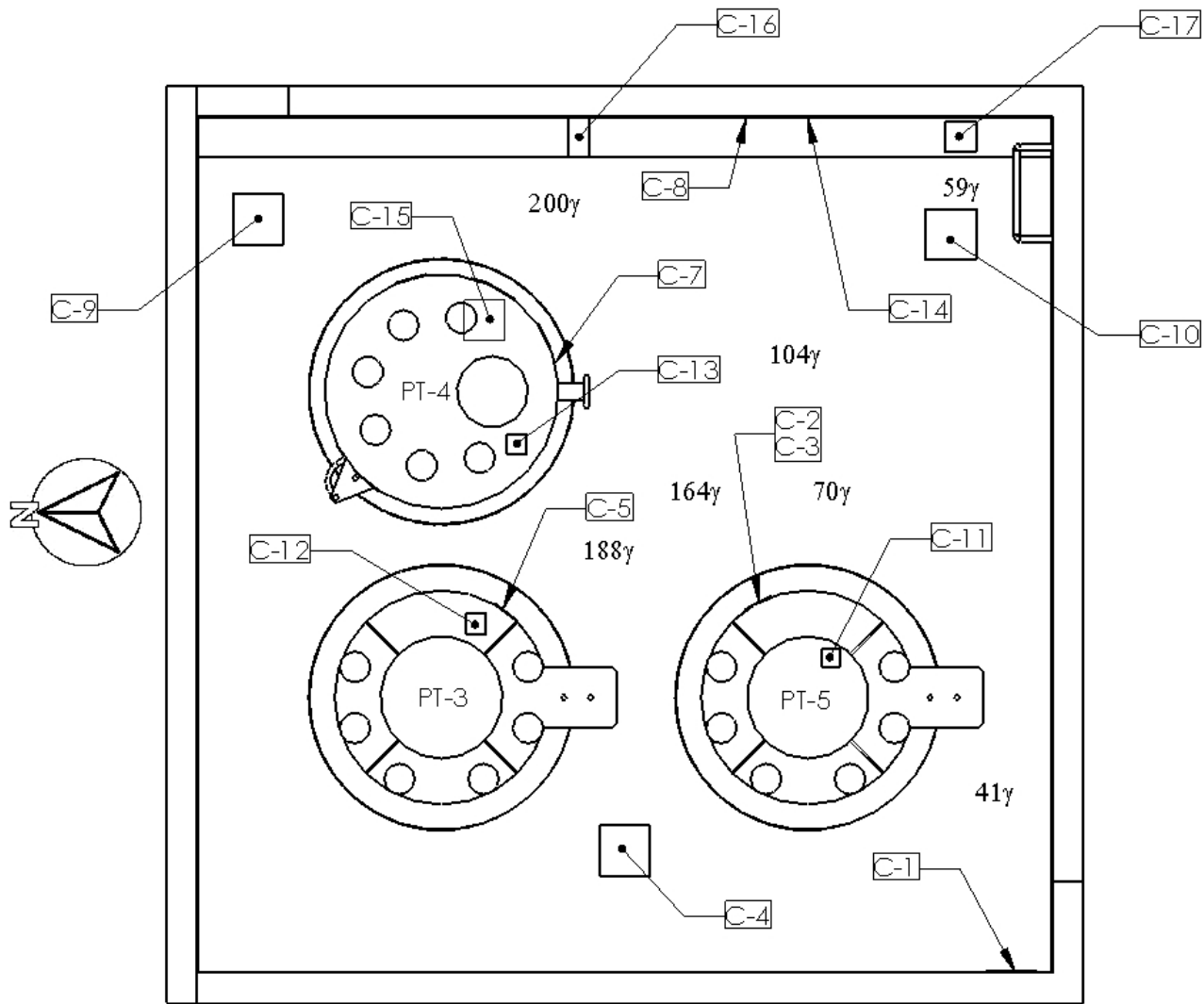


Table A.3. C-Vault Overhead Diagram and Sample Information

Field Sample ID#	Dose rate, smear, or liquid	Approximate Sample Location and Analytical Sample ID#	Approximate Height (feet)	Dose Rate* (mRem/hr)	$\beta\gamma$ dpm/smear of ~100 cm ²	α dpm/smear of ~100 cm ²
C-1	Smear	Robot smear, west wall approx 1 foot north of south wall. Identified in analytical report as # 07-01745 smear (C-8)	2	41	15,000	<MDA
C-2	Smear	Robot smear, northeast side of PT-5. Smear not retrieved, lost in vault.	1.5	73	--	--
C-3	Smear	Robot smear, northeast side of PT-5. Identified in analytical report as # 07-01744 smear (C-7).	2	71	40,000	3500
C-4	Smear	Robot smear, floor between PT-3 and PT-5, approx 3 feet east of west wall. Identified in analytical report as # 07-01743 smear (C-6).	0	198	20,000	700
C-5	Smear	Robot smear, southeast side of PT-3. Identified in analytical report as # 07-01742 smear (C-5).	1.5	120	20,000	1400
C-6	Dose	Parked near sump	--	175	--	--
C-7	Smear	Robot smear, south side of PT-4. Identified in analytical report as # 07-01741 smear (C-4).	2	--	10,000	<MDA
C-8	Smear	Robot smear, east wall approx 5 feet north of south wall. Identified in analytical report as # 07-01740 smear (C-3).	2	--	6000	350
C-9	Smear	Robot smear, floor in northeast corner of vault near trench. Identified in analytical report as # 07-01739 smear (C-2).	0	--	80,000	2100
C-10	Smear	Robot smear, floor beneath vault opening near ladder. Identified in analytical report as 07-1738 smear (C-1).	0	--	60,000	1400
C-11	Smear	Pole smear, top of tank PT-5, southeast quadrant of large central riser. Identified in analytical report as # 07-01746 smear (C-11).	5	100 [†]	6000	350
C-12	Smear	Pole smear, top of tank PT-3, southeast quadrant of main tank. Identified in analytical report as # 07-01747 smear (C-12).	4.5	138 [†]	600,000	21,000
C-13	Smear	Pole smear, top of tank PT-4, southwest quadrant of main tank. Identified in analytical report as # 07-01748 smear (C-13).	7	105 [†]	70,000	4200

Table A.3. (contd)

Field Sample ID#	Dose rate, smear, or liquid	Approximate Sample Location and Analytical Sample ID#	Approximate Height (feet)	Dose Rate* (mRem/hr)	$\beta\gamma$ dpm/smear of $\sim 100 \text{ cm}^2$	α dpm/smear of $\sim 100 \text{ cm}^2$
C-14	Smear	Pole smear, east wall approx 4 feet north of south wall. Combined with smear C-15 and identified in analytical report as 07-1749 smear (C-14#4)	10	61 [†]	<MDA (1000)	<MDA
C-15	Smear	Pole smear, underside of cover block, approx 9 feet north of south wall, approx 3 feet west of east wall. Combined with smear C-14 and identified in analytical report as 07-1749 smear (C-14#4)	12	39 [†]	<MDA (1000)	<MDA
C-16	Liquid	Robot liquid sample center of sump	--	--	--	--
C-17	Debris	Robot debris sample, east trench, 2 feet north of south wall	0	--	--	--

*Unless otherwise noted, all dose rates were recorded on the vehicle, approximately 12 inches above the vault floor, not at the height of the smear. Robot dosimeter power failure after C-6.

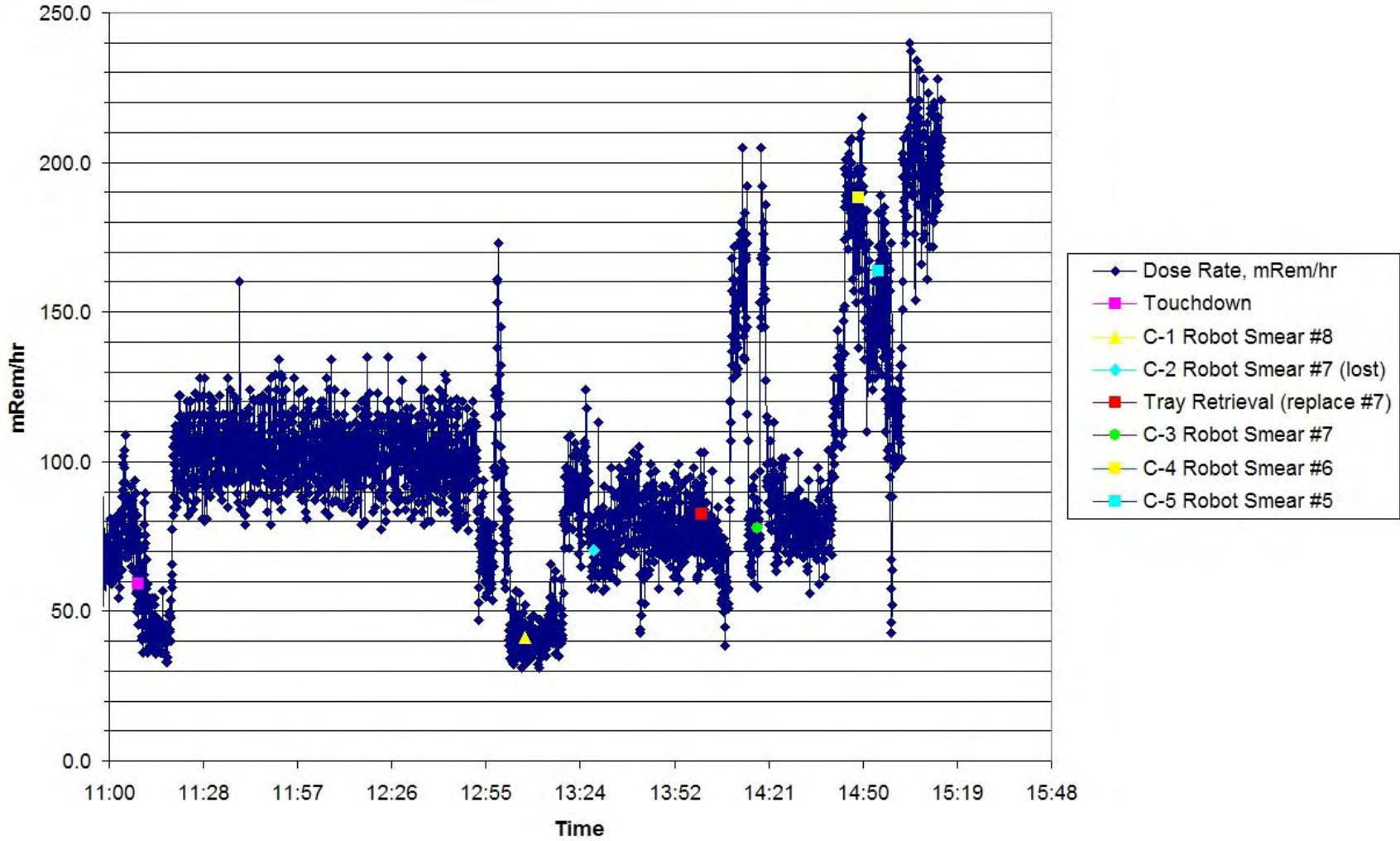
[†]Dose rate measured at smear location (i.e. on the end of the pole)

NOTE: All dose rates on maps are average dose rates.

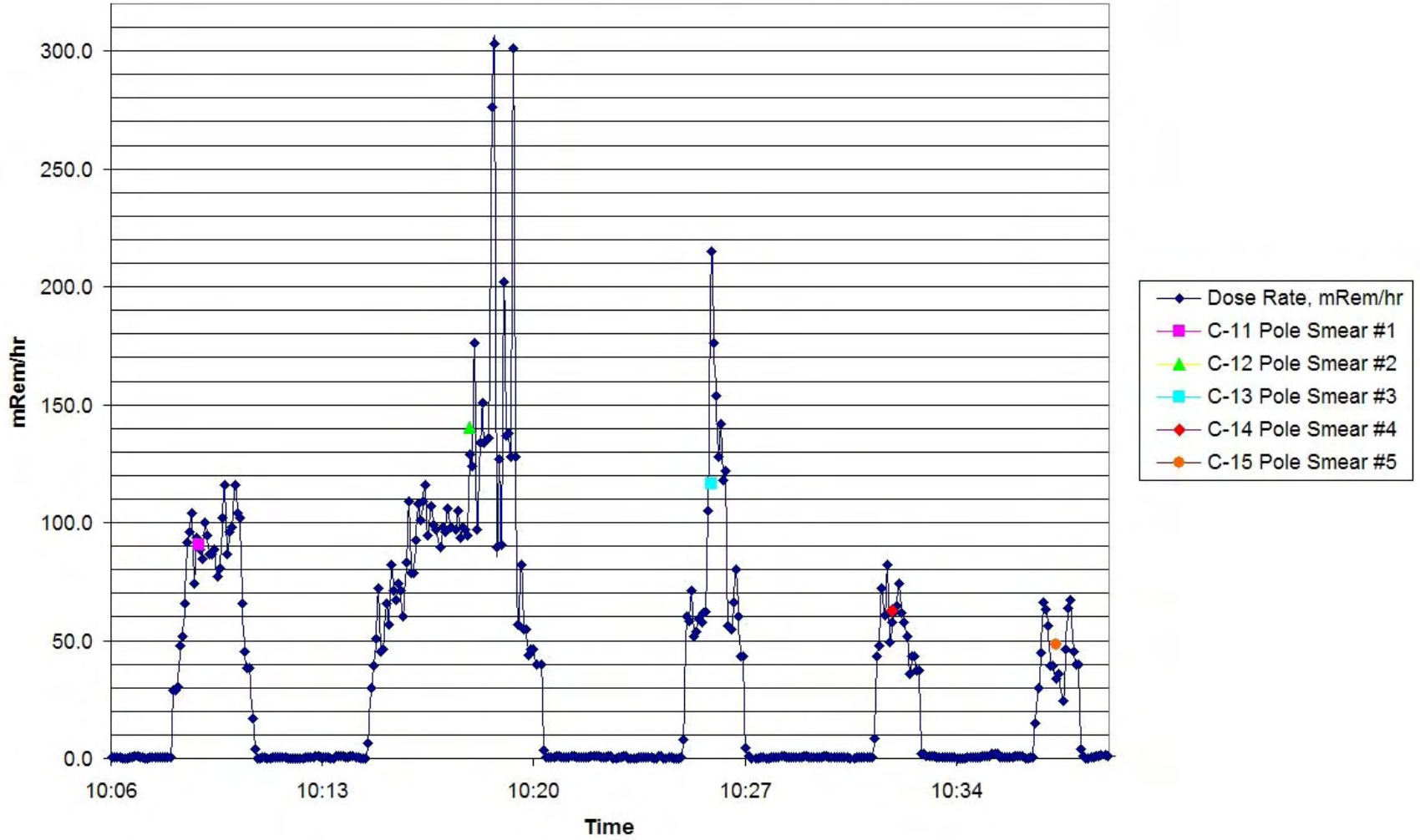
The cover blocks are hidden for diagram clarity.

