Use of the Pipe Explorer™ System to Deploy a Custom Gamma Tool in the Laterals Beneath High Level Waste Tanks in the “A” and “SX” Tank Farms, US DOE Hanford Site

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ABSTRACT

The “laterals” are 3-inch tubing installed beneath single shell high level waste tanks in the “A” and “SX” Tank Farms at the US DOE Hanford Site during the late 1950’s as part of a multi-faceted leak detection system. A pneumatic deployment/wire line retrieval system was originally used to deploy two different custom Geiger-Muller detectors (a “RED GM” and a “GREEN GM”) into the laterals for the purposes of characterizing activity levels in the soils beneath the waste tanks. Logging of the laterals was carried out from the mid 1970’s through the early 1990’s, when the activity was suspended.

In support of the on-going vadose zone characterization efforts in the tank farms, CH2M Hill Hanford Group Inc. contracted with Apogen Technologies to utilize the Pipe Explorer™ system to deploy a custom gamma tool designed by Three Rivers Scientific and operated by Pacific Northwest Geophysics into selected laterals in the “A” and “SX” tank farms. The Pipe Explorer™ System is a unique deployment tool that utilizes a patented inverting membrane technology to deploy various detectors into piping, duct and drain lines. The conventional Pipe Explorer™ system was modified to interface with the PNG tool cabling and winch system that is typically used in bore hole applications. The gamma tool is comprised of three different detector systems, each with a different sensitivity. The most sensitive detector is a sodium iodide spectral gamma detector utilizing an on-board multi-channel analyzer. This detector is sensitive enough to measure the natural background radioactivity in these soils. Two additional Geiger-Muller gamma ray detectors complete the detector complement of the tool. These were designed with sensitivities similar to the historically used “Green” and “Red” GM detectors. The detectors

were calibrated for Cs-137 concentration in the formation, and incorporated a correction for gamma ray attenuation due to the steel pipe of the lateral. The calibrations are traceable to the National Institute of Standards and Technology (NIST). In total, the gamma tool provides a dynamic range of eight orders of magnitude, from less than 200 Bq kg^{-1} (5 pCi g^{-1}) to 1.11 x 10^{10} Bq kg^{-1} (300,000,000 pCi g^{-1}) eCs-137. With an overall length of 8 ft. and a weight of 13 lbs., this is the longest and heaviest detector package yet deployed by the Pipe Explorer™ system.

INTRODUCTION

Apogen Technologies teamed with Three Rivers Scientific (3Rivers) and Pacific Northwest Geophysics (PNG) to deploy geophysical logging detectors in potentially contaminated tubing (i.e. laterals) that extend under the "self boiling" tanks in the "A" and "SX" tank farms. Additionally Apogen Technologies conducted video logs of selected laterals in the A-Tank Farm. The video survey's were performed prior to deployment of the gamma tool primarily to ascertain that the lateral pipe was in sufficiently good shape to risk deployment of the PNG gamma tool, i.e. no foreign objects, or breaks in the pipe that might result in the gamma tool becoming stuck, or damaged. This paper describes the deployment system used, the gamma logging detectors and their calibration, and provides summary results of the surveys conducted. The complete set of survey results, as well as historical survey results obtained with the "Red" and "Green" GM detectors may be found in [1].

DESCRIPTION OF THE "A" AND "SX" TANK FARMS AND ASSOCIATED LATERALS

The A Tank Farm consists of six 3,800 m^3 (1,000,000-gal) single shell storage tanks (SSTs) constructed between 1954 and 1955 in the 200 East Area at the US DOE Hanford Site to store high-level radioactive waste from chemical processing of irradiated uranium fuel from the PUREX process. The tanks are 23 m (75 ft.) in diameter and nominally 10 m (33 ft.) high, and covered by approximately 2 m (7 ft.) of backfill. The A Tank Farm received wastes from various processes during its active use resulting in a complex mixture of sludge, salt cake, and residual liquids, including various organics. Sr-89, Sr-90, and Cs-137 are significant sources of radioactivity within the tank wastes [2]. Three tanks in the A Tank Farm are assumed to have leaked substantial volumes of waste, A-103, A-104, and A-105 [2].

The SX Tank Farm consists of 15-single shell storage tanks (SSTs), each of 3,800 m^3 (1,000,000-gal) capacity situated in the 200 West Area. The SX tanks are 23 m (75 ft.) in diameter and approximately 13.6 m (44.5 ft.) tall, covered by approximately 2 m (7 ft.) of backfill material. The SX tanks received various waste materials, predominantly from the REDOX process. Cs-137 and Sr-90 account for the bulk of the activity in the present tank contents [3]. Nine of the SX tanks are currently assumed to be leakers, SX-107, SX-108, SX-109, SX-110, SX-111, SX-112, SX-113, SX-114, and SX-115 [3].

In both the A Tank Farm and the SX Tank Farm, "laterals" were installed for leak detection purposes beginning in 1958, with the prototype laterals under SX-113 [3]. The laterals are 3-inch (7.6 cm) pneumatic tubing that extend radially underneath the tanks from large caissons (3.7 m [12-ft] diameter) situated between four tanks. A "lateral shack" was constructed over each caisson to house equipment used for leak monitoring. With the exception of Tank SX-113, all of the tanks have three laterals lying underneath them. One centrally positioned lateral generally bisects the tank along a diameter line. The remaining two laterals are equally positioned either side of this central lateral.

