Contract No:

This document was prepared in conjunction with work accomplished under Contract No. DE-AC09-08SR22470 with the U.S. Department of Energy.

Waste Management 2010
WM Symposia
Phoenix, Arizona
March 6 – 10, 2010
Paper No.10368

Savannah River Site

Tank 18 and Tank 19 Wall Sampler Performance

Robert A. Leishear
Savannah River National Laboratory
robert.leishear@srnl.doe.gov

Mark Fowley
Savannah River National Laboratory
mark.fowley@srnl.doe.gov

George Thaxton
Savannah River Remediation, LLC
donald.thaxton@srs.gov

William Vetsch
ACTS, Inc.
William.Vetsch@srs.gov

Thomas France
Savannah River Remediation, LLC
thomas03.france@srs.gov

Tim Steeper
Savannah River National Laboratory
timothy.steeper@srnl.doe.gov

Jerry Corbett
Savannah River National Laboratory
jerry.corbett@srnl.doe.gov

Rick Minichan
Savannah River National Laboratory
richard.minichan@srnl.doe.gov

Bruce Martin
Savannah River Remediation, LLC
bruce.martin@srs.gov

ABSTRACT

A sampling tool was required to evaluate residual activity (µCuries per square foot) on the inner wall surfaces of underground nuclear waste storage tanks. The tool was required to collect a small sample from the 3/8 inch thick tank walls. This paper documents the design, testing, and deployment of the remotely operated sampling device. The sampler provides material from a known surface area to estimate the overall surface contamination in the tank prior to closure.

The sampler consisted of a sampler and mast assembly mast assembly, control system, and the sampler, or end effector, which is defined as the operating component of a robotic arm. The mast assembly consisted of a vertical 30 feet long, 3 inch by 3 inch, vertical steel mast and a cantilevered arm hinged at the bottom of the mast and lowered by cable to align the attached sampler to the wall. The sampler and mast assembly were raised and lowered through an opening in the tank tops, called a riser. The sampler is constructed of a mounting plate, a drill, springs to

This manuscript has been authored by Savannah River Nuclear Solutions, LLC under Contract No. DE-AC09-08SR22470 with the U.S. Department of Energy. The United States Government retains and publisher, by accepting this article for publication, acknowledges that the United States Government retains a non-exclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for United States Government purposes.

provide a drive force to the drill, a removable sampler head to collect the sample, a vacuum pump to draw the sample from the drill to a filter, and controls to operate the system. Once the sampler was positioned near the wall, electromagnets attached it to the wall, and the control system was operated to turn on the drill and vacuum to remove and collect a sample from the wall. Samples were collected on filters in removable sampler heads, which were readily transported for further laboratory testing.

INTRODUCTION

Wall samples were successfully machined from Tanks 18 and 19 in FTF (F-Area Tank Farm), SRS (Savannah River Site) to establish the residual activity (μCuries) prior to permanent closure of these two 85 feet diameter, 1.3 million gallon, steel lined, radioactive waste storage tanks (Figure 1). SRNL (Savannah River National Laboratory) was authorized by SRR (Savannah River Remediation, LLC) to fabricate and test a sampling device to obtain these samples. The sampling device to be utilized was based upon a sampler originally designed by ORNL (Oak Ridge National Laboratory [1 and 2]) to sample concrete tanks, and a sampler design that was used at West Valley [3] to sample steel line tanks. SRNL modified the ORNL sampler design to ensure success in SRS waste tanks (Figure 2). The modifications included an innovative identification and correction of equipment resonance problems which would have caused failure of the sampler in SRS tanks. This paper was condensed from an SRNL report (Leishear and Fowley [4] that was issued to describe the development, fabrication, testing, and deployment of the sampling device.

To reduce costs, a simplified sampler and mast assembly was designed, tested, and installed in the waste tanks (Figure 3). In comparison, West Valley deployed the sampler using a reported 50 million dollar robotic arm. Based on their work, SRS developed a simplified and improved design. Total costs were less than five million dollars to obtain wall samples, where the cost of the sampler fabrication and evaluation was approximately $400,000 and estimated costs for sample analyses are $300,000 to $400,000. A 45 million dollar cost savings was realized by SRS from the novel design.