C-Vault 20070726 Vanguard Dose Rate

A.13



C-Vault 20070727 Pole Dose Rates



A.14

Appendix B
Analytical Results

Appendix B – Analytical Results

Filename: 07-01722
Report date: 8/23/2007

Battelle Pacific Northwest National Laboratory
Radiochemical Chemical Science & Engineering -325 Building

Project: 47022
WP: F93727

Client: FH Steen
ASR: 7989

Date: 8/23/07
Date: 8/29/07

Prepared by: T. Trang-le
Technical Reviewer: Z. R. Alamedd

Procedures: RPG-CMC-450, Rev. 1 - Gamma Energy Analysis
M&TE: Gamma detectors C,D,E,G
Count date: August 21-23, 2007 for GEA

Measured Activities ($\mu\text{Ci}/\text{sa}$) with 1-sigma error

Sample ID	RPL ID	Cs-137 $\pm 1s$	Eu-154 $\pm 1s$	Eu-155 $\pm 1s$	Am-241 $\pm 1s$
07-01722 Smear (A-1)	07-01722	2.03E-3 $\pm 2\%$	1.97E-5 $\pm 7\%$	<7.E-6	7.14E-5 $\pm 14\%$
07-01723 Smear (A-4)	07-01723	2.12E-4 $\pm 2\%$	<4.E-6	<6.E-6	<2.E-5
07-01724 Smear (A-5)	07-01724	1.81E-4 $\pm 3\%$	<4.E-6	<6.E-6	1.10E-5 $\pm 42\%$
07-01725 Smear (A-6)	07-01725	4.37E-3 $\pm 2\%$	9.70E-5 $\pm 7\%$	3.86E-5 $\pm 25\%$	3.76E-4 $\pm 15\%$
07-01726 Smear (A-17)	07-01726	1.95E-4 $\pm 4\%$	<1.E-5	<2.E-5	<5.E-5
07-01727 Smear (B-1)	07-01727	3.50E-2 $\pm 2\%$	2.63E-3 $\pm 2\%$	1.79E-3 $\pm 3\%$	4.62E-3 $\pm 9\%$
07-01728 Smear (B-2)	07-01728	6.76E-4 $\pm 4\%$	<3.E-5	<2.E-5	<3.E-5
07-01729 Smear (B-3)	07-01729	1.22E-2 $\pm 4\%$	3.30E-4 $\pm 4\%$	2.27E-4 $\pm 9\%$	5.32E-4 $\pm 9\%$

Measured Activities ($\mu\text{Ci/sa}$) with 1-sigma error

Sample ID	RPL ID	Cs-137 $\pm 1s$	Eu-154 $\pm 1s$	Eu-155 $\pm 1s$	Am-241 $\pm 1s$
07-01730 Smear (B-4)	07-01730	1.83E-4 $\pm 4\%$	<2.E-5	<2.E-5	<5.E-5
07-01731 Smear (B-5)	07-01731	9.41E-5 $\pm 6\%$	<1.E-5	<2.E-5	<4.E-5
07-01732 Smear (B-7)	07-01732	1.33E-3 $\pm 2\%$	8.31E-5 $\pm 7\%$	5.82E-5 $\pm 19\%$	<1.E-4
07-01733 Smear (B-1D)	07-01733	9.00E-4 $\pm 2\%$	<2.E-5	<2.E-5	6.05E-5 $\pm 34\%$
07-01734 Smear (B-11)	07-01734	6.26E-4 $\pm 3\%$	<1.E-5	<2.E-5	<5.E-5
07-01735 Smear (B-12)	07-01735	8.65E-4 $\pm 2\%$	<1.E-5	<3.E-5	<1.E-4
07-01736 Smear (B-13)	07-01736	2.77E-4 $\pm 5\%$	<2.E-5	<2.E-5	<2.E-5
07-01737 Smear (A-3)	07-01737	4.79E-4 $\pm 3\%$	<3.E-5	<3.E-5	<7.E-5
07-01738 Smear (C-1)	07-01738	7.98E-3 $\pm 4\%$	4.46E-4 $\pm 3\%$	2.17E-4 $\pm 8\%$	1.08E-3 $\pm 6\%$
07-01739 Smear (C-2)	07-01739	1.15E-2 $\pm 3\%$	1.15E-3 $\pm 2\%$	6.20E-4 $\pm 5\%$	2.46E-3 $\pm 6\%$
07-01740 Smear (C-3)	07-01740	5.66E-4 $\pm 3\%$	3.88E-5 $\pm 4\%$	1.99E-5 $\pm 10\%$	1.25E-4 $\pm 7\%$
07-01741 Smear (C-4)	07-01741	5.18E-4 $\pm 3\%$	<3.E-5	<2.E-5	1.40E-4 $\pm 22\%$

Measured Activities (μCi/isa) with 1-sigma error

Sample ID	RPL ID	Cs-137 ± 1s	Eu-154 ± 1s	Eu-155 ± 1s	Am-241 ± 1s
07-01742 Smear (C-5)	07-01742	3.08E-3 ± 3%	1.75E-4 ± 4%	1.21E-4 ± 11%	8.86E-4 ± 8%
07-01743 Smear (C-6)	07-01743	2.15E-3 ± 2%	1.10E-4 ± 6%	6.63E-5 ± 18%	5.67E-4 ± 17%
07-01744 Smear (C-7)	07-01744	4.40E-3 ± 2%	2.93E-4 ± 3%	9.99E-5 ± 17%	2.54E-3 ± 8%
07-01745 Smear (C-8)	07-01745	3.88E-3 ± 2%	3.35E-4 ± 2%	1.56E-4 ± 3%	1.01E-3 ± 5%
07-01746 Smear (C-11)	07-01746	4.14E-4 ± 5%	3.86E-4 ± 3%	2.03E-4 ± 6%	4.70E-4 ± 6%
07-01747 Smear (C-12)	07-01747	7.80E-2 ± 2%	1.79E-4 ± 2%	7.83E-5 ± 12%	1.25E-2 ± 5%
07-01748 Smear (C-13 #3)	07-01748	6.51E-3 ± 3%	2.56E-4 ± 2%	1.19E-4 ± 4%	1.16E-3 ± 4%
07-01749 Smear (C-14 #4)	07-01749	6.43E-5 ± 7%	<2.E-5	<2.E-5	<9.E-5

The sample was counted as received directly on the face of high-efficiency gamma detectors for 1-14 hours and all gamma emitters detected are listed above. Since the counting geometry did not exactly match one of our calibrated geometries, absolute uncertainties are higher than indicated above.

Measured Activity, μCi per Smear $\pm 1\text{s}$

Sample	Lab ID	Gross Alpha	Gross Beta	Pu-239 + Pu-240	Pu-238 + Am-241	Cm-243 + Cm-244	Cm-242
A-Vault Smears	07-1806	1.21E-3 $\pm 9\%$	6.33E-3 $\pm 4\%$	8.52E-6 $\pm 9\%$	1.16E-3 $\pm 2\%$	6.70E-6 $\pm 10\%$	3.14E-7 $\pm 45\%$
B-Vault Smears	07-1807	4.46E-3 $\pm 5\%$	8.47E-2 $\pm 3\%$	1.15E-4 $\pm 8\%$	3.96E-3 $\pm 2\%$	7.16E-5 $\pm 9\%$	3.00E-6 $\pm 41\%$
C-Vault Smears	07-1808	2.71E-2 $\pm 2\%$	1.27E-1 $\pm 3\%$	2.57E-3 $\pm 3\%$	2.46E-2 $\pm 2\%$	5.00E-4 $\pm 5\%$	3.30E-5 $\pm 20\%$
	Smear digestion blank	< 1.E-4	9.52E-4 $\pm 5\%$	< 5.E-7	2.24E-6 $\pm 16\%$	< 1.E-7	< 1.E-7

Measured Activity, μCi per Gram $\pm 1\text{s}$

Sample	Lab ID	Gross Alpha	Gross Beta	Pu-239 + Pu-240	Pu-238 + Am-241	Cm-243 + Cm-244	Cm-242
B-Vault Soil	07-1809	4.63E-2 $\pm 19\%$	1.06E+0 $\pm 4\%$	9.61E-4 $\pm 6\%$	3.48E-2 $\pm 2\%$	5.43E-4 $\pm 8\%$	6.09E-5 $\pm 22\%$
C-Vault Soil	07-1810	2.16E-1 $\pm 8\%$	3.07E+0 $\pm 4\%$	7.75E-3 $\pm 6\%$	2.09E-1 $\pm 2\%$	3.24E-3 $\pm 10\%$	3.24E-4 $\pm 30\%$
	Fusion blank	< 2.E-2	1.73E-1 $\pm 4\%$	< 2.E-5	5.26E-5 $\pm 19\%$	< 1.E-5	< 4.E-6
	Lab blank	< 3.E-6	< 4.E-7	< 3.E-8	< 2.E-8	< 1.E-8	< 1.E-8
	Matrix spike	103%	89%	91%	--	--	--
	Reagent spike	98%	88%	86%	--	--	--

**Battelle, Pacific Northwest National Laboratory
Radiochemical Sciences and Engineering Group - 325 Building
Richland, WA**

Client: F. Steen Project: 47022 Prepared by: C. Soderqvist 9-27-07
 ASR 8006 WP: F93727 Concur: T. Krang-ke 9-27-07

Procedures: RPG-CMC-128, Acid digestion of liquids
 PNL-ALO-106, Acid digestion of smears
 RPG-CMC-4001, -408, Gross alpha and gross beta counting
 RPG-CMC-496, Coprecipitation mounting of samples for alpha spectrometry
 RPG-CMC-422, Alpha spectrometry
 M&TE: Ludlum alpha counters
 LB4100 proportional counter
 Alpha spectrometry counting system

Reference date: 19-Sep-07

Sample	Lab ID	Gross Alpha	Gross Beta	Measured Activity, $\mu\text{Ci per mL} \pm 1\text{s}$					
				Pu-239 + Pu-240	Pu-238 + Am-241	Cm-243 + Cm-244	Cm-242		
A-Vault Liquid	07-1803	< 3.E-5	2.00E-3 \pm 4%	8.32E-8 \pm 40%	4.87E-6 \pm 5%	1.01E-7 \pm 33%	< 7.E-8		
	07-1803 Dup	< 3.E-5	1.99E-3 \pm 4%	< 2.E-7	5.85E-6 \pm 5%	8.61E-8 \pm 35%	< 3.E-8		
B-Vault Liquid		RPD	1%	--	18%	16%	--		
	07-1804	< 3.E-5	2.50E-1 \pm 4%	< 7.E-7	3.38E-6 \pm 30%	< 2.E-7	< 5.E-8		
	07-1805	1.07E-1 **	1.68E+0 \pm 4%	< 3.E-4	1.43E-1 \pm 2%	2.37E-3 \pm 5%	2.95E-4 \pm 12%		
C-Vault Liquid	07-1805 Dup	1.11E-1 **	1.57E+0 \pm 3%	< 2.E-4	1.50E-1 \pm 2%	2.55E-3 \pm 5%	3.53E-4 \pm 11%		
		RPD	7%	--	5%	8%	18%		
Acid digestion blank		6.26E-5 \pm 18%	8.86E-4 \pm 4%	< 1.E-7	< 1.E-7	< 7.E-8	< 3.E-8		

**The gross alpha data for the C-Vault Liquid sample (shaded in the table) is biased about 25% low by mass loading on the counting plate.