Figure 1 shows a typical sectional drawing of a lateral installation underneath a single shell tank in the “A” Tank Farm. This section is taken from Hanford Drawing # H-2-31880. The laterals were originally emplaced to allow two different styles of Geiger-Muller detectors to be deployed underneath the tanks that were suspected of leaking. These detectors have been referred to as the “Red GM” and the “Green GM” in historical documents. Only one GM detector could be deployed per logging run. And only one detector type (Red or Green) was used in all laterals under a given tank. As is evident from the design of the system, the detectors were blown to the distal end of the lateral using compressed air, and then retrieved using a motorized reel system. The air compressor and motorized reel system are still installed in the lateral shacks. The lateral pipe was fabricated from 3-inch (7.6 cm) pneumatic tubing. The transition from vertical to horizontal in the tubing was accomplished by a 90° elbow with a bend radius of 1.2 m (4-ft.). The horizontal portion of the lateral was enclosed in a length of 4-inch steel pipe. The distal end of the pneumatic tubing was plugged, and four 1 ½-inch (3.8 cm) holes were cut near the end to allow the air in the pneumatic tubing to be exhausted into the annular volume between the OD of the pneumatic tubing and the ID of the steel pipe during detector deployment. This exhausted air would flow out of the annular volume and dump into the caisson volume. Small metal shacks were installed over the caissons to serve as a weather shelter for the support equipment for the laterals logging.

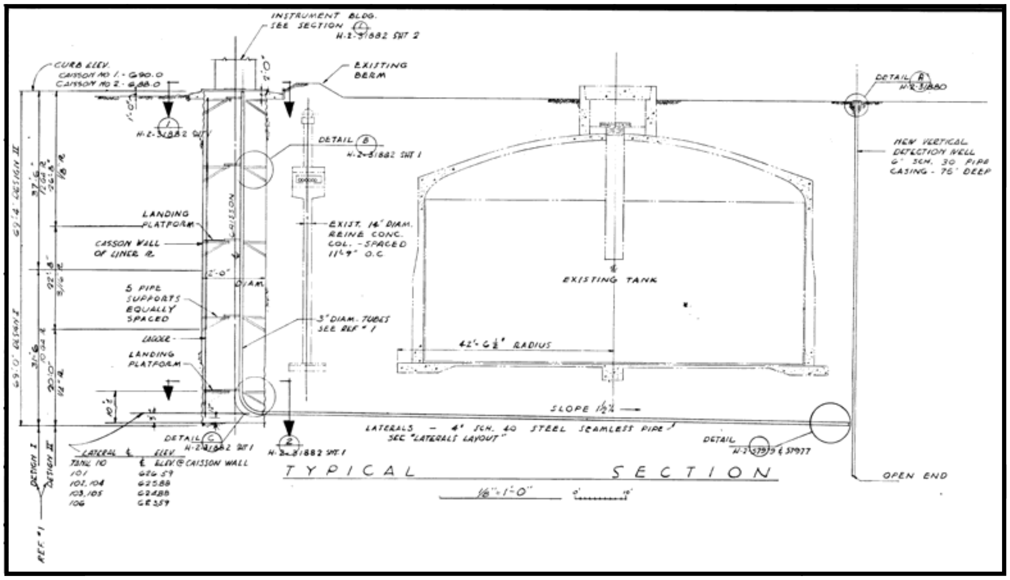


Fig. 1. Drawing of a typical section of a lateral installation in the "A" Tank Farm, from Hanford drawing# H-2-31880

DESCRIPTION OF THE EQUIPMENT USED

The Geophysical Logging Sonde

The geophysical logging sonde was segmented (flexible joint between each of the four detector sections) in order to traverse the tubing as it transitioned from vertical to horizontal. The sonde had three detectors, each with different sensitivity ranges:

1. In background and low contamination levels the NaI gamma detector (scintillating crystal and MCA for gamma spectra) was used.
2. The Green GM (Geiger-Muller detector) equivalent detector spanned the high gamma activity levels, and
3. The Red GM equivalent detector surveyed the highest gamma activity level.

When combined, these detectors span a large dynamic range (8 orders of magnitude), from less than 200 Bq kg^{-1} (5 pCi g^{-1}) to 1.11×10^{10} Bq kg^{-1} (300,000,000 pCi g^{-1}) eCs-137.

The main gamma-ray emitting constituent expected in the subsurface is Cs-137. The objective of the gamma survey is to measure soil concentrations as a function of distance along the lateral. Spectra acquired by the NaI detector identified Cs-137 as the dominant gamma emitting radionuclide in the soils beneath the tanks. Logging speed of the rapid scan gamma surveys was controlled to 4 ft $minute^{-1}$ (2×10^{-2} m s^{-1}). The survey data were processed as gross gamma logs and reported as Cs-137 concentration in pCi/g. A laptop computer was used to monitor encoder depth positions, control the winch motor, and record responses from the three detectors.

The NaI gamma detector contains a multi-channel analyzer, installed in a separate section of the flexible sonde assembly. Detector responses are converted to digital format within the logging tool, which significantly improves system stability.