Fabrication of two identically designed wall samplers and a performance evaluation were required, along with full scale testing and sampling activities in Tank 18 and Tank 19. In short, the sampler machined small samples from the tank walls, and the mast positioned the sampler into the waste tanks to machine these wall samples to establish the activity of waste tank wall surfaces. Much of the testing was performed using the same sampler that was installed in the waste tanks to collect samples. The other sampler was used to complete SRNL testing parallel to FTF installation and testing. After testing the sampler at SRNL, the sampler was attached to the mast assembly, and the fully assembled sampler and mast assembly were installed by crane and tested at a non-radioactive SRS full scale testing facility, which is an 85 feet diameter tank with overhead structural steel platforms. Once testing was complete in the Full Tank, the sampler and mast assembly were transported to FTF, and samples were taken from the Tank 18 and Tank 19 at two different elevation ranges in both tanks by SRR. Additional analysis will be provided by SRNL to identify the total activity and radionuclides in the collected samples which were transported to SRNL, and those test results will be identified in a later report. This paper provides a description of sampler fabrication, testing, and evaluation as well as a description of sampling in Tanks 18 and 19.

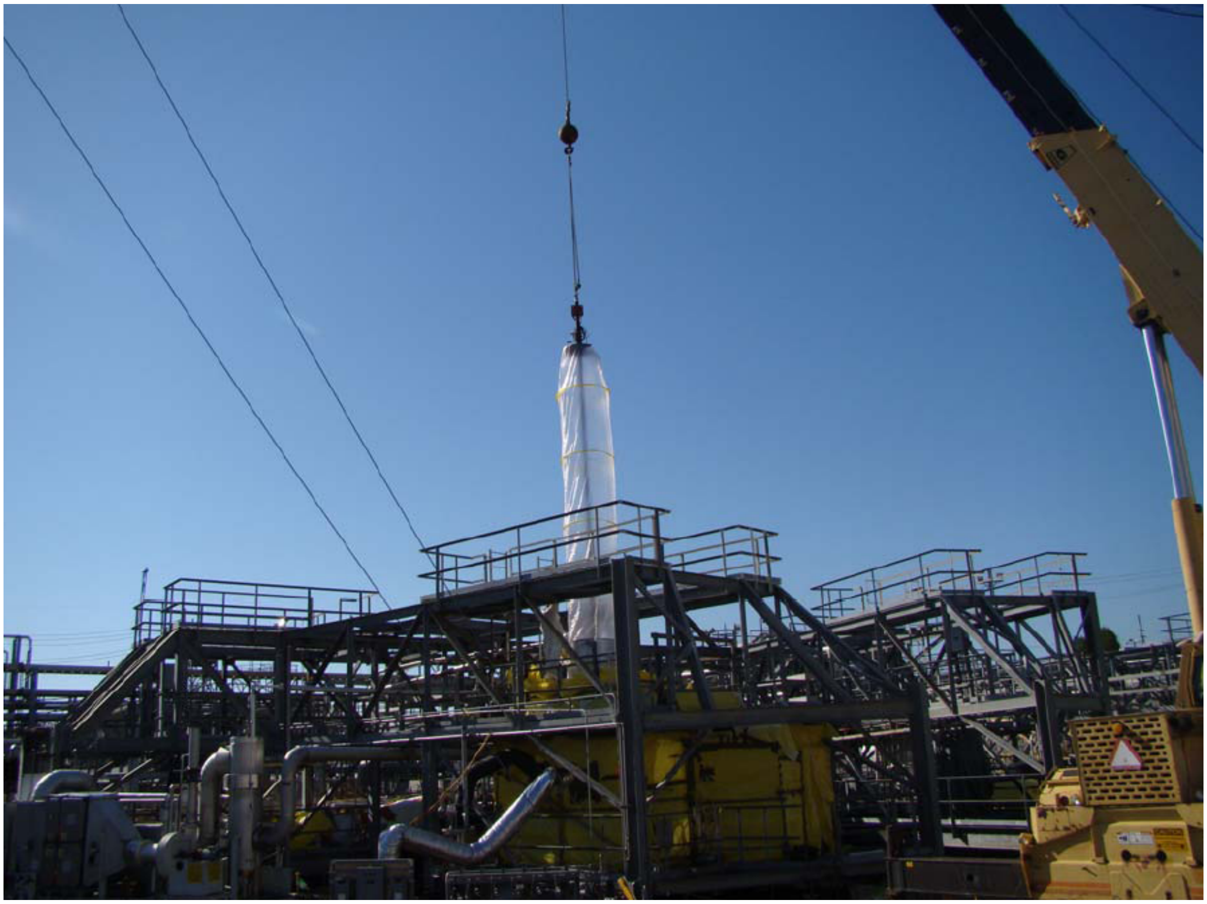


Figure 1: Installation of Sampler and Mast Assembly in an SRS Waste Tank

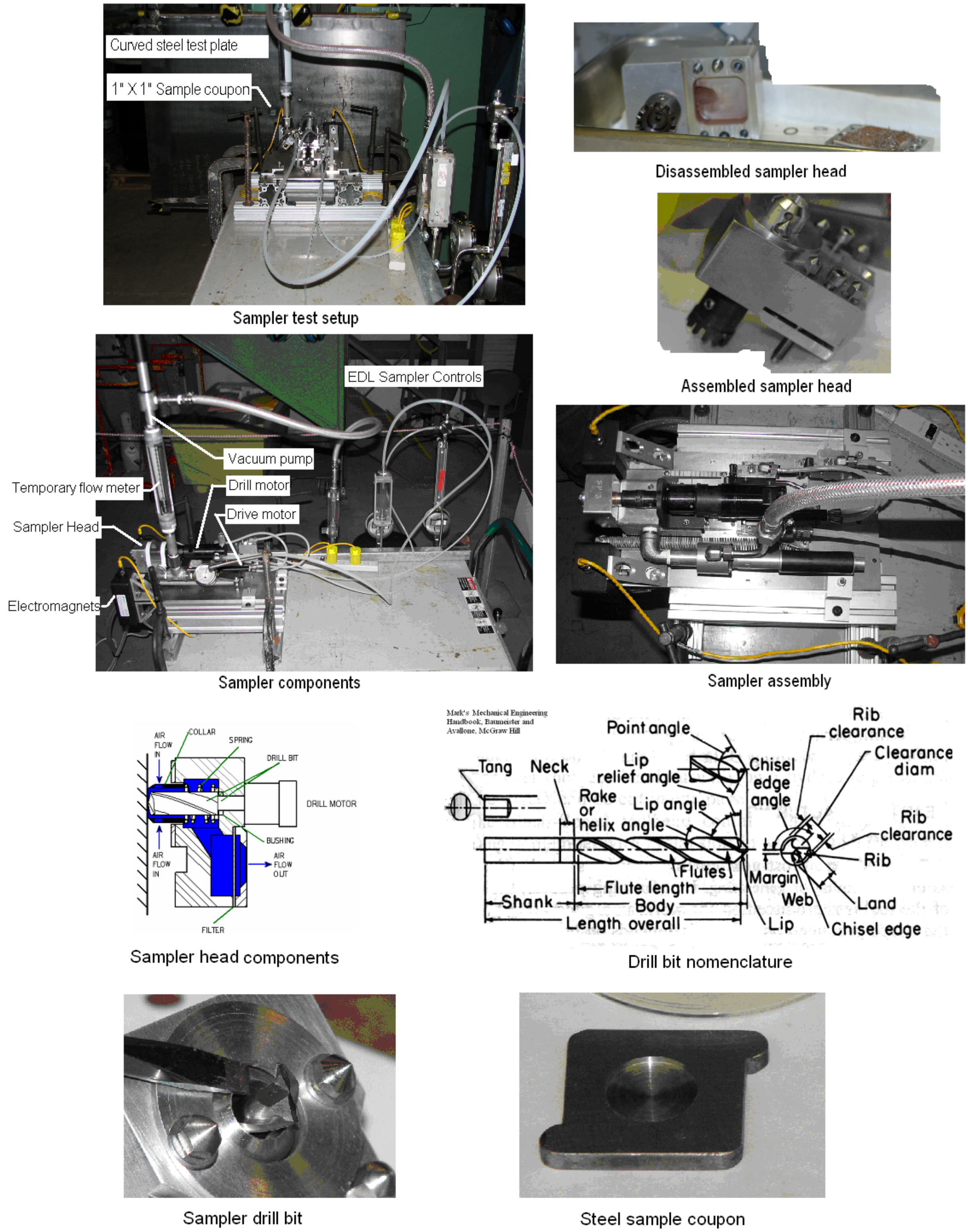


Figure 2: Sampler Design and SRNL Lab Testing

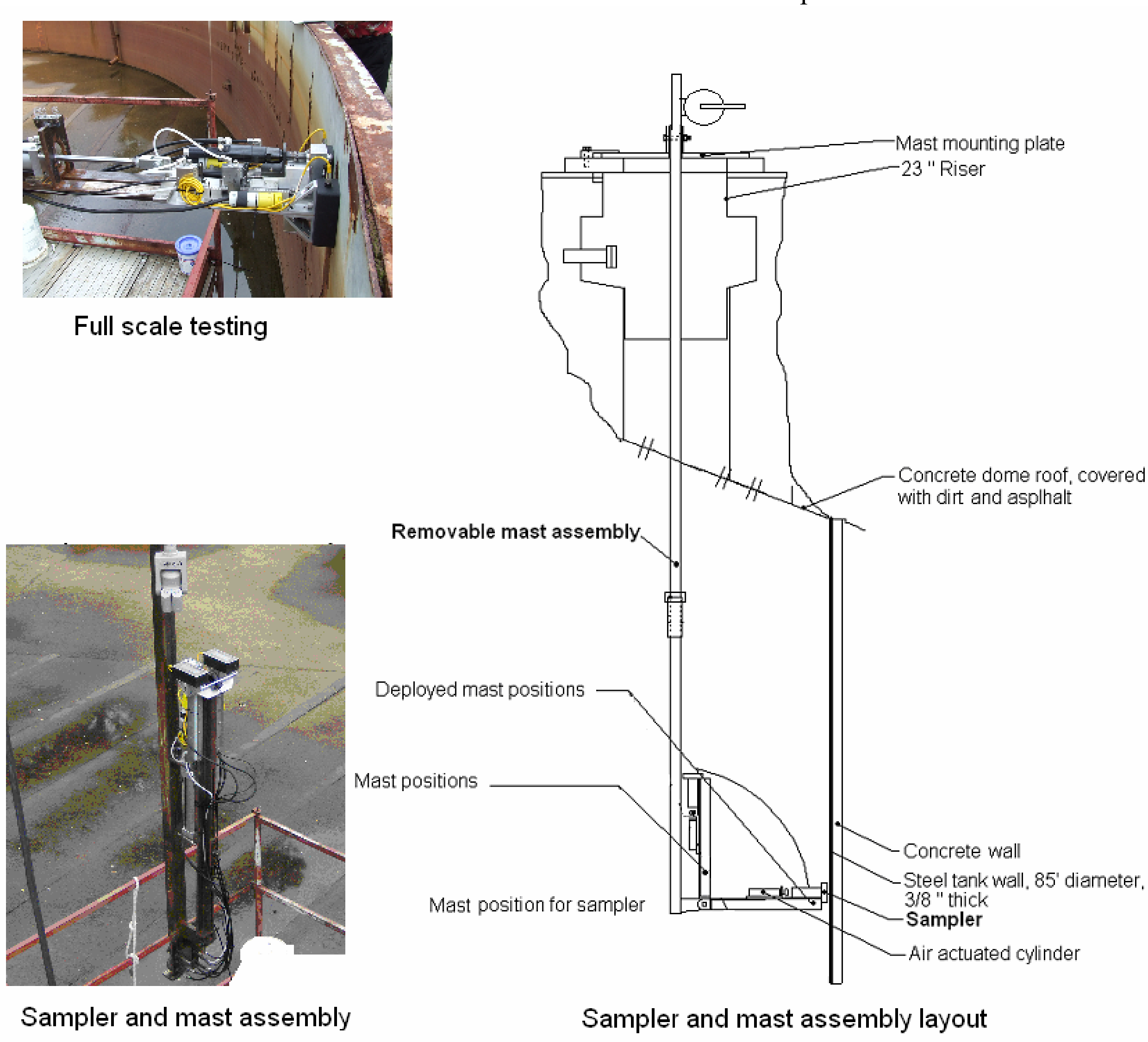


Figure 3: Mast Assembly Design and Full Scale Testing

SAMPLE REQUIREMENTS

The sampler and the mast were used to collect samples from the tank walls at two different elevation ranges in each tank (Table 1). At each elevation, the sampler was designed to drill shallow holes (0.500” diameter by 0.060“, or less, maximum depth) in the walls of the nuclear waste storage tanks to obtain samples of the waste on the wall, the corrosion layer on the wall, and the base metal below the corrosion. One set of samples was collected where minimum corrosion was expected, and the other set of samples where maximum corrosion was expected. Success was achieved when the sampler machined down to exposed, shiny steel surfaces, materials were collected from the surfaces, and sample surface areas were established.

Table 1: Elevation Requirements for Tank Samples

Sample requirement	Tank 18, Upper	Tank 18, Lower	Tank 19, Upper	Tank 19, Lower
Elevation from tank bottom, ft	> 15	6 - 15	> 7	6 - 7

WASTE TANK SURFACES