Client : F. Steen Project: 47022
ASR: 8006 WP: F93727

Prepared by: T Trang-le Date: 9/24/07

Technical Reviewer: J R Greenwood Date: 9/27/07

Procedures: RPG-CMC-450, Rev. 1 - Gamma Energy Analysis
M&TE: Gamma detectors C, D, & E
Count date: September 18-20 for gamma emitters

Measured Activities with 1-sigma error

RPL ID Client ID	Units	Cs-137 ± 1s	Eu-152 ± 1s	Eu-154 ± 1s	Eu-155 ± 1s	Am-241 ± 1s
07-01803PB Acid digestion blank	µCi/mL	1.53E-5 ± 45%	<5.E-5	<3.E-5	<4.E-5	<8.E-5
07-01803 A-Vault Liquid	µCi/mL	5.73E-4 ± 4%	<6.E-5	<3.E-5	<5.E-5	<7.E-5
07-01804 B-Vault Liquid	µCi/mL	3.16E-2 ± 4%	<6.E-5	<3.E-5	<1.E-4	<2.E-4
07-01805 C-Vault Liquid	µCi/mL	3.41E-1 ± 3%	2.74E-3 ± 3%	1.19E-1 ± 2%	5.33E-2 ± 2%	1.57E-1 ± 4%
07-01805 Dup C-Vault Liquid	µCi/mL	3.32E-1 ± 4%	2.58E-3 ± 3%	1.15E-1 ± 2%	5.16E-2 ± 3%	1.56E-1 ± 4%
07-01805 Trip C-Vault Liquid	µCi/mL	3.32E-1 ± 4%	2.74E-3 ± 3%	1.16E-1 ± 2%	5.10E-2 ± 2%	1.50E-1 ± 4%
	RSD	2%	3%	2%	2%	2%
07-01809PB KOH Fusion blank	µCi/g	7.93E-4 ± 22%	<2.E-3	<1.E-3	<2.E-3	<5.E-3
07-01809 B-Vault Soil	µCi/g	2.44E-1 ± 3%	<2.E-3	1.78E-2 ± 3%	8.45E-3 ± 9%	2.32E-2 ± 16%
07-01810 C-Vault Soil	µCi/g	8.87E-1 ± 3%	<2.E-3	1.74E-1 ± 2%	7.73E-2 ± 3%	2.60E-1 ± 6%

Sample aliquots were prepared in standard counting geometries and then counted for 18 hours on high-efficiency gamma detectors. All of the detected gamma emitters are listed. Weak Cs-137 contamination was observed in the process blanks. Duplicate samples showed good agreement. Daily control samples are counted to demonstrate detector calibration and performance.

Battelle PNNL/RS&E/Inorganic Analysis ... ICPOES Analysis Report
 PO Box 999, Richland, Washington 99352

Project / WP#: 47022 / F93727
ASR#: 8006
Client: F. Steen
Total Samples: 3 (liquid) & 3 (solid) smears

	First	Last
RPL#:	07-01803	07-01808
Client ID:	A Vault Liquid	C Vault Smears
Sample Preparation: RPG-CMC-128, "HNO ₃ -HCl Acid Extraction of Liquids for Metals Analysis Using a Dry-Block Heater", 9/13/07 (1d), and PNL-ALO-106 "Acid Digestion of Waters, Soils, and Sludges for Subsequent Radiochemical Sample Preparation and Analysis", 9/13/07 (1d).		

Procedure: RPG-CMC-211, "Determination of Elemental Composition by Inductively Coupled Argon Plasma Optical Emission Spectrometry (ICPOES)", Rev 1.

Analyst: J. R. Deschane

Analysis Date (File): 9-18-2007 (C0062)

See Chemical Measurement Center 98620 file: ICP-325-405-3
 (Calibration and Maintenance Records)

M&TE Number: N827583 (ICPOES instrument)
M19445 (Mettler AT400 Balance)

B.M. Dem 9/26/07
 Preparer

Angela Bugawan 9/26/07
 Review and Concur

Battelle PNNL/RPG/Inorganic Analysis ... ICPOES Data Report

		Run Date >	9/18/2007	9/18/2007	9/18/2007	9/18/2007	9/18/2007	9/18/2007
		Multiplieir >	4.90	4.90	24.5	122.6	24.4	121.2
		RPL/LAB >	PB-01805-128	07-01803-128	07-01804-128 @5	07-01804-128 @25	07-01805-128 @5	DUP-01805-128 @25
Instr. Det. Limit (IDL)	Est. Quant. Limit (EQL)	Client ID >	Prep Blank	A Vault Liquid	B Vault Liquid		C Vault Liquid	
(µg/mL)	(µg/mL)	(Analyte)	(µg/mL)	(µg/mL)	(µg/mL)	(µg/mL)	(µg/mL)	(µg/mL)
0.0035	0.035	Ag	--	--	--	--	[0.20]	--
0.0311	0.311	Al	[0.17]	[0.63]	--	--	257 (b)	139
0.0577	0.577	As	--	--	--	--	61.8 (b)	--
0.0151	0.151	B	--	[0.73]	--	--	7.73	--
0.0028	0.028	Ba	--	0.158	1.30	--	2.58	[2.6]
0.0001	0.001	Be	--	--	--	--	--	--
0.0189	0.189	Bi	--	--	--	--	[0.55]	--
0.0174	0.174	Ca	11.1	574	over-range	13,900	sat	42,600 (a)
0.0020	0.020	Cd	--	0.409	--	--	36.0	32.8
0.0099	0.099	Ce	--	--	[0.72]	--	12.8	16.9
0.0032	0.032	Co	--	[0.077]	--	--	3.78	--
0.0031	0.031	Cr	[0.067]	[0.11]	--	--	2.10	--
0.0040	0.040	Cu	[0.067]	[0.17]	[0.36]	--	7.24	7.55
0.0029	0.029	Dy	--	--	--	--	1.82	--
0.0009	0.009	Eu	--	--	--	--	0.888	[0.16]
0.0169	0.169	Fe	--	[0.22]	[0.87]	--	[2.9]	[4.1]
0.1007	1.007	K	[1.0]	69.0	1,130	--	3,120	2,970
0.0011	0.011	La	--	[0.022]	--	--	28.8	29.1
0.0045	0.045	Li	[0.024]	[0.11]	[0.39]	--	[0.91]	[2.6]
0.0058	0.058	Mg	2.02	28.3	1,160	--	385	383
0.0017	0.017	Mn	--	9.72	30.1	--	1,150	1,190
0.0054	0.054	Mo	--	--	--	--	8.42	--
0.0270	0.270	Na	[1.1]	295	917	--	993	931
0.0142	0.142	Nd	--	--	--	--	47.7	47.7
0.0048	0.048	Ni	--	0.987	--	--	15.2	9.67
0.0452	0.452	P	--	--	--	--	37.7	--
0.0306	0.306	Pb	--	--	--	--	843	823
0.0104	0.104	Pd	--	--	--	--	48.7	--
0.0209	0.209	Rh	--	--	--	--	5.81	--
0.0068	0.068	Ru	--	--	--	--	4.21	--
0.2703	2.703	S	--	277	536	--	311 (b)	[280]
0.0260	0.260	Sb	--	--	--	--	33.5	--
0.0405	0.405	Se	--	--	--	--	40.7	--
0.0094	0.094	Si	1.83	20.4	11.6	--	29.1	29.2
0.0166	0.166	Sn	--	--	--	--	31.8	--
0.0001	0.001	Sr	0.047	1.65	38.9	--	69.4	70.4
0.0110	0.110	Ta	--	--	--	--	9.90	--
0.0261	0.261	Te	--	--	--	--	31.1	--
0.0098	0.098	Th	--	--	--	--	--	--
0.0008	0.008	Ti	--	--	--	--	1.47	--
0.0537	0.537	Tl	--	--	--	--	46.1	--
0.0693	0.693	U	[0.47]	--	--	--	110 (b)	--
0.0026	0.026	V	--	--	--	--	0.844	--
0.0124	0.124	W	--	--	--	--	18.4	--
0.0007	0.007	Y	--	--	--	--	2.99	1.56
0.0047	0.047	Zn	[0.20]	9.23	[0.47]	--	440	466
0.0067	0.067	Zr	--	--	--	--	--	--

Other Analytes

1) "--" indicates the value is < MDL. The method detection limit (MDL) = IDL times the "multiplier" near the top of each column. The estimated sample quantitation limit = EQL (in Column 2) times the "multiplier". Overall error for values ≥ EQL is estimated to be within ±15%.

2) Values in brackets [] are ≥ MDL but < EQL, with errors likely to exceed 15%.

"sat" indicates that the signal saturated the detector. (a) Level > estimated upper linear range - subject to higher uncertainty. (b) Possible high bias from interelement interference from calcium.

Battelle PNNL/RPG/Inorganic Analysis ... ICPOES Data Report

Run Date >	9/18/2007	9/18/2007	9/18/2007	9/18/2007
Multiplier >	25.0	25.0	25.0	25.0
RPL/LAB >	PB-01806-106	07-01806-106	07-01807-106	07-01808-106
Client ID >	<u>Prep Blank</u>	<u>A Vault Smears</u>	<u>B Vault Smears</u>	<u>C Vault Smears</u>
(Analyte)	(µg/mL)	(µg/mL)	(µg/mL)	(µg/mL)
Ag	--	--	--	[0.38]
Al	[0.91]	368	415	230
As	--	--	--	--
B	--	23.2	31.5	56.7
Ba	[0.26]	16.6	166	42.7
Be	--	[0.005]	--	--
Bi	--	--	--	[1.5]
Ca	[0.78]	3,470	5,840	5,330
Cd	--	9.25	1.22	1.72
Ce	--	--	--	--
Co	--	[0.48]	[0.18]	[0.53]
Cr	--	21.4	15.6	27.1
Cu	--	10.7	21.7	42.4
Dy	[0.082]	--	--	--
Eu	--	[0.039]	--	--
Fe	--	1,340	2,860	7,290
K	[4.2]	233	613	188
La	--	0.502	0.477	1.24
Li	[0.16]	[1.1]	[1.1]	[1.1]
Mg	--	434	515	1,030
Mn	--	35.6	104	169
Mo	--	--	--	--
Na	[0.92]	1,230	1,200	3,300
Nd	--	--	--	--
Ni	--	16.2	4.10	18.5
P	--	96.9	281	513
Pb	--	494	409	1,130
Pd	--	--	--	--
Rh	[0.59]	--	--	--
Ru	--	--	--	--
S	--	870	1,360	873
Sb	--	--	--	--
Se	--	--	--	--
Si	6.02	9.33	10.2	10.2
Sn	--	--	--	--
Sr	[0.012]	13.8	27.6	23.9
Ta	--	--	--	--
Te	--	--	--	--
Th	--	--	--	--
Ti	--	16.0	42.6	17.9
Tl	--	--	--	--
U	[4.2]	[3.1]	--	--
V	--	5.92	4.02	2.65
W	--	--	--	[1.6]
Y	[0.023]	0.376	0.296	[0.15]
Zn	1.27	320	53.4	209
Zr	--	--	--	--

Battelle PNNL/RPG/Inorganic Analysis ... ICPOES Data Report

QC Performance 9/18/2007

Criteria >	≤ 20%	80%-120%	75%-125%	75%-125%	75%-125%	≤ 10%
QC ID >	07-01805 Dup	LCS/BS	07-01805 MS	07-01803 + PS-A	07-01803 + PS-B	07-01803 5-fold Serial Dil
Analytes	RPD (%)	%Rec	%Rec	%Rec	%Rec	%Diff
Ag		91	96	96		
Al	0.5	99	99	103		
As	1.5			95		
B	2.1	102	91	110		
Ba	0.4	96	91	101		
Be		98	89	102		
Bi		81	83	97		
Ca		99		89		0.4
Cd	1.6	93	86	99		
Ce	1.1	103	98		102	
Co	2.5			100		
Cr	3.4	93	86	102		
Cu	1.6	101	91	104		
Dy	1.2				101	
Eu	1.7				96	
Fe		105	95	103		
K	0.1	96	96	101		2.5
La	0.1	99	91		104	
Li		102	107	104		
Mg	0.9	98	91	103		0.2
Mn	2.2	97	nr	97		0.6
Mo	1.9	93	88	98		
Na	1.7	97	nr	98		0.5
Nd	0.3	93	87		98	
Ni	2.2	95	85	99		
P	1.2	90	91	98		
Pb	0.6	92	nr	97		
Pd	0.9				95	
Rh	6.1				97	
Ru	1.8				95	
S	3.2			95		1.7
Sb	1.1			98		
Se	0.4			95		
Si	2.3	91	88	125		7.5
Sn	0.5			96		
Sr	2.0	98	nr	101		0.2
Ta	3.3			94		
Te	0.2				96	
Th		91	80		94	
Ti	1.0	96	89	102		
Tl	1.7			90		
U	0.5	97	90		98	
V	2.8	97	87	99		
W	0.5	85	82	95		
Y	0.5			99		
Zn	0.5	96	nr	96		1.4
Zr		97	89	102		

Other Analytes

Shaded results are outside the acceptance criteria.

nr = not recovered; spike concentration less than 25% of sample concentration.

Battelle PNNL/RS&E/Inorganic Analysis ... ICPOES Analysis Report
PO Box 999, Richland, Washington 99352

Project / WP#: 47022 / F93727
ASR#: 8006
Client: F. Steen
Total Samples: 2 (solid)

	First	Last
RPL#:	07-01809	07-01810
Client ID:	B Vault Soil	C Vault Soil
Sample Preparation: PNL-ALO-115, "Solubilization of Metals from Solids Suing a KOH-KNO ₃ Fusion", 9/14/07 (ld).		