Temperature in the laterals was not requested in the project RFQ. An experimental temperature sensor was installed in the multi-channel analyzer segment of the NaI gamma detector. Its primary purpose is to evaluate detector performance at various formation temperatures. This temperature is reported on the logging results to allow the relative temperature differences between the various tanks to be compared. The temperature sensor responses were reported as degrees-F, and converted to degrees-C in this paper. The highest temperature in each lateral is generally recorded near the center of the tank. The temperature response time was expected to be slow and may lag behind changes in the formation, because there are several layers between the sensor and formation. These layers are as follows:

1. The sensor is attached to the stainless steel chassis of the sonde, which slows down the response time,
2. The sonde housing is thin wall aluminum tubing,
3. The sonde housing is wrapped with Teflon tape to reduce friction with the Pipe Explorer^{TM} membrane,
4. The Pipe Explorer^{TM} membrane lines the lateral tubing,
5. Lateral tube is 3-inch (7.6 cm) pneumatic stainless steel tubing, and
6. Lateral tube is protected from formation pressures by 4-inch (10.2 cm) carbon-steel pipe.

Detector Calibrations

The gross gamma scintillation detector is a sodium-iodide (NaI) crystal. The NaI crystal is a 1-inch diameter by 1-inch long (2.54 cm by 2.54 cm) crystal. Because of its hydroscopic nature it is enclosed in a hermetically sealed can to maintain its integrity. Other components of the gamma detector are the high-voltage supply, photo-multiplier tube, pre-amp, and multi-channel analyzer. The settings of the detector components are fixed (i.e. set-up during assembly, prior to calibration) and are not adjustable by the field-logging engineer. The detector gain and lower threshold are set to record gamma ray activity with energies between 100 and 3000 keV. By comparison, the highest gamma ray energy from naturally occurring radionuclides is from Th-232, at 2614 keV. Coleman lantern mantles containing Th-232 are used as a field verifier at the beginning and ending of each daily logging activities to check detector resolution (integrity) and energy calibration (amplifier gain).

The NaI detector was calibrated for equivalent Ra-226 (e Ra-226) in gross gamma borehole calibration models located at U.S.-DOE Hanford Site near Richland, Washington. e Ra-226 is a measurement standard in the geophysical logging industry and is appropriate for gross gamma detectors to establish the activity levels of the naturally occurring radionuclides (potassium, uranium, and thorium, or KUT). Calibration was performed in the two most appropriate (lowest concentration) gross gamma calibration zones (SBA and SBU). The calibration algorithm used is documented in [4].

Also, the NaI detector and both GM detectors (Green GM equivalent and Red GM equivalent) were calibrated for Cs-137 in a newly established Cs-137 Calibration Well. The calibration for e Cs-137 (activity mass^{-1}) assumes that all of the gammas are due to the presence of Cs-37. The calibration for e Cs-137 was performed by using high-resolution spectral gamma log data collected by Stoller [5] at Hanford vadose well 299-W10-72 located in the 216-T-7 Crib. The concentration of Cs-137 was assigned from measurements at 0.3 m (1-foot) increments along the well depth. The Stoller instruments were calibrated at the Hanford borehole calibration facility, which is traceable to NIST standards.

The range of the Cs-137 concentration in the cesium calibration well (299-W10-72) is 7.4 Bg kg^{-1} to 1.48 x 10^6 Bg kg^{-1} (0.2 to 40,000 pCi g^{-1}). The sensitivity of the Red-GM equivalent detector is so low that it does not register statistically significant count rates in the cesium calibration well, thus it was not calibrated in this well. It was calibrated from survey data collected in Tank Farm laterals where enough zones of overlapping activity exist for both the Green and Red GM detectors, and the calibrated Green-GM was used as a reference. The details of the detector calibrations may be found in [1].

The Green-GM equivalent detector has substantially lower sensitivity than the NaI detector and is designed to measure high gamma ray flux. The Green-GM equivalent detector data were depth shifted to match the Stoller HPGe log data. Excellent agreement between raw count rate and Cs-137 activity indicated a low dead time correction, of approximately 0.5%.

The Red-GM equivalent detector cannot be calibrated in the cesium calibration well (299-W10-72) because of its very low sensitivity. Its highest count rate in the calibration well is less than 2 counts s^{-1}. Correspondingly, field data collected during surveys of the laterals were used to establish the relationship between the Green-GM equivalent detector and the Red-GM equivalent detector responses. Selected data intervals where the observed count rates are valid for both GM instruments were used to derive both the dead time correction factor and the Red-GM equivalent detector sensitivity factor.

Calibration Summary

The NaI logging instrument was calibrated for both e Ra-226 and e Cs-137 from the gross count rate. The Green-GM equivalent and Red-GM equivalent logging instruments were calibrated for e Cs-137 from the gross count rate. The dead time factor for each instrument was determined. The calibration coefficients and dead time constants are given in the Table I for each gamma tool used to survey the Tank Farm Laterals.

Table I. Summary of Calibration Coefficients and Dead Time Constants for the Geophysical Logging Sonde

Gross Gamma Tool	e Ra-226 Calibration Coefficient (Bg kg^{-1} c^{-1} s)	e Cs-137 Calibration Coefficient (Bg kg^{-1} c^{-1} s)	Dead Time Constant (μs)
NaI (1x1)	2.62	1.18 x 10^1	8.1
Green-GM Equivalent	N/A	4.303 x 10^4	160
Red-GM Equivalent	N/A	7.574 x 10^5	160

The Pipe Explorer™ Deployment System

The Pipe Explorer™ is a system designed to tow various characterization sensors into piping and duct systems through the use of an inverting membrane technology. In this application, the Pipe Explorer™ system was used to tow a custom spectral and gross gamma detector designed and operated by Pacific Northwest Geophysics (PNG) into selected laterals underneath high level waste tanks in the “A” and “SX” tank farms at the Hanford facility.

Figure 2 illustrates how the Pipe Explorer™ uses inverting membrane technology to deploy radiation detectors into pipes. The figure shows 8 panels numbered in sequence. Panel 1 shows the initial step, which is to load the appropriate length of membrane, sized for the pipe to be surveyed, into the membrane canister. To conduct a 100 m survey, 100 m of membrane will be loaded into the membrane canister. For the laterals surveys the membrane used was 6-mil (0.15 mm) thick, 5-inch (12.7 cm) lay-flat polyethylene tubing.

The canister extension is positioned with its outlet aligned with the pipe to be surveyed and the membrane canister is clamped onto the canister extension. The membrane is fed through the extension, inverted over the extension outlet and clamped in place. This starts the inversion front on the membrane.

The canister extension and membrane canister are then pressurized with air to between 7 and 21 kPa (1 and 3 PSIG). This causes the membrane to inflate and to invert into the pipe. The towing force in pounds that pulls the membrane into the pipe is approximately ½ the cross sectional area of the pipe in square inches multiplied by the canister pressure in PSIG. For the laterals surveys, with a 3-inch tubing ID and an applied pressure of 21 kPa (3 PSIG), approximately 62 N (14 lbs.) of towing force were generated.

When the membrane has been deployed ½-way into the pipe, the un-deployed end of the membrane presents its self in the canister extension. At this point the air pressure is relieved and the un-deployed end of the membrane is disconnected from the tether in the membrane canister. The membrane canister is replaced with a detector canister that is equipped with the necessary slip-rings to allow detector power and signal to pass through the canister. The appropriate detector is connected to the tether of the detector canister, and the front end of the detector harness is connected to the un-deployed end of the membrane in the canister extension. The canister and extension are again pressurized to the required deployment pressure causing the membrane to inflate again, and continue the inversion process into the pipe. The detector is then towed into the pipe. To retrieve the detector back out of the pipe, the air pressure is reduced to approximately 0.7 kPa (0.1 PSIG), just enough to keep the membrane inflated, and the tether is wound back onto the spool in the detector canister. It is necessary to keep the membrane inflated during the retrieval process to prevent it from slipping along the wall of the pipe, e.g. forcing it to go through the inversion process in reverse.

Separate canisters are used for membrane deployment and detector deployment because this allows for a more time efficient deployment process since the detector can usually be left connected to the tether in the detector canister. An additional feature of this procedure is that while a survey is being conducted in one pipe with the detector canister, the membrane canister may be loaded with membrane for the next survey to be conducted.

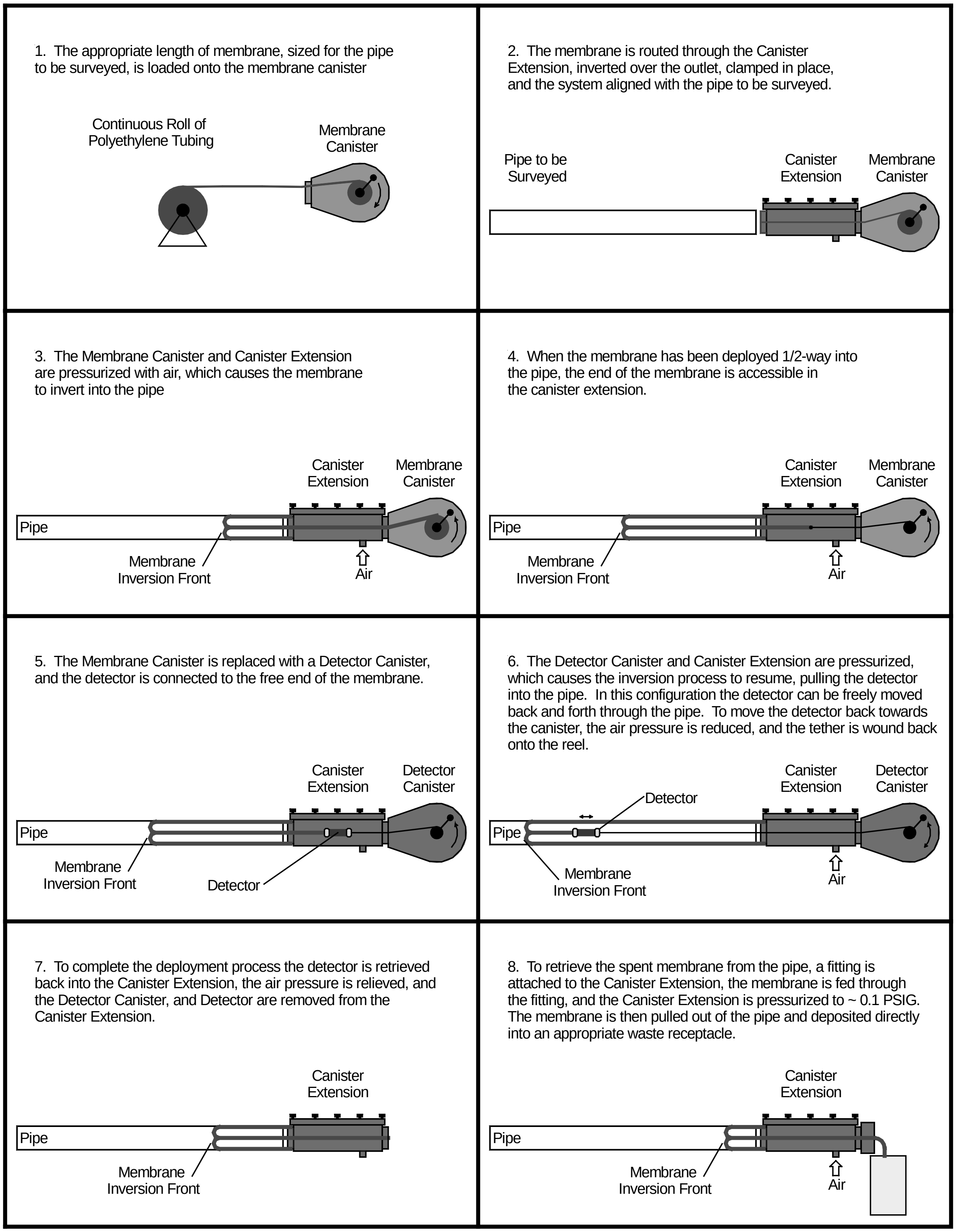
Radiological data for the surveys are usually obtained during detector retrieval because it is during retrieval that the detector rate can be best controlled. Once the detector has been retrieved back into the canister extension, the air pressure is again relieved, and the detector and detector canister are removed. The membrane inversion front is approximately ½-way into the pipe at this point. A custom fitting is attached to the inlet to the canister extension that acts like a sphincter. The un-deployed membrane passes through the sphincter, but it holds enough air pressure in the canister extension to allow the membrane to be kept inflated as the membrane is pulled from the pipe by hand and deposited directly into an appropriate waste receptacle.