Procedure: RPG-CMC-211, "Determination of Elemental Composition by Inductively Coupled Argon Plasma Optical Emission Spectrometry (ICPOES)", Rev 1.

Analyst: J. R. Deschane

Analysis Date (File): 9-18-2007 (C0062)

See Chemical Measurement Center 98620 file: ICP-325-405-3
(Calibration and Maintenance Records)

M&TE Number: N827583 (ICPOES instrument)
M19445 (Mettler AT400 Balance)

S.M. Dem 9/19/07
Preparer

David Burgeon 9/26/07
Review and Concur

Battelle PNNL/RPG/Inorganic Analysis ... ICPOES Data Report

		Run Date >	9/18/2007	9/18/2007	9/18/2007
		Multiplier >	3453.0	3592.0	3324.5
		RPL/LAB >	PB-01809-115 @5	07-01809-115 @5	07-01810-115 @5
Instr. Det. Limit (IDL)	Est. Quant. Limit (EQL)	Client ID >	Prep Blank	B Vault Soil	C Vault Soil
(µg/mL)	(µg/mL)	(Analyte)	(µg/g)	(µg/g)	(µg/g)
0.0052	0.052	Ag	--	--	--
0.0459	0.459	Al	[410]	11,500	14,800
0.0835	0.835	As	--	--	--
0.0273	0.273	B	--	[100]	[93]
0.0124	0.124	Ba	--	[240]	[290]
0.0003	0.003	Be	--	--	--
0.0461	0.461	Bi	--	--	--
0.9500	9.500	Ca	--	[27,000]	69,700
0.0024	0.024	Cd	--	--	[40]
0.0625	0.625	Ce	--	--	--
0.0064	0.064	Co	--	--	--
0.0049	0.049	Cr	[31]	1,050	1,710
0.0087	0.087	Cu	[52]	448	491
0.0160	0.160	Dy	--	--	--
0.0051	0.051	Eu	--	--	--
0.0247	0.247	Fe	[210]	385,000	177,000
10.7000	107.000	K	na	na	na
0.0033	0.033	La	--	--	[40]
0.0099	0.099	Li	--	--	--
0.0479	0.479	Mg	--	2,970	2,950
0.0077	0.077	Mn	[180]	2,080	3,500
0.0092	0.092	Mo	--	--	--
3.8000	38.000	Na	--	--	--
0.0963	0.963	Nd	--	--	--
0.0144	0.144	Ni	na	na	na
0.0486	0.486	P	--	[1,600]	[230]
0.0279	0.279	Pb	--	[620]	7,300
0.0568	0.568	Pd	--	--	--
0.0372	0.372	Rh	--	--	--
0.0160	0.160	Ru	--	--	--
0.2239	2.239	S	--	[4,300]	[6,600]
0.0529	0.529	Sb	--	--	--
0.0902	0.902	Se	--	--	--
0.1299	1.299	Si	--	41,900	62,500
0.0844	0.844	Sn	--	--	--
0.0032	0.032	Sr	--	119	180
0.0182	0.182	Ta	--	--	--
0.0716	0.716	Te	--	--	--
0.0558	0.558	Th	--	--	--
0.0084	0.084	Tl	--	4,200	5,520
0.0649	0.649	Tl	--	--	--
0.3893	3.893	U	--	--	--
0.0042	0.042	V	--	--	[23]
0.0284	0.284	W	--	--	--
0.0061	0.061	Y	--	--	--
0.0156	0.156	Zn	--	[540]	770
0.0182	0.182	Zr	[160]	--	--

Other Analytes

1) "--" indicates the value is < MDL. The method detection limit (MDL) = IDL times the "multiplier" near the top of each column. The estimated sample quantitation limit = EQL (in Column 2) times the "multiplier". Overall error for values ≥ EQL is estimated to be within ±15%.

2) Values in brackets [] are ≥ MDL but < EQL, with errors likely to exceed 15%.

na = not applicable; KOH flux and Ni crucible or Na₂O₂ flux and Zr crucible used for preparing samples.

Battelle PNNL/RPG/Inorganic Analysis ... ICPOES Data Report

QC Performance 9/18/2007

Criteria >	≤ 20%	80%-120%	75%-125%	75%-125%	75%-125%	≤ 10%
QC ID >	Dup (none)	LCS/BS	MS (none)	07-01809 + AS-A	07-01809 + AS-B	07-01809 5-fold Serial Dil
Analytes	RPD (%)	%Rec	%Rec	%Rec	%Rec	%Diff
Ag				88		
Al		91		95		27.7
As				91		
B				97		
Ba		89		101		
Be				93		
Bi				93		
Ca				122		
Cd				95		
Ce					94	
Co				93		
Cr				94		7.1
Cu		90		96		
Dy					94	
Eu					91	
Fe		91		nr		8.5
K	na	na	na	na	na	na
La					97	
Li				97		
Mg		91		95		
Mn		94		96		4.7
Mo				93		
Na				98		
Nd					93	
Ni	na	na	na	na	na	na
P				98		
Pb		85		96		
Pd					89	
Rh					88	
Ru					90	
S				98		
Sb				93		
Se				92		
Si		82		95		2.4
Sn				91		
Sr		89		95		
Ta				86		
Te					92	
Th					90	
Ti		85		97		8.8
Tl				86		
U					90	
V				91		
W				89		
Y				92		
Zn		88		99		
Zr				94		

Other Analytes

Shaded results are outside the acceptance criteria.

nr = not recovered; spike concentration less than 25% of sample concentration.

na = not applicable; KOH flux and Ni crucible or Na₂O₂ flux and Zr crucible used for preparing samples.

Appendix C
Equipment and Materials

Appendix C – Equipment and Materials

The following sections provide a detailed description of the types of equipment used during the HLV characterization process.

C.1 Remotely Operated Vehicle

The Allen-Vanguard Mark II ROV was selected for use in the HLV characterization effort. This family of remotely operated vehicles (ROV) is used primarily for explosive-related law-enforcement activities, and was extensively evaluated by the Battelle Memorial Institute (National Institute of Justice 2000). The favorable performance of the Vanguard ROV in these tests, in combination with the availability and adaptability of the design, led to the selection. The ROV unit and attached components performed most of the in-vault work. The ROV was operated and data was collected from a remotely located control station. The operators used handheld poles to position the ROV sampling devices near the vault-access ports. A photograph of the ROV is shown in Figure C.1.

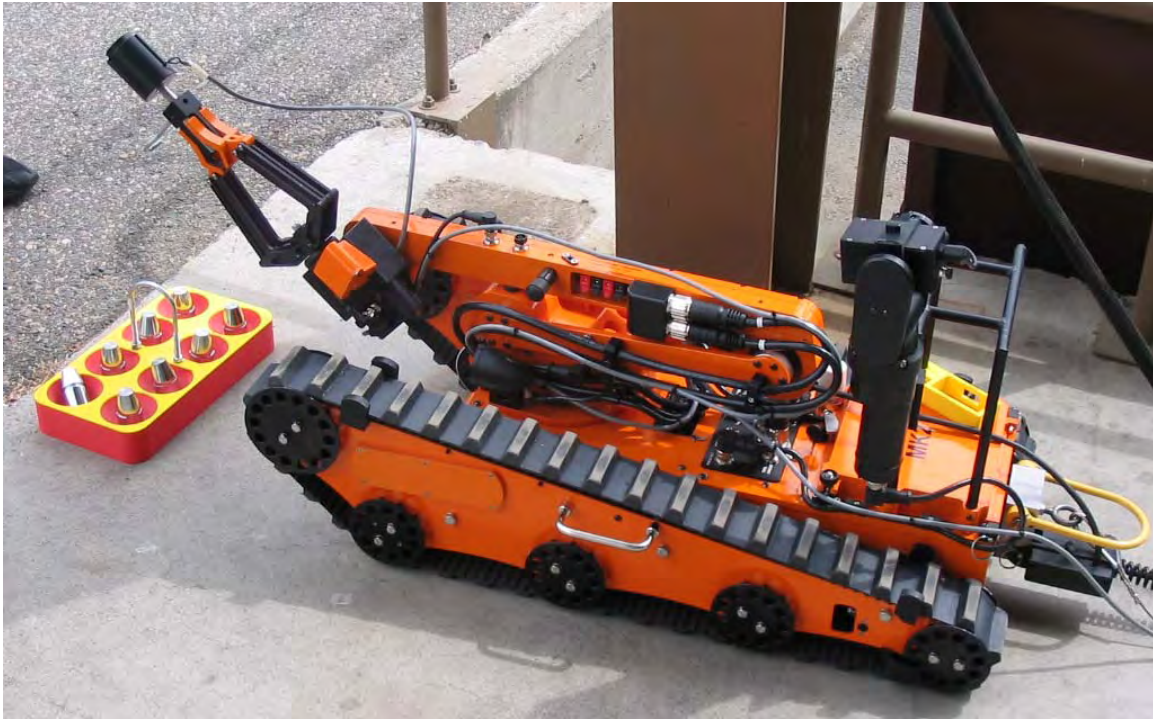


Figure C.1. Vanguard Mark II ROV

The crawler unit is approximately 36 inches long and 17 inches wide. With the manipulator fully stowed, the unit is approximately 16.0 inches in height. The ROV weighs approximately 115 lb and is powered by an onboard lead-acid battery pack. Command signals are transmitted to the vehicle (and video signals returned to the control station) via a radio-frequency communications system or a copper-wire tether. The arm payload ranges from 17.6 lb at full extension to 35 lb when positioned very close to the arm base. The arm reach is 38 inches.

The unit has three onboard cameras and two onboard lighting systems, which provide capability for an overview visualization of work taking place within the vault. One camera is mounted low and in front of the vehicle in a fixed, forward-facing configuration. This camera is normally used for driving the vehicle. A second camera is mounted to the wrist of the robot, approximately coaxially with the gripper. This allows the operator to verify that items are within the gripper jaws before closing the gripper. The third camera is a pan/tilt/zoom unit mounted fairly high up, near the back of the vehicle. This allows the operator to observe the arm configuration, tether position and orientation, view items beside the vehicle, and drive in reverse. Lighting is provided through the wrist-mounted camera. Lighting is also available on the base of the main turret for the manipulator, which provides lighting for the driving camera. Camera and lighting locations are shown in Figures C.2 and C.3.



Figure C.2. ROV Camera locations



Figure C.3. ROV Wrist Camera Location

The robot is powered by a field-replaceable, onboard battery, which allows for mission times of several hours (depending on the level of vehicle activity required). As most RPL-vault missions extended over several days, a low-current battery-charge maintainer was used to recharge the onboard battery overnight when the vehicle was not in use.

Removable contamination smears were obtained within the vault using metal billet-type samplers. The samplers are relatively simple turnings fabricated from Tajima PQB-400 14 oz. plumb bobs. The pointed end was cut off to produce a flat surface 3/4-inch in diameter. This flat surface provided a convenient location to apply identification numbers to the samplers, and a mating surface for the magnet that was used to transport them. The plastic hangar and other hardware were removed from the large end. That end was then machined off to produce a smooth, rounded surface to which the sampling media was attached. The rubber bumper was removed from the transition region between the cylindrical and conical portions of the sampler, and a nylon cable tie applied in its place. The head of the cable was intended to prevent the samplers from rolling should these be dropped.

A sampling end-effector, consisting of an electromagnetic gripper and a hook, was carried in the ROV-manipulator arm gripper. The sampling end-effector was machined out of high-strength Delrin plastic. The gripper portion of the end-effector was machined to have a +-shaped cross section that meshed well with the gripper jaws. A hole was drilled and tapped just outboard of the gripper, to which a hook could be threaded. This hook allowed the operator to carry the sampler tray via a loop fixed to the tray. A second hole in the end of the gripper block allowed an electromagnet, surrounded by a Delrin guide, to attach to the end of the gripper. The electromagnet was powered by an operator-controlled tool power circuit built into the robot. This allowed the ROV to transport and maneuver the samplers within the vault. Each sampler was numbered and sample information was recorded to prevent reuse of previously used sampler numbers. The sampler and end-effector are shown in Figures C.4 and C.5. The billet samplers were stored and transported via the sampler tray shown in Figure C.6.



Figure C.4. Sampler



Figure C.6. Sampling End-Effector



Figure C.5. Billet Sampler Tray

C.2 Radiological Dose Measurement Instrumentation

The DMC 2000 series electronic dosimeter was selected as the onboard dose-rate measurement system. This compact instrument was primarily designed to be worn by individuals working in areas where real-time measurement of the prevailing radiation dose was desirable. The DMC 2000 was also equipped with the CTM 2000 transmitter for remote data logging. This combination of instruments was extensively evaluated by PNNL () and demonstrated superior performance. Other dose-measurement systems, such as the RO-7 and AMP-100, were considered, but not implemented due the difficulties associated with mobility and remote data logging. The DMC 2000 is shown in Figure C.7.

The DMC 200 dosimeter was mounted to the body of the ROV and used for obtaining beta/gamma-radiation dose information within the HLV. The radiation-dose measurements were transmitted via radio signals to the control station and recorded.

Battery life for the dosimeter was not an issue because the battery powers the unit for several months. The radio unit is powered by a separate battery. However, during the initial field deployment, the radio-unit battery only lasted one day. An external battery pack was added to the radio unit to prolong its operational life in the subsequent deployments.

C.3 Extended Reach Tools

The ROV robotic arm had a limited reach of approximately 3 feet above the floor of each HLV. Therefore, a set of long-reach tools was developed to acquire samples within each vault at higher elevations. These tools allowed the ROV robotic arm to sample the underside of the cover blocks, the tops of some of the tanks, and the vault walls near the access point.

A telescoping pole—commonly sold and used for swimming pool maintenance—was used to obtain additional characterization samples. The pole was inserted into the vault-access opening and manipulated by hand with the aid of video cameras. The telescoping pole was sturdy, lightweight, and extended up to 16 feet in length. Straight and curved fixed-length segments and an end tool, which served as both a dosimeter holder and a removable contamination-smear sampler, were designed and fabricated for use with the telescoping poles. The pole-end tool is shown in Figure C.8.



Figure C.7. MGP 2000 Dosimeter



Figure C.8. Pole-End Smear/Dosimeter Holder

C.4 Overview Camera Platform

An overview camera, lighting, and communications platform were developed to support an overview video camera, overview lighting system, and dosimeter-communications antenna.

The platform-mounted lighting system provided improved overall lighting within the vault, resulting in improved image quality. The accompanying video camera provided an overview of ROV operations, which was an important advantage to the operator of the ROV. The camera also provided an additional vantage point from which to observe and guide vehicle insertions, extractions, and sampling activities performed using the pole tools. A video display for the overview video camera was also provided within the tent near the vault-access opening.

The overview platform was constructed of a commercially available structural extruded-tubing system (from Bosch Rexroth, Inc.). In use, the platform rested in the cover-block opening and extended into the vault, providing a platform for the lighting systems, overview camera, and radio antenna. Drawings and an image of this equipment are shown below.

The camera system was a Sony SNC-RZ30N network camera, which was enclosed in a Sony-provided sealed-dome enclosure. The enclosure and camera are shown in Figures C.9 and C.10. The camera was equipped with pan/tilt/zoom capability and a web interface for control of the camera. The camera allowed still images to be saved to the computer. Images were captured in this way to record significant events that occurred during the operation. The camera also provided an analog-output signal, which was displayed at the vault access point and at the control station (where the signal was also recorded). Unfortunately, the overlay of visible time/date stamps onto the camera image was not possible.

As the camera system did not provide on-camera lighting, additional lighting was provided. A separate joystick-controlled motorized pan/tilt head fitted with lamp bases for 12-volt video lamps was mounted on the overview platform. Because this system did not provide sufficient lighting, the image quality from the C-vault deployment was less than desired. Thus, a set of fixed (downward and side-facing) lights were added for the B- and A-vault deployments. This provided



Figure C.9. Sony Camera Enclosure



Figure C.10. Sony Video Camera

adequate lighting and image quality. Locating the lighting and the camera on separate pan/tilt units was cumbersome, however. Additional light could have proven beneficial in some circumstances.

C.5 Control Station

Controls for the various systems were located in a trailer approximately 150 feet from the vault-access points. These controls included those for the ROV, the pan/tilt-lighting system, the pan/tilt/zoom camera system and the dosimeter-data collection. A video display for the overview camera was also provided at the control station, and video signals from both the overview camera and the ROV were recorded on VHS tape.

The ROV-control station was provided by the ROV manufacturer, and included a laptop computer, which displayed vehicle status and controls, and the current video image from the vehicle. The displayed images were captured and saved to the laptop hard drive. In addition, images were captured during deployments. The ROV control station is shown in Figures C.11 and C.12.



Figure C.11. ROV Control Station

The pan/tilt lighting system was controlled and powered by a small handheld joystick unit located at the control station.



Figure C.12. ROV Controls and Indicators

A second computer at the control-station location provided control of the pan/tilt/zoom overview-camera system. Digital-image display and capture for this camera were provided by this interface, as were other camera-control parameters (e.g., focus, aperture, etc.). Images captured by this system were also retained on this computer's hard drive.

The second computer was also connected to the dosimeter base station. This allowed for the recording of the dosimeter data as it was reported.

A flat-panel monitor at the control station displayed the analog image from the overview camera, a signal that was also recorded using a VHS VCR. A second VHS VCR was connected to an analog output on the ROV control station to record the video signal from the ROV.

C.6 Work Structure

A portable work structure (containment) was designed for use during the characterization activities. The primary purpose of the containment was to provide radiological-contamination control. The containment also provided cover to staff, sampling equipment, and instrumentation from inclement weather.

The containment is shown in Figure C.13. The main chamber in the containment measured 20 feet wide by 15 feet long by 14 feet high. The majority of the characterization activities were performed in the main chamber. An anti-room attached to the west side of the main chamber measured 7 feet wide by 7 feet long by 8 feet high. The anti-room provided staff with an area to doff protective clothing and perform radiological surveys. The work structure was fabricated using laminated vinyl plastic and

support was provided by a metal frame. Both wind and snow loading were considered in the design. Ventilation for the greenhouse was provided by the HLV open-cover block.

The vaults were exhausted via the RPL Radioactive Exhaust Ventilation System, and the existing system design and configuration was adequate to exhaust the containment and the vault being accessed.



Figure C.13. Containment Installed over High Level Vault

Appendix D

Deployment Highlights

Appendix D – Deployment Highlights

The vaults were accessed in the reverse of alphabetical order. A layout sketch of the three vaults is shown as Illustration 1. The following sections describe the highlights of the work in each vault in the order that they were inspected.

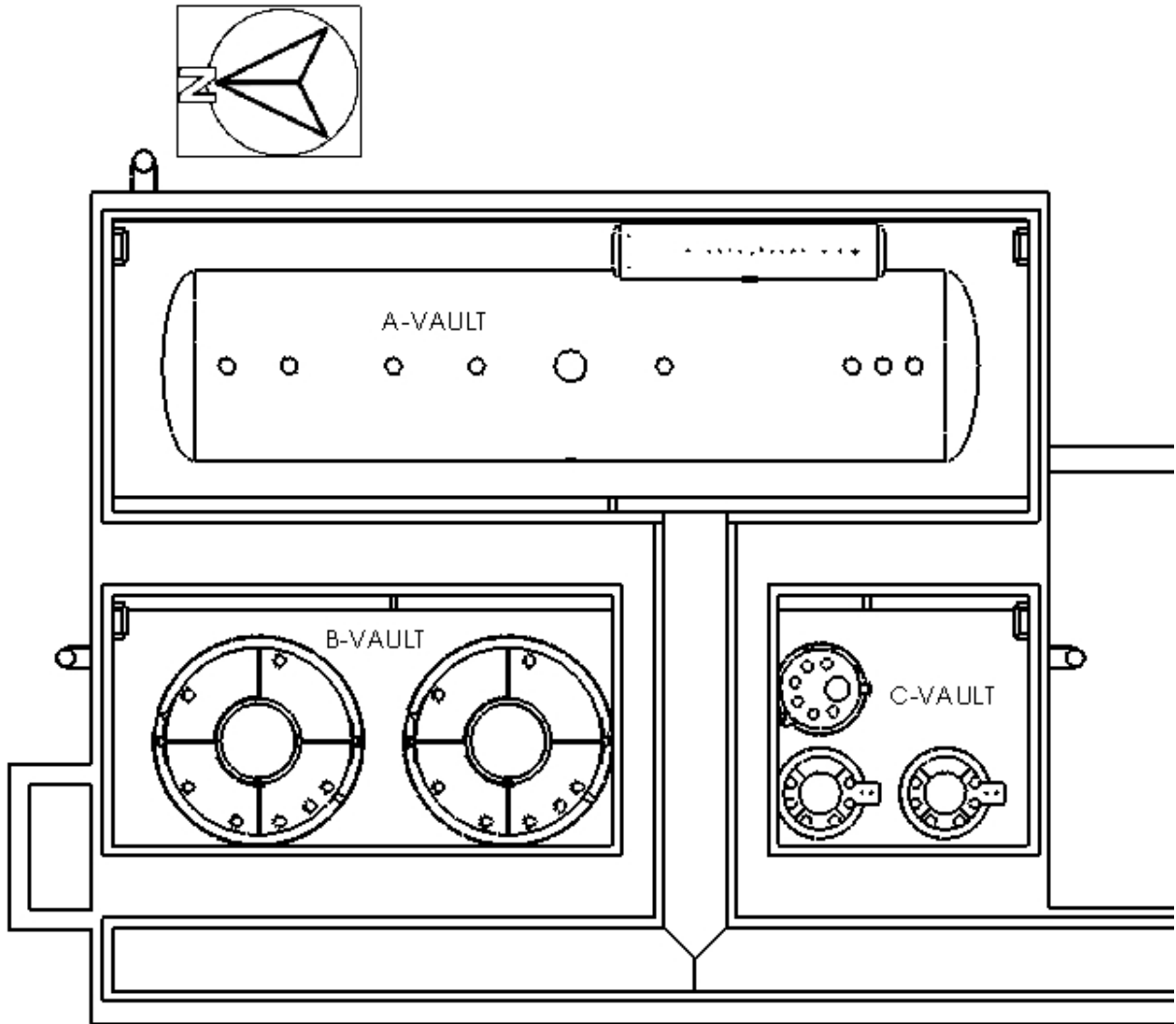


Illustration 1: RPL Vaults Configuration

D.1 C-Vault

This is the smallest vault, and it was originally designed to have four upright cylindrical tanks installed in it. Only three of these tanks were actually installed, and the missing tank is the one nearest the access point. The layout of this vault is shown in Illustration 2. The entry point for this vault is in the upper right hand corner of the sketch.

The “missing” tank left sufficient open space in the vault that it was possible to deploy the ROV into this vault. Illustration 3 was taken by the ROV during the deployment and shows the three tanks in the vault. The access point is directly overhead.

Navigating the ROV in this vault was challenging as the anchor bolts for the absent tank were in place. Also, the handles on the sides of the ROV were left in their extended position rather than being folded down. These handles would catch on the anchor bolts as the vehicle passed by and interfere with vehicle navigation.

Unfortunately only a limited number of images were captured from the deployment in this vault. Some of interest are presented here. Illustration 4 is an image of the sampling surface of a removable contamination sampler after a sample was taken. Despite the poor image quality, the soil is visible on the fabric. The sample tray is visible in the background, as is the lowest ladder rung. This sample was taken directly below the access point. Illustration 5 is a “robot’s eye” view of a smear and dose rate sample being taken on the underside of the vault cover block.

The vaults use a trench and sump system to manage liquids that enter the vault. This is visible in the sketch (Illustration 2) along the East wall of the vault. A sample was taken of the liquid in this sump. Illustrations 6 and 7 depict the trench and sump and illustrations 8 and 9 depict views of this sampling process.

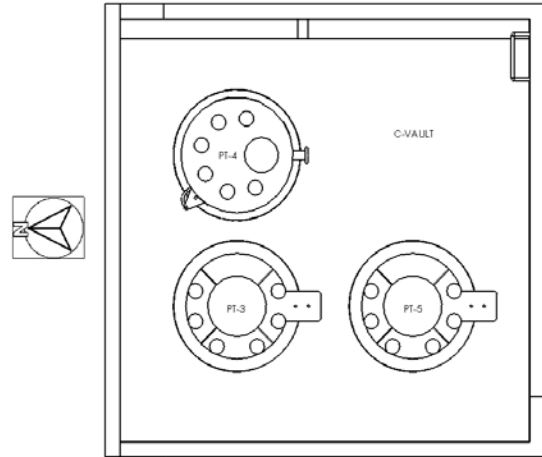


Illustration 2: C-Vault Configuration



Illustration 3: C-Vault Tanks



Illustration 4: Removable Contamination & Dose Sample - Cover block Underside



Illustration 5: C-vault Smear Sample



Illustration 6: C-Vault Sump



Illustration 7: Sump Liquid Sampling



Illustration 8: Sump Liquid Sampling



Illustration 9: Solid Material Sample

The solid particulate (dirt) in the vault was also collected. This sample was taken from the trench near the access point. A picture of the solid material sampler filled with particulate is shown in Illustration 10.



Illustration 10: C-Vault Sump and Trench

D.2 B-Vault

The second vault characterized was B-Vault. A sketch of the B-Vault layout is shown in Illustration 11. The entry point for this vault is in the upper left hand corner of the sketch. B Vault contains two large tanks which together occupy much of the floor space.

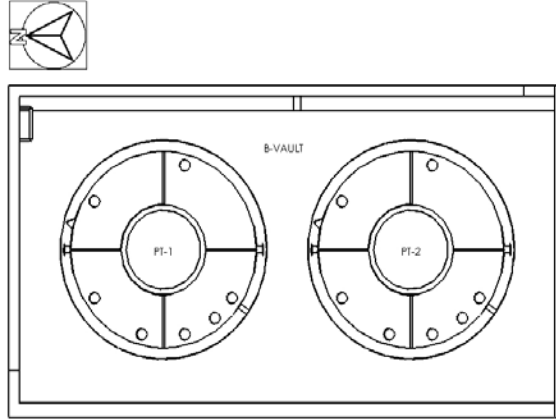


Illustration 11: B-Vault Configuration

Illustrations 12 and 13 and 14 provide “robot's eye” views of the trench and sump from the ROV's initial position at the insertion location. Illustration 15 shows the ROV shortly after insertion into the vault.