There are several key features of the inverting membrane process that provide significant advantages in conducting radiological investigations in pipes and duct work.

1. Because the pipe is lined with a thin polyethylene membrane prior to the detector passing through it, any removable contamination in the pipe does not come into contact with the detector. This not only protects the detector from contamination, but ensures that a contamination is not “picked-up” on the detector and carried with it resulting in erroneous readings.
2. Because of the inversion process any contamination transferred to the membrane becomes on the inside of the membrane when it is inverted during retrieval. The operators never need handle the contaminated side of the membrane. As further protection against contaminating operators and equipment a special swipe fixture is attached to the canister extension during retrieval that allows the entire length of the tether to be swiped. These swipes are then surveyed in the field by radiological control technicians prior to extracting the spent membrane. This provides further assurance that the detector canister has not become contaminated due to a breach in the membrane.

Although not shown in the Figure 2, a short length of pipe is commonly used to connect the outlet of the canister extension to the pipe to be surveyed. This pipe is referred to as the *pre-pipe*. Use of pre-pipe allows the Pipe Explorer™ canister to be located at a convenient height and distance from the pipe access point.

The ‘pre-pipe’ served multiple purposes. First it allowed the canisters to be located outside of the lateral shacks where there was space to work, rather than inside the shacks where there was virtually no free space. Secondly, the use of a sanitary “Y” configured with a cam & groove cap for the horizontal to vertical transition, provided a convenient place to insert the rather long PNG tool into the piping system.



1. The appropriate length of membrane, sized for the pipe to be surveyed, is loaded onto the membrane canister

2. The membrane is routed through the Canister Extension, inverted over the outlet, clamped in place, and the system aligned with the pipe to be surveyed.

3. The Membrane Canister and Canister Extension are pressurized with air, which causes the membrane to invert into the pipe

4. When the membrane has been deployed 1/2-way into the pipe, the end of the membrane is accessible in the canister extension.

5. The Membrane Canister is replaced with a Detector Canister, and the detector is connected to the free end of the membrane.

6. The Detector Canister and Canister Extension are pressurized, which causes the inversion process to resume, pulling the detector into the pipe. In this configuration the detector can be freely moved back and forth through the pipe. To move the detector back towards the canister, the air pressure is reduced, and the tether is wound back onto the reel.

7. To complete the deployment process the detector is retrieved back into the Canister Extension, the air pressure is relieved, and the Detector Canister, and Detector are removed from the Canister Extension.

8. To retrieve the spent membrane from the pipe, a fitting is attached to the Canister Extension, the membrane is fed through the fitting, and the Canister Extension is pressurized to ~ 0.1 PSIG. The membrane is then pulled out of the pipe and deposited directly into an appropriate waste receptacle.

Fig. 2. Sketch showing the Pipe Explorer™ system deployment sequence

Temperature Considerations

The temperatures within the laterals were substantially elevated above that of ambient soil due to radiogenic heating from the waste. The elevated temperatures, combined with the small pipe diameter of the 3-inch (7.6 cm) pneumatic tubing and the relatively heavy weight of the PNG sonde presented something of a challenge for use of the Pipe Explorer™ system. The towing force generated at the inversion front of the membrane is approximately ½ of the cross sectional area of the pipe multiplied by the deployment pressure. Thus, deployment of a given detector/tether payload in a smaller diameter pipe requires a higher pressure than in a larger diameter pipe. Based on the weight of the PNG tool and the tether composition, it was estimated that the minimum required deployment pressure would be 19.3 – 20.7 kPa (2.8 – 3.0) PSIG in the 3-inch pneumatic tubing of the laterals.

Typical Pipe Explorer™ deployments use a 4-mil (0.1 mm) thick membrane material. Laboratory tests conducted prior to mobilizing the Pipe Explorer™ equipment to the field showed that the 4-mil (0.1 mm) membrane material would loose enough strength to be marginal in its ability to hold 20.7 kPa (3.0 PSIG) at even modestly elevated temperatures. Data available prior to the start of the field work indicated that temperatures within some laterals were at least 65.5° C (150° F), and could be higher. To ensure that the field deployments would proceed safely, a number of laboratory tests of membrane burst pressure were conducted at elevated temperature.