Illustration 12: Trench and Sump as Seen by ROV

Smear samples were taken in various locations in the vault; illustrations of some of those samples are presented here: The ROV could not pass between tank PT-1 (or PT-2) and the trench without dropping a track into the trench. To sample portions of the tank beyond the area near the entry location the ROV had to crawl behind tank PT-1 on the west side where it could not be seen by the overview camera. Illustrations 15 through 38 show the some of the sampling locations and types of samples obtained in the HLVs. Illustrations 19 and 20 are of the vehicle as it moves past tank PT-1 and out of sight and of the sump as seen by the ROV when it is between the two tanks. While in this area of the tank, a removable contamination sample was taken in the southeast corner of the tank. After taking the removable contamination sample, the ROV conducted a visual inspection of the southeast corner of the vault.



Illustration 13: Trench and Sump as seen by ROV



Illustration 14: Gutter and Sump as Seen by ROV



Illustration 15: ROV in B-Vault



Illustration 16: Metal Smear Sampler after Sampling

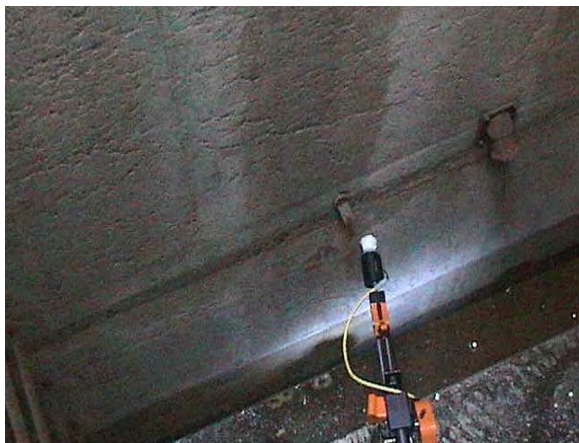


Illustration 17: Removable Contamination Sampling on Wall



Illustration 18: Smear Sampling on Wall



Illustration 19: ROV passing west of tank PT-1



Illustration 20: Sump as Seen From Between Tanks



Illustration 21: Removable Contamination Sampling



Illustration 22: Metal Sampler Returned to Tray



Illustration 23: Sampling in Southeast Corner



Illustration 24: Removable Contamination Sampling

After removable contamination sampling was completed, the sample tray containing the metal samplers was removed from the vault.



Illustration 25: Visual Inspection of Southeast Corner of Vault



Illustration 26: Visual Inspection of B-Vault Southeast Corner

A sample was taken of the liquid in the sump.



Illustration 27: Sample Tray Staged for Removal



Illustration 28: Sample Tray Extraction



Illustration 29: ROV Approaching Sump



Illustration 30: Acquiring Sample Bottle



Illustration 31: Sample Acquisition

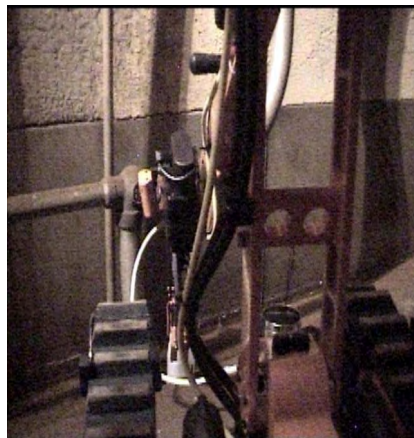


Illustration 32: Sample Acquisition

And the bottle was removed from the vault. A scoop sampler for collecting a debris sample was then lowered into the vault in the same way, and a sample of the debris was taken from the trench near the entry location.

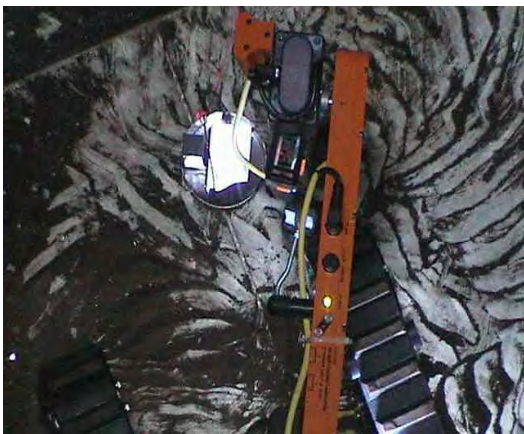


Illustration 33: Debris Sampler Lowered Into Vault



Illustration 34: Debris Sample Collection

This concluded sampling activities with the ROV. The next sampling activity was the use of the pole samplers to collect removable contamination and dose rate samples at selected locations within the vault.



Illustration 35: Smear & Dose Rate Sample - Top of PT-1



Illustration 36: Smear & Dose Sample - Top of PT-1

Once samples were collected from locations within the vault, the team conducted cleanup and retrieval activities. A scrap of smear sampling material which was inadvertently dropped into the trench was retrieved and placed on the foot of tank PT-1.

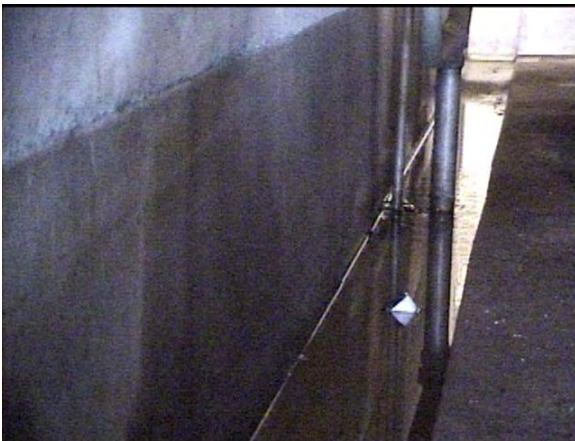


Illustration 37: Sampling Debris in Gutter

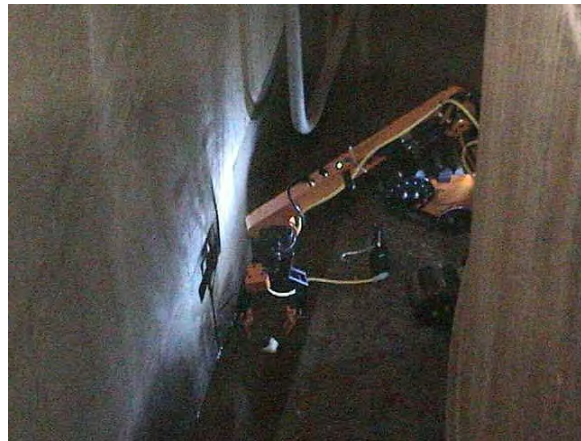


Illustration 38: Debris Retrieval



Illustration 39: ROV retrieval from B-Vault

The vehicle was then retrieved from the vault as shown in illustration 39.

D.3 A-Vault

The final vault characterized was A-Vault. A sketch of the vault layout is shown below. Access to A-Vault was in the upper-left (Northeast) corner of the vault.

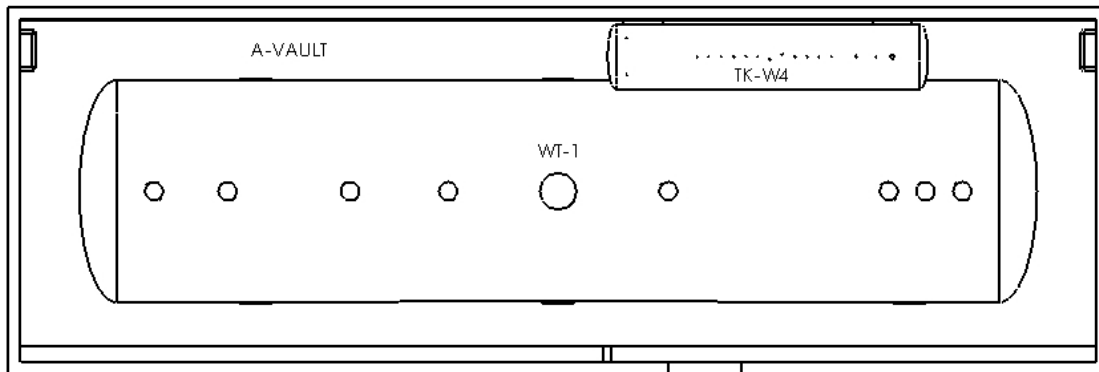
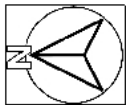


Illustration 40: A-Vault Plan View

Tank WT-1 is supported on three cradles, one at the middle of the tank and one near each end. These cradles support the tank approximately 18” above the floor of the vault. Tank W4 is supported on brackets mounted to the wall well above the floor of the vault. Tank W4 is visible end-on in the overview camera view below and the top portion of tank WT-1 is visible in the lower right of the image. An ROV-eye view from floor level directly beneath this location is also shown. The tank supports are visible in the right side of the image, as is a portion of tank WT-1, and tank W-4 is visible in the upper center of the image. Views of A-Vault are shown in illustrations 41 through 46.



Illustration 41: A-Vault - Tank W-4



Illustration 42: ROV View of Tanks WT-1 and W-4



Illustration 43: A-Vault Piping



Illustration 44: A-Vault Piping



Illustration 45: A-Vault Piping



Illustration 46: A-Vault Piping

This vault is well populated with piping, some of which is visible above. Additional images of the piping above the tanks are shown below. The large size of this vault allowed the team to simplify the

tether management task. In C-Vault and B-Vault it was necessary for the ROV to back out of each corner it entered, as there wasn't space to turn around. This made it necessary to have an operator pay the tether in and out as the robot navigated within the vault. In A-Vault, the ROV began by driving to the far corner of the vault for the first removable contamination sample. The operators were then able to secure the tether, and the vehicle drove around fairly freely within the vault. The following images are of the first smear samples – one in the Southwest corner of the vault and one in the center of the South wall near the top edge of the steel liner. The next two samples were taken with the robot between the South and center tank supports. The first of these was a sample on the wall above the trench near (South of) the sump and the other was on the underside of tank WT-1. The fifth sample was taken on the East wall of the vault below tank W-4 about 6” below the top of the steel liner. Images from the sixth sample (taken near the trench between the center and North tank supports) are shown in illustrations 47 through 52.

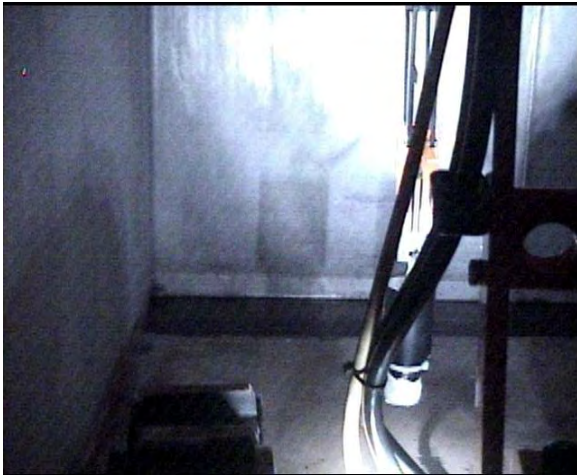


Illustration 47: Sampling - Southwest corner of A-Vault



Illustration 48: Sampling - SW Corner of A-Vault



Illustration 49: Sampling - SW Corner of A-Vault



Illustration 50: Sampling - South Wall of A-Vault



Illustration 51: A-Vault Sample 6



Illustration 52: Sump Viewed From Sample 6 Location



Illustration 53: Acquiring Seventh Sampler

The seventh smear sample, as shown in illustrations 53 through 55, was taken from the East side of WT-1 a short distance north of the center support with the arm extended upward as far as it would reach.

The eighth sample was taken on the North wall approximately centered in the East-to-West direction and about 12" below the liner top. Once this sample was taken, work concluded for the day. The next day (August 17th), work began with the extraction of the sample tray and insertion of a liquid sample bottle shown in illustration 56. The ROV transported the sample bottle to the sump and extracted a sample.



Illustration 54: Preparing to Sample



Illustration 55: Acquiring Sample 7



Illustration 56: A-Vault Sump Sampling

Little particulate was observed in this vault, so no solid debris sample was collected. There was interest, however, in tank W4, which was out of reach of the hand held pole tools. A handle designed to mate with the gripper was fabricated and attached to a section of pole. A dosimeter holder and dosimeter was attached to the other end, and the resulting tool lowered to the ROV, which grasped the handle in its gripper. The ROV carried this tool to the far end of the vault and used it to sample the W4 tank.