A 6-mil (0.15 mm) thick membrane material is commercially available as a stock item in the size needed for the 3-inch (7.6 cm) pneumatic tubing, i.e. 5-inch (12.7 cm) lay flat. Membrane thicker than 6-mil (0.15 mm) in a 5-inch (12.7 cm) lay-flat size is only available as a special order item and therefore requires a significant lead time (4-6 weeks). To cover the possibility of very high temperatures in the laterals ten rolls of 8-mil (0.20) membrane were obtained prior to deploying to the field. All deployments were, however, conducted using the 6-mil (0.15 mm) membrane material.

A small, manually operated Pipe Explorer™ canister was used to conduct the video surveys. This canister is typically used for station-to-station surveys, video logging, and other applications where a motorized control of the deployment process is not required. One of the benefits of a manually operated canister is that the operator can maintain a feel for the ease with which the deployment/retrieval is proceeding because of the direct mechanical coupling of the operator through the hand crank.

Initially a large motorized canister was used for deployment of the PNG gamma tool. This system was selected because of the requirement by PNG to have a motorized deployment system that could be controlled in real-time to vary the retrieval rate of the detector being deployed. This canister was used on the first several laterals surveyed in the A-Tank Farm. However, a different arrangement of equipment was used for later surveys conducted in the A-Tank Farm, and for all gamma surveys conducted in the SX-Tank farm.

Fig. 3 shows photos taken during one of the deployments in the “SX” Farm with the later and final equipment configuration. The left pane shows the membrane canister used to deploy the membrane, and the right pane shows the final equipment configuration used to deploy the PNG sonde. The change in equipment configuration was made for several reasons that will be discussed below. The principle change in the equipment configuration was the elimination of the large motorized canister, and its replacement with an existing motorized wench system from PNG, and a pressure pass thru for the detector cabling.

Fig. 3. Photo of the final Pipe Explorer™ equipment configuration used. The pane on the left shows the membrane canister, while the right pane shows the PNG winch and cabling configured with the Pipe Explorer™ canister extension.

The initial Pipe Explorer™ deployment was a video survey conducted in lateral # 14-03-03. This deployment proceeded as planned. The video camera deployed easily at a pressure of approximately 17.2 kPa (2.5 PSIG), was retrieved out of the lateral, and the used membrane retrieved and bagged. The initial deployments of the PNG gamma tool did not proceed as smoothly. The first deployment in 14-03-03 suffered a problem with the distance encoder that required a day to remedy. Subsequent attempts at deployment of the PNG tool revealed that the tool became stuck just as it was leaving the 90° elbow in the vertical to horizontal transition in the laterals. Moreover, because of the fact that the tether was completely contained within the canister pressure vessel in the motorized canister, it was difficult for the operator to determine exactly when and how the tool stopped deploying.

In an effort to remedy the difficulties in deploying the PNG tool, the tool segments were shortened wherever possible, and the way in which the tether was attached to the tool was made more flexible. Even with these modifications the deployments of the PNG tool remained difficult, and it was easy to get into trouble because of the operator’s lack of feel, having only the motor controls, a tension meter, and a slack indicator to ascertain how the tool deployment was progressing.

In addition to these difficulties with the equipment configuration, there was another problem that plagued the early attempts at deploying the PNG gamma tool. The symptoms were that the first deployment into a given lateral went smoothly, but the second deployment always encountered difficulty, mostly during retrieval of the tool and subsequently the used membrane. Various mechanisms were postulated to explain the deployment difficulties, but the actual mechanism in operation could not be ascertained from the available data.

The final remedy to these difficulties was two-fold. First, a strategy was adopted where only one deployment in a given lateral was attempted. Since the primary purpose of the characterization effort was to obtain the gamma logs of the laterals, it was decided to abandon the video surveys in favor of the gamma surveys. The second part of the solution came from reconfiguring the deployment system used to deploy and retrieve the PNG tool, see Figure 3.

Elimination of the large canister was accomplished by engineering a pressure fitting on the back of the canister extension that would allow the logging cable conventionally used by PNG to be passed into the extension with no significant loss of pressure. This allowed the logging cable to be fed into the canister extension directly from an existing PNG wench drum. A hinged "stiff arm" fitted between the canister extension and the wench drum ensured that the distance between the wench and the extension would remain fixed for a given deployment. The distance encoder mounted in the canister extension was still used to determine tool position and deployment/retrieval speed.

The primary objective in eliminating the deployment canister was to get the tether, or in this case the logging cable, out in the open so that the operator could feel the tension on the cable, and if appropriate manually feed it into the pre-pipe so that the towing force applied to the PNG tool could be entirely used for pulling the tool, not shared between pulling the tool and pulling the cable. Another benefit of this configuration was the elimination of the two 90° elbows that were needed when the large deployment canister was used. Elimination of these 90° elbows substantially reduced the amount of towing force that was required to pull the cable off of the canister reel and made it available for towing the tool. Once these two changes were made, the work pace picked up substantially and reasonable progress was made toward obtaining the needed gamma surveys of the laterals.

RESULTS

Table II lists the survey distances and the tank shadow distances for the laterals surveyed. The various distances needed to compute the vertical to horizontal transitions, total lateral lengths, and the tank shadows on top of the laterals were obtained from Hanford drawings H-2-31880, H-2-31881, and H-2-31882.