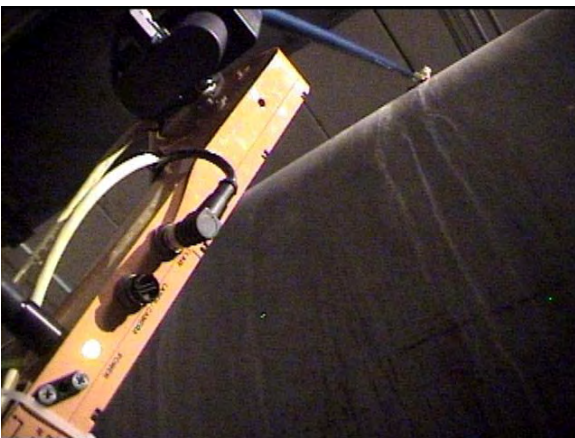


Illustration 57: Pole Tool from ROV

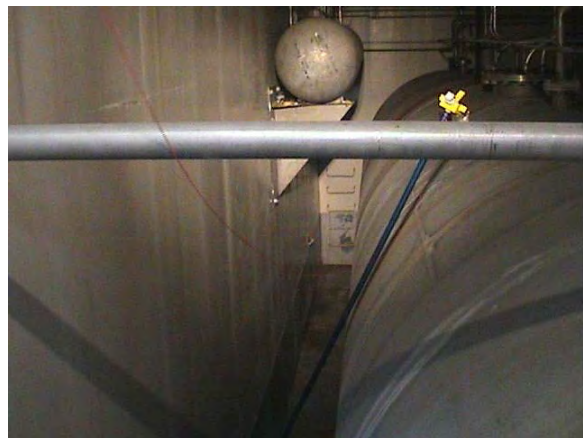


Illustration 58: Pole carried by ROV to W4

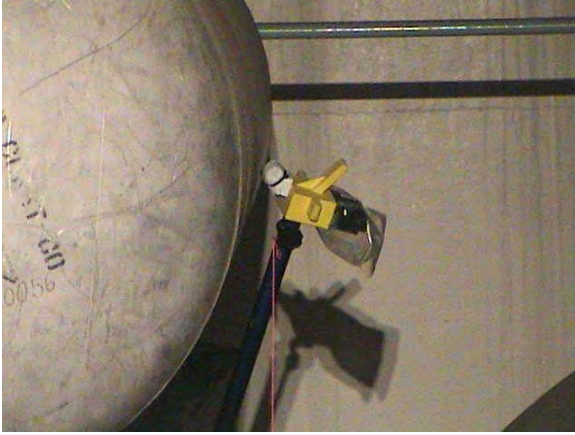


Illustration 59: Sampling Tank W4



Illustration 60: W4 Sampling Seen by ROV

Once vehicle sampling was completed, samples were taken using handheld pole tools, as shown in illustrations 57 through 63.



Illustration 61: Sampling on WT-1

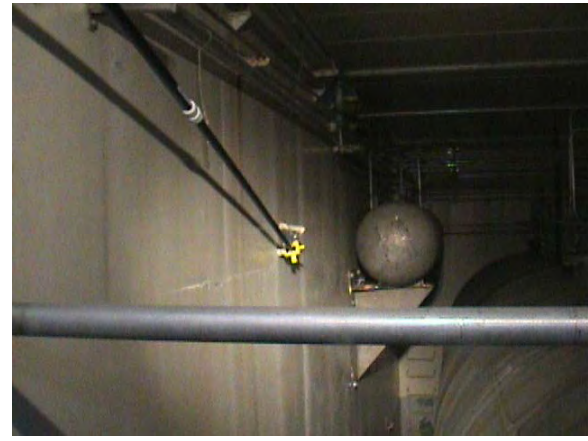


Illustration 62: Sampling East Wall of Vault



Illustration 63: Vault Ceiling Sample

A-vault contains a number of interesting artifacts left over from construction which were observed during the characterization. Perhaps the most amusing is a caricature of a bearded man located on the liner behind the ladder at the South end of the vault, illustrations 64 and 65..



Illustration 64: Bearded Man Caricature



Illustration 65: Bearded Man Caricature

Another item of interest in the vault is a fire extinguisher hanging on the wall just west of the caricature, illustrations 66.



Illustration 66: Fire Extinguisher

Another item remaining in the vault is a section of twist-lock scaffold tube, which can be seen in the illustrations 67 and 68.



Illustration 67: Scaffold Tube



Illustration 68: Scaffold Tube

During the deployment (while preparing for tank W-4 sampling), a piece of scaffold pipe, illustration 69, was dislocated by the ROV tether strain relief when the ROV turned tightly at the base of the ladder at the North end of the vault.



Illustration 69: Scaffold Tube on Floor

The final item of interest is a can of Never-Seez, a wrench and a roll of tape on the bracket supporting tank W-4. These items are shown in illustration 70.



Illustration 70: Never-Seez on W4 Bracket

Appendix E

A-, B- and C-Vault Deployment Field Notes

Appendix E – A-, B- and C-Vault Deployment Field Notes

E.1 A-Vault Deployment Field Notes

A-Vault contains a large horizontal tank (WT-1) mounted low in the vault, and a small horizontal tank (W-4) mounted above and to one side of the lower tank. Deployment of the Vanguard ROV was conducted from Monday 08/17/07 through Thursday 08/24/07. A narrative of the deployment of the Vanguard ROV in A-Vault is provided below.

Mon 8/15 – AM

- Insert Overview Camera system
- Insert Vanguard
- Sample A-1: Dose rate under north end of large tank
- Sample A-2: Dose rate under south end of small tank
- Sample A-3: Robot sample #1 – smear in southwest corner near sump
- Sample A-4: Robot Sample #2 – smear in center of south wall near top of liner
- Sample A-5: Dose rate under south end of large tank
- Sample A-6: Robot Sample #3 – smear on west wall south of sump midway between large tank supports
- Sample A-7: Robot Sample #4 – smear underside of tank about 2 ft south of center support

Mon 8/15 – PM

- Sample A-8: Robot Sample #5 – East wall below small tank
- Sample A-9: Robot Sample #6 – Floor west of large tank between center and north support
- Sample A-10: Dose rate north of sump & center tank support
- Sample A-11: Robot Sample #7 – East side of large tank 18 inches north of center support. Arm fully extended upward (about 48” above floor).
- Sample A-12: Robot Sample #8 – north wall of vault approximately centered on large tank approximately 1 ft below top edge of liner.

Tue 8/16 - PM

- Sampling was delayed due to 300 area emergency drill.
- Sample tray retrieved
- Sample A-13: Robot Sample #9 – liquid sample of sump contents.
- Sample A-14: Smear sample of small tank (mid height & length) taken by robot using dosimeter holder on a pole.

Wed 8/17 – AM

- Handheld pole sampling only
- Sample A-15: Pole Sample #1 – North wall near level of top of large tank
- Sample A-16: Dosimeter sample – same location as sample A-15
- Sample A-17: Pole Sample #2 – East side of large tank above tank midline
- Sample A-18: Pole Sample #3 – East wall of vault about 6 cover blocks into vault near level with top of large tank

- Sample A-20: Pole Sample #4 – Vault ceiling

Thu 8/24 – AM

- Vanguard retrieval into 85 gallon drum
- Disassembled and bagged for disposal

One of the tasks of the Vanguard unit is to take smear samples of selected surfaces within the vault. To accomplish this, eight samplers are carried in a partitioned carrier hanging from a hook that's part of the sampling end-effector. When a sample is taken, the carrier is set down, one of the samplers is removed from the carrier using the sampling end-effector, the sampler is rubbed on the appropriate surface and returned to the carrier. The carrier is then picked up using the hook and the robot moves to another location. In some cases, this task is performed differently from the above description, in which case it's described more thoroughly. Where little description of the sampling task is given, one should assume it was carried out as described above.

On Monday 8/15, the overview system was removed from its bag and inserted into the vault. Initial images from the overview system were taken at 9:16 AM. The Vanguard vehicle was unbagged over the access hole and functionally tested (except for track operation due to concerns over contamination spread) prior to insertion. Initial images from the Vanguard unit were taken at 9:40 AM; the robot was on the floor of the vault shortly after 10:00 AM.

The sample tray was lowered down on a hook and string into the cell at approximately 10:16 AM, while the robot was parked under the north end of the large tank. Dosimeter readings were recorded during this time. The large size of the vault allowed us to simplify tether management as compared to the B and C vaults. Rather than have an operator continuously tend the tether, we began sampling at the far end of the vault, paying out tether as needed into the vault. Once the tether was in the vault, the robot was able to drive around and over the tether as it lay on the floor and little further tether management was required.

Once the sample tray was collected, the vehicle traveled along the east side of the vault, pausing under the South end of the small tank for a dosimeter reading to be recorded. The vehicle then traveled to the far southwest corner of the vault.

Smear Sample #1 was taken at approximately 11:00 AM in the southwest corner of the vault near the sump.

Shortly after this sample was taken and the sampler returned to the tray, the vehicle ceased responding to joystick input. Restarting the Vanguard software corrected this problem. This problem recurred later, but the incident was not recorded. It turns out to have been due to an inadvertent key press that redirected joystick (and some keyboard) input to Windows rather than to the Vanguard software. It was possible to restore proper functionality by escaping from the Windows menu that was displayed.

Smear Sample #2 was taken at approximately 11:12 AM from a location in the center of the south wall near the top edge of the steel vault liner.

Sample #3 was taken at approximately 11:35 on the west wall of the vault, south of sump (half way between south supports) ~18 in above floor.

Sample #4 was taken at approximately 11:50 am on the underside of the large tank, approximately 24 inches south of center support.

At this point, testing was temporarily halted for a lunch break.

Sample #5 was taken at approximately 13:04 on the east wall below the small tank about 6" below top of liner. Dose rates of approximately 600 mR/hr were observed.

Sample #6 was taken at approximately 13:17 on the floor west of the large tank between the center and north supports near the trench. Dose rates of approximately 801 mR/hr were observed.

Sample #7 was taken at approximately 13:42 on the east side of large tank, approximately 18 inches north of the center support, and approximately 36 inches above floor. The manipulator arm was at full extension nearly straight up.

Sample #8 was taken at approximately 14:01 on the north wall, approximately in line with the centerline of the tank and approximately 24 inches above the floor (about 12 inches below the liner top).

The sample tray was picked up and returned to the vault access and set down near the ladder for retrieval in the morning. Robot operations ended at 14:08.

On Tuesday, August 16 a 300 area alarm drill delayed the start of work until late morning. The two sampling tasks performed were to sample the liquid in the sump and to take a smear sample and dose rate sample of the small tank using a dosimeter and smear sampler on an 8 foot pole held by the manipulator gripper.

The first task performed (at approximately 11:30) was the retrieval of the full sample tray by facility operators. After the sample tray was bagged and removed from the tent, a paint can containing a plastic 250 mL bottle with holes drilled in it was lowered into the vault for the robot to collect a water sample from the sump. The robot picked up the small can using the hook and navigated along the east wall to the opening between the north and center supports of the large tank to attempt to access the sump. On determining that the sump was not readily accessible from this location, the robot returned to the east side of the tank and accessed the sump between the center and south tank supports. The paint can was set down, and then the magnetic sampling tool was set down. The sample bottle was retrieved from the can at 11:55, the sample was collected in the bottle at 12:04 and the bottle was returned to the paint can at 12:05. The sampling tool was retrieved and then the paint can containing the liquid sample. The robot operator navigated back along the same path to return the paint can to the ladder area. The paint can was retrieved from the vault at approximately 12:17.

Next, a pole with a grip point on one end and a dosimeter holder/smear sampler on the other was lowered down to the robot. The robot gripped the end of the pole at approximately 12:34 and traveled to the south end of the vault to take dose measurements and obtain a smear sample on the small tank. This activity was almost immediately punctuated by the robot knocking down a piece of scaffold twist-lock pole that had been left in the vault during construction. Fortunately, no damage was done to the robot or anything else. It was necessary to reposition the robot arm to allow the pole to travel under one of the pipes connecting to the top of the large tank. Once past this obstacle (at approximately 12:40), we were able to drive to the south end of the vault, swing the smear sampler into contact with the tank, and obtain

a smear sample and a dose reading. This happened at approximately 12:47; the dose reading at contact with the tank was 872 mR/hr. Once the reading was taken, the robot returned to the north end of the vault and the operations personnel retrieved the pole sampler at 12:54.

At 12:58 the magnet tool was reacquired and robot operations were halted for the day.

On August 17, four smear and dose samples were taken using pole-mounted dosimeters and smear samplers.

Pole sample #1 was taken at 08:55 from the north wall near the elevation of the top of the large tank. This sample was repeated at 8:56 with the dosimeter in place in the dosimeter holder.

Pole sample #2 was taken at 09:00 from the east side of the large tank above the tank midline.

Pole sample #3 was taken at 09:10 on the east wall of the vault near the elevation of the small tank and approximately 16 feet from the north end of the vault.

Pole sample #4 was taken at 09:26 on the underside of cover block, approximately the 6th block south of the north end near the center of the block.

Sampling was concluded at approximately 09:41 and the robot was returned to the base of the ladder.

On August 23 the ROV and overview camera system were retrieved from the vault. Retrieval efforts began at approximately 08:47. The robot was fully extracted from the vault and powered down at 09:13. The vehicle was turned off, tether cables cut, and bagged while hanging over the opening of A-Vault. The bagged vehicle was placed into an 85 gallon drum overpack.

The overview system was then retrieved from the opening and disassembled. Most of the structural elements were cut up as needed and placed into a burial drum; other elements were placed in plastic bags for later survey, decontamination (if feasible) and disposition.

E.2 B-Vault Deployment Field Notes

B-Vault contains two identical vertical tanks, with tank PT-1 located on the north side of the vault and tank PT-2 located on the south side of the vault. Deployment of the Vanguard ROV was conducted from Monday 08/06/07 through Wednesday 08/08/07. A narrative of the deployment of the Vanguard ROV in B-Vault is provided below.

Mon 8/6 – AM

- Insert Overview Camera system
- Insert Vanguard

Mon 8/6 – PM

- Robot Sample #1 – Floor sample east of PT 1 between tank and trench
- Robot Sample #2 – East wall, ~ 3 feet south of North wall
- Robot Sample #3 – Floor sample in southwest corner of vault
- Robot Sample #4 – South Wall, approximately 2 feet east of west wall, 18 inches above floor
- Robot Sample #5 – NW side of PT 2
- Robot Sample #6 – stuck in tray – not used
- Robot Sample #7 – West wall, ~ centered in vault, 18 inches above floor
- Robot Sample #8 – West side of PT 1

Tues 8/7 – AM

- Sample tray retrieved
- Water sample at sump
- Scoop sample in trench near ladder
- Pole Sample #1 – Top of PT 1
- Pole Sample #2 – North Wall, approx centered, XXX feet below cover block
- Pole Sample #3A – attempted East wall, lost swab
- Pole Sample #3B – East wall (above Robot sample #2), XXX feet below cover block
- Lost overview video from tent to trailer – coax stretched too tightly
- Pole Sample #4 – Underside of cover block, approx centered over PT 1 (check video....)
- Pole Sample #5 – Attempted PT 2, lost swab, called it a day

Wed 8/8 – AM

- Retrieved dropped swab (Pole Sample #3A) from water in trench
- Parked for vehicle extraction
- Vanguard retrieval – into 85 gallon drum
- Overview retrieval – bagged

8/6 –

On Monday 8/6, the morning was spent inserting the overview system and the vehicle into B-Vault. A replacement halogen bulb was added to the overview lighting system. Additional lighting was added to the bottom of the overview system for improved visibility directly below the overview system. During initial positioning for insertion of the overview system, the replaced halogen bulb was dislodged and fell to the floor of B-Vault. A second replacement bulb was installed prior to final insertion. The vehicle was unbagged over the access hole and some of the debris from C-Vault was knocked from the vehicle tracks.

Robot sample taking began after lunch. The tray of samples was lowered down on a hook and string to the robot. Sample #1 was removed from the tray and taken on the floor east of PT 1 between the tank and the trench. Sample #1 was returned to the tray.

Sample #2 was retrieved from the tray and taken on the east wall about 36 inches from the north wall, at a height of approximately 18 inches from the floor. It was then returned to the tray. The tray was picked up and carried around the west side of PT 1 and PT 2 into the southwest corner of B-Vault.

Sample #3 was taken on the floor in the southwest corner of the vault, approximately 24 inches from each wall.

Sample #4 was taken on the south wall, approximately 24 inches from the west wall and 18 inches above the floor.

The robot operator left the tray in place and navigated to the south side of PT 2 to perform a visual inspection of the south and southeast portions of the vault. The tray was then retrieved and carried to west side of the tanks, roughly centered in the vault.

Sample #5 was taken on the northwest side of PT 2, about 24 inches above the ground. It was noted that the vehicle appears to fit between PT 1 and PT 2 for access to the sump.

Sample #6 was stuck in the retrieval tray. After several minutes of effort, it could not be extracted and was not used.

Sample #7 was taken on the west wall, approximately centered in the vault and 24 inches above the floor.

Sample #8 was taken on the west side of PT 1, approximately 24 inches above the floor.

The sample tray was picked up and returned to the vault access and set down near the ladder for retrieval in the morning.

8/7 –

The first thing performed was the retrieval of the full sample tray by radcon personnel. After the sample tray was bagged and removed from the tent, a paint can containing a plastic 250 mL bottle with holes drilled in it was lowered into the vault for the robot to collect a water sample from the sump. The robot navigated along the north and west walls before passing between PT 1 and PT 2 to arrive at the sump. The sample was collected in the bottle and the bottle was returned to the paint can. The robot operator navigated back along the same path to return the paint can to the ladder area. The paint can was retrieved from the vault.

Next, a paint can containing a fabricated scoop was lowered into the vault. The robot acquired the scoop and took a debris sample from the trench along the east wall near the ladder. The scoop (and debris) was returned to the paint can and the paint can was retrieved from the vault. The vehicle was repositioned with the lifting bail pointed north for easy retrieval the following morning.

SFO Technicians proceeded to perform dose and smear sampling with reconfigurable poles and a wireless dosimeter.

Pole sample #1 was taken from the top of PT 1.

Pole sample #2 was taken from the north wall, approximately centered in the vault, ~6 feet below cover block.

Pole sample #3 was attempted on the east wall a few feet south of the ladder. The initial attempt lost the sample swab. The pole was extracted and a new swab was placed on the pole. The second attempt on the east wall was successful and the sample was obtained above Robot Sample #2, approximately 36 inches from the north wall and ~6 feet below the cover block.

Sometime between Pole samples #3 and #4, the overview video feed from the tent to the trailer was lost for long periods of time. It was determined that the cable in the tent was stretched very tightly and was prone to being snagged on equipment by personnel in the tent. The personnel did their best to avoid it, but long stretches of the rest of the deployment were lost. The personnel in the tent still had overview video available to them via a direct cable from their monitor to the overview camera. The camera operator in the trailer had only non-recordable Ethernet video and was able to still use the camera to guide pole sampling.

Pole sample #4 was taken on the underside of cover block, approximately centered over PT 1 (check video....).

Pole sample #5 was attempted on tank PT 2. In the process of taking or retrieving the sample, the swab was lost from the pole. As there were no more smear swabs on hand, it was decided to end sampling.

At system startup, a foreign object was viewed in the trench near the sump. Upon closer inspection, the foreign object was the dropped smear sample from the first attempt at pole sample #3. The robot operator navigated around the north and west sides of PT 1 before passing between PT 1 and PT 2 to retrieve the swab from the trench. The swab was retrieved and placed on the grout ledge around PT 1 to keep it from falling into and/or obstructing the sump pipes. Then the robot was navigated back to the ladder for retrieval.

The robot was retrieved from the vault using the A-frame hoist. The vehicle was lifted a few inches above the vault floor to allow the operator to run the tracks in an attempt to reduce the amount of contaminated debris on the tracks. Upon arrival on the deck, the vehicle was turned off, disconnected, and bagged while hanging over the opening of B-Vault. The bagged vehicle was placed into an 85 gallon drum overpack.

The overview system was retrieved from the opening and surveyed. The overview system was disconnected and bagged for future deployment.

The control trailer was shut down and we left, taking all data and video tapes with us.

E.3 C-Vault Deployment Field Notes

C-Vault contains three vertical tanks, with tank PT-3 located on the northwest side, tank PT-4 located on the northeast side, and tank PT-5 located on the southwest side of the vault. Deployment of the Vanguard ROV was conducted from Wednesday 07/25/07 through Wednesday 08/08/07. A narrative of the deployment of the Vanguard ROV in B-Vault is provided below.

Wed 7/25 – PM

- Insert Overview Camera system

Thurs 7/26 – AM

- Insert Vanguard

Thurs 7/26 – PM

- Robot samples #8-#5
- Robot sample #8 – West wall, south corner
- Lost sample #7 (lost masslin paper) – retrieved tray and re-taped all samples
- Robot sample #7 – NE side of PT 5; dropped billet after successful tank sample, picked up and placed in tray
- Robot sample #6 – floor sample between PT 3 and PT 5
- Robot sample #5 – SE side of PT 3
- Drove over near sump to get dosimeter reading (did we drive into NE corner???), parked near sump

Fri 7/27 – AM

- Dosimeter battery DOA
- Robot sample #4 – South side of PT 4
- Robot sample #3 – East wall above sump
- Robot sample #2 – floor sample NE corner near sump
- Robot sample #1 – floor sample SE corner under ladder

Fri 7/27 – PM

- Pole sample #1 – top of PT 5
- Pole sample #2 – top of PT 3
- Pole sample #3 – top of PT 4
- Pole sample #4 – East wall above Robot sample #3
- Pole sample #5 – underside of cover block, approx center of vault
- Robot water sample at sump
- Robot scoop sample from trench near ladder

Mon 7/30 – AM

- Vanguard retrieval (into 85 gallon drum) – high contamination on tracks
- Overview retrieval – some contamination that fell from tracks onto bosch frame, sealed contamination into bosch frame groove by taping over groove

7/25 –

On Wednesday 7/25, the overview system was lowered into C-Vault. Upon insertion, the first unexpected feature was four threaded studs exposed in the floor where the fourth (never installed) tank was to reside. These studs would pose some navigation difficulty, but did not preclude the mission from continuing.

7/26 –

The morning of Thursday 7/26 was spent performing operational checks of the Vanguard robot and inserting the unit into C-Vault. Wireless dosimeter data was recorded during the entire day. During installation, it was determined that cable routing on the overview system had caused one of the overview lights to become dislodged and fall to the floor of C-Vault. Additionally, it was determined that there was insufficient lighting for the area of vault directly below the overview system.

Robot sample taking began after lunch. The tray of samples was lowered down on a hook and string to the robot. The tray was picked up and carried to the southwest corner of C-Vault after navigating the studs in the floor. Sample #8 was taken on the west wall in the south corner, approximately 2 feet above the vault floor. The sample was returned to the tray before picking up the tray. The robot then was navigated through the studs in the floor to a position centered between the three tanks.

Sample #7 was taken from the tray and a sample was attempted on the northwest side of PT 5. In the process of taking the sample, the sample pad peeled away from the sample billet held by the robot. The robot operator unsuccessfully attempted to retrieve the pad by pressing the billet against the adhesive side. The billet was returned to the sample tray and the tray was retrieved by radcon personnel. The billets and sample pads were taped to prevent any further pad loss. The pad for Sample #7 was replaced. The tray was then lowered back into C-Vault for continued sampling.

Sample #7 was re-taken on the northwest side of PT 5. It was subsequently dropped on the floor by the robot while trying to return it to the sample tray. The robot operator recovered the sample billet and returned it to the sample tray.

Sample #6 was taken on the floor between PT 3 and PT 5 before being returned to the sample tray. The tray was picked up and relocated to an area on the southwest side of PT 4.

Sample #5 was taken on the southeast side of PT 3 and returned to the sample tray.

Due to alarm settings on the dosimeter that appeared to be draining the dosimeter battery, it was decided to complete a radiological dose survey of C-Vault. The sample tray was left in its location while the robot operator navigated to the east side of the vault near the sump and into the northeast corner of the

vault. —verify this via video.... The dose data was logged for the day and the robot was parked near the sump overnight.

7/27 –

Upon system power up in the morning, it was determined that the dosimeter wireless transmitter on the Vanguard unit had a dead battery and no dosimetry could be retrieved from the vehicle for the remainder of the C-Vault deployment. This was a minor inconvenience as a comprehensive dose survey was performed the prior afternoon.

The robot was navigated back to a location south of PT 4 to resume smear sampling. Robot sample #4 was taken on the south side of PT 4 approximately 18 inches above the floor. The sample was returned to the tray.

The sample tray was picked up and the robot was navigated to an area just south of the sump, where Sample #3 was taken on the east wall, approximately 18 inches above the vault floor. The sample was returned to the tray.

The sample tray was picked up and the robot was navigated to the northeast corner of the vault. Sample #2 was taken on the floor near the sump about a one foot from both the north and east walls. After the sample was returned to the tray, a visual inspection was performed along the north wall as well as could be achieved from the robot's position to the east of PT 4. – verify this on the video....

The tray was picked up and transported to the southeast corner of the cell, where Sample #1 was taken on the floor near the ladder. The sample was returned to the tray and the tray was retrieved by radcon personnel.

SFO Technicians proceeded to perform dose and smear sampling with reconfigurable poles and a wireless dosimeter.

Pole sample #1 was taken from the top of PT 5.

Pole sample #2 was taken from the top of PT 3.

Pole sample #3 was taken from the top of PT 4.

Pole sample #4 was taken on the east wall above the area where robot sample #3 was taken, just south of the sump, approximately XXXX feet below the cover block.

Pole sample #5 was taken on the underside of the cover block approximately centered in the vault.

After lunch, a paint can containing a plastic 250 mL bottle with holes drilled in it was lowered into the vault for the robot to collect a water sample from the sump. The sample was collected in the bottle and the bottle was returned to the paint can. The paint can was retrieved from the vault.

A paint can containing a fabricated scoop was lowered into the vault. The robot acquired the scoop and took a debris sample from the trench along the east wall near the ladder. The scoop (and debris) was

returned to the paint can and the paint can was retrieved from the vault. The vehicle was repositioned with the lifting bail pointed south for easy retrieval the following Monday (7/30).

7/30 –

The robot was retrieved from the vault using the A-frame hoist. Upon arrival to the deck, a high contamination level (> one million dpm???) was found on the robot tracks. The vehicle was turned off, disconnected, and bagged while hanging over the opening of C-Vault. The bagged vehicle was placed into an 85 gallon drum overpack.

The overview system was retrieved from the opening and surveyed. It also contained significant contamination presumably due to debris that shook free of the vehicle tracks during vehicle extraction. Some debris was visible in the top raceway of the overview structure (Bosch aluminum frame). An attempt to seal the contamination was performed by taping over the top raceway of the system. The overview system was disconnected and bagged for future deployment.

The control trailer was shut down and we left, taking all data and video tapes with us.