Table III lists a summary of the radiological results from the gamma surveys. It is noteworthy that three tanks that were assumed to be leakers (A-103, A-104, and SX-110) do not exhibit the significantly elevated gamma signatures of other tanks that are also assumed to be leakers.

Figure 4 shows two logarithmic scale plots of survey results from two different laterals. All three detector results sets are plotted on one log scale over their appropriate response ranges. The plot on the left is from the center lateral under Tank A-103, while the plot on the right is the central lateral under Tank A-105. Both tanks are categorized as assumed leakers. The survey results from Tank A-103 do not, however, exhibit any significantly elevated Cs-137 activity in the soil near the laterals. The elevated gamma feature at a distance of 20 m (65 ft.) is believed to be from a verification source in the bottom of the caisson.

Table II. Survey Distances and Calculated Tank Shadow Distances of the Laterals Surveyed

Tank Farm	Lateral ID	Max Survey Depth (m)	Distance to Horizontal (m)	Distance Center Caisson to Tank Edge (m)	Length Tank Shadow (m)	Start Tank Shadow (m)	End Tank Shadow (m)	Horizontal Length from As-Built Drawing (m)	Total Length (ground-level to end lateral) (m)
A	14-03-01	53.1	19.9	12.3	18.0	31.8	49.8	33.5	53.5
A	14-03-02	50.5*	19.9	11.0	23.1	30.4	53.6	36.6	56.5
A	14-03-03	51.2	19.9	12.4	18.0	31.8	49.9	33.5	53.5
A	14-04-01	52.5	20.2	12.3	18.2	32.0	50.2	33.5	53.8
A	14-04-02	56.1	20.2	10.8	23.3	30.5	53.8	36.6	56.8
A	14-05-01	52.2	19.9	12.3	18.0	31.8	49.8	33.5	53.5
A	14-05-02	55.2	19.9	11.1	23.1	30.5	53.6	36.6	56.5
A	14-05-03	51.2	19.9	12.3	18.0	31.8	49.8	33.5	53.5
SX	44-07-01	45.4	19.4	6.0	19.0	24.9	43.9	27.4	46.8
SX	44-07-02	48.3	19.4	5.2	23.1	24.0	47.1	30.5	49.9
SX	44-07-03	45.8	19.4	6.0	19.0	24.9	43.9	27.4	46.8
SX	44-08-01	50.1	19.3	12.1	18.3	30.8	49.2	33.5	52.8
SX	44-08-02	54.8	19.3	10.9	23.0	29.7	52.7	36.6	55.8
SX	44-10-01	43.5	19.2	4.9	19.5	23.6	43.2	27.4	46.7
SX	44-10-02	50.2	19.2	4.4	23.1	23.1	46.3	30.5	49.7+
SX	44-10-03	44.0	19.2	5.1	18.0	23.8	41.8	27.4	46.7
SX	44-11-01	50.1*	19.5	11.3	20.8	30.2	51.0	30.5	50.0+
SX	44-11-02	50.9	19.5	10.6	23.2	29.6	52.7	33.5	53.0
SX	44-11-03	49.3	19.5	11.9	18.2	30.8	49.0	30.5	50.0
SX	44-12-01	49.3*	19.6	10.5	20.0	29.5	49.5	33.5	53.1
SX	44-12-02	54.7	19.6	9.7	23.0	28.7	51.8	36.6	56.1
SX	44-12-03	51.4	19.6	11.2	18.1	30.2	48.2	33.5	53.1
SX	44-15-01	46.9	19.6	6.6	19.6	25.6	45.2	27.4	47.0
SX	44-15-02	49.1	19.6	5.8	23.1	24.8	47.9	30.5	50.0
SX	44-15-03	46.5	19.6	7.2	16.8	26.2	43.0	27.4	47.0

*Short Survey (does not extent past end of tank shadow)

+Survey Length (Max survey Depth) is greater than computed length of lateral (Total Length)

Table III. Summary of Gamma Results and Temperature Measurements for the Laterals Surveyed.

Lateral ID	Tank Farm	Gamma Survey Date	Max Survey Depth (ft)	Maximum Cs-137 (Bq kg^{-1})	Max Cs-137 Depth (m)	Maximum Temperature (deg-C)	Max Temp Depth (m)
14-03-01	A	Apr 19,2005	53.1	Background		33	26.8
14-03-02	A	Mar 31,2005	50.5	Background		33	26.8
14-03-03	A	Mar 21,2005	40.7	Background		32	18.3
14-04-01	A	Apr 20,2005	52.5	Background		48	30.8
14-04-02	A	Apr 21,2005	56.1	Background		50	30.2
14-05-01	A	Apr 19,2005	52.2	1.9×10^{7}	48.8	56	32.9
14-05-02	A	Apr 19,2005	55.2	1.7×10^{8}	29.2	59	32.3
14-05-03	A	Apr 13,2005	51.2	1.3×10^{9}	47.5	53	32.9
44-07-01	SX	May 2,2005	45.4	2.0×10^{8}	29.6	46	26.5
44-07-02	SX	May 2,2005	48.3	2.6×10^{9}	40.3	51	28.0
44-07-03	SX	May 3,2005	45.8	3.0×10^{8}	40.0	48	27.4
44-08-01	SX	May 12,2005	50.1	4.4×10^{9}	32.5	51	30.5
44-08-02	SX	May 13,2005	54.8	7.6×10^{9}	30.2	57	31.7
44-10-01	SX	May 12,2005	43.5	Background		43	24.1
44-10-02	SX	May 12,2005	50.2	Background		44	25.3
44-10-03	SX	May 12,2005	44.0	Background		42	24.7
44-11-01	SX	May 10,2005	50.1	Background		44	29.3
44-11-02	SX	May 11,2005	50.9	2.3×10^{5}	38.6	48	29.6
44-11-03	SX	May 11,2005	49.3	Background		47	30.5
44-12-01	SX	May 4,2005	49.3	1.8×10^{5}	35.7	41	30.8
44-12-02	SX	May 5,2005	54.7	2.7×10^{8}	39.7	44	30.8
44-12-03	SX	May 5,2005	51.4	1.6×10^{6}	35.0	43	32.6
44-15-01	SX	May 9,2005	46.9	5.9×10^{6}	25.7	31	22.6
44-15-02	SX	May 10,2005	49.1	5.6×10^{3}	26.7	31	22.9
44-15-03	SX	May 10,2005	46.5	1.1×10^{9}	26.7	32	22.9

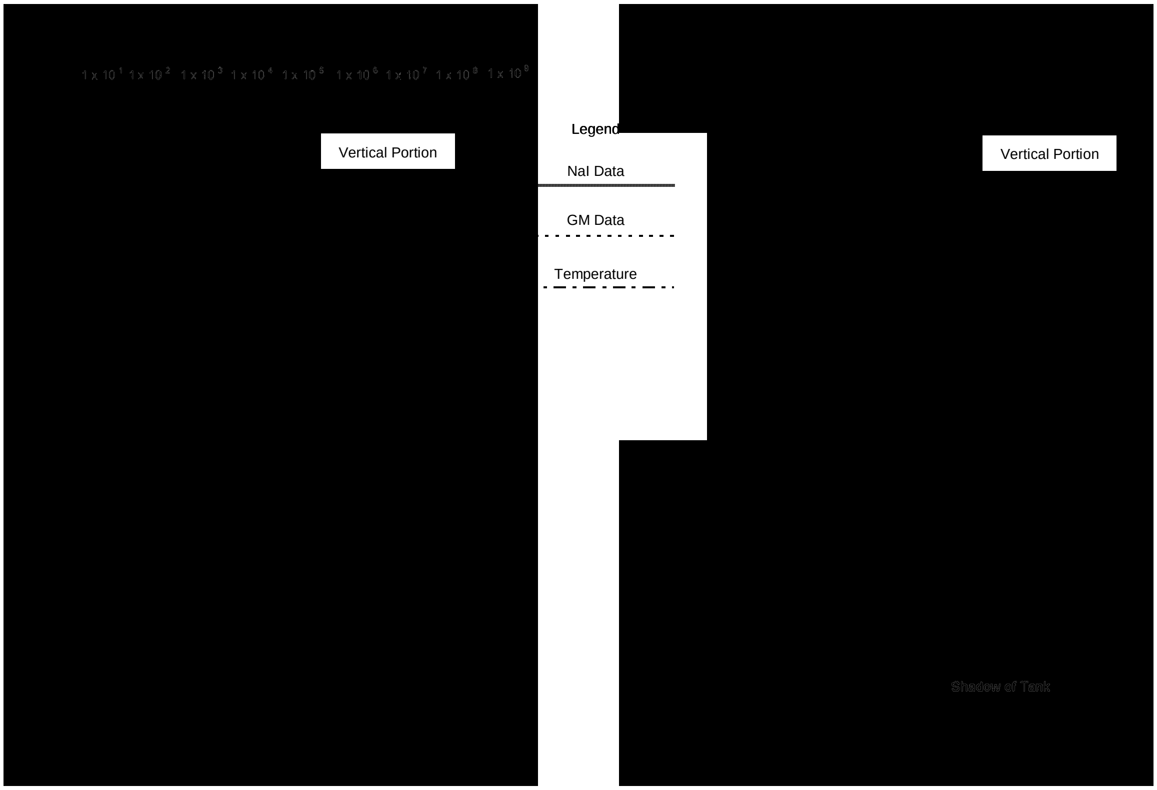


Fig. 4. Logarithmic scale plots of survey results for the center lateral from Tank A-103 (14-03-02) and Tank A-105 (14-05-02).

CONCLUSIONS

The condition of the Tank Farm laterals was unknown because there has been no entry into the laterals since at least 1993 for a few tanks, since 1989 for most tanks, and surveys of many tanks stopped as early as 1986.

The calibrated logging equipment used in these surveys collected high quality gamma surveys of 25 laterals (8 in the A-Tank Farm, 17 in the SX-Tank Farm). The three gamma detectors (NaI Scintillator and two GM’s) were calibrated for eCs-137 (pCi/g) and have a detection range from less than 200 Bq kg^{-1} (5 pCi g^{-1}) to 1.11 x 10^{10} Bq kg^{-1} (300,000,000 pCi g^{-1}) eCs-137, spanning 8 orders of magnitude.

The distribution and concentration of Cs-137 in the soils under several tanks in the “A” and “SX” Tank Farm have been measured for the first time, from background levels to the maximum level of activity. The historic Tank Farm surveys have restricted calibration pedigrees and detectors did not measure low gamma activity levels.

The gamma surveys of all laterals, except the two with the highest concentration (44-08-01 and 44-08-02) are within the detection range and count rate capabilities of the logging system used. Survey results of these two have an unresolved condition, and the computed eCs-137 concentration may be low.

It is noteworthy that the survey results for some tanks that are assumed to be leakers (A-103, A-104, and SX-110) do not show the significantly elevated gamma activity that is clearly measurable in other assumed leaking tanks.

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