Corrosion and waste accumulated on the walls of Tank 18 and 19. Note that salt accumulation in Tank 19 appears to be negligible, while waste may be as thick as 3/8 inch, or more, in some areas of Tank 18. The exact thickness of waste was difficult to distinguish, but the shadows from the nuts on the 5/8 " diameter bolts on the tank stiffener were compared to the shadows of the waste to provide a crude approximation of the waste thickness. Since a primary goal of sampling was to discern the activity contained in the tank wall corrosion layer, the sampler was positioned to ensure that it was located away from thick waste deposits on the waste tank walls. In addition to the corrosion layer samples, material was also sampled from the thicker waste deposits for characterization of this material.

ANALYSIS

Activity analysis was the reason for obtaining the tank wall samples discussed in this report, where the micro-Curie content will be measured for the samples, and radionuclides will be identified in a separate report. To better handle the wall samples, a removable sampler head is part of the sampler, and once the wall samples were collected in this head, the radioactive samples were transported to SRNL for analysis. Along with the surface areas associated with the samples, those test results will be provided to SRR engineering to further evaluate residual nuclear waste activity on the tank walls in Tank 18F and Tank 19F. This report is confined to a discussion of the fabrication and testing of the sampler at SRNL and its use to collect samples from the waste tanks. In particular, the sampler collection efficiency and the estimated surface area for each sample was required, i.e., what percentage of material drilled from the wall was collected by the sampler in laboratory conditions and what was the surface area for samples transported to SRNL for analysis?

SRNL EQUIPMENT DESCRIPTION

The SRNL equipment required for testing consisted of samplers, removable sampler heads for the samplers, a curved wall test plate installed at SRNL to mimic the tank walls, and removable sample coupons used to validate sampler operation. Attached to each sampler was a removable sampler head, which contains a drill bit to obtain the samples and a filter to collect machined particles as they are vacuumed from the wall surface. The drill bits were end mills modified to have an approximate 170º drill point angle. The sampler heads are self contained units, which were transported to the lab at SRNL after samples were obtained to process the samples contained in the sampler heads. The wall plate was a 4 feet by 3 feet curved plate installed, and the sample coupons were 1 inch by 1 inch steel plates, which were bolted to the wall plate for machining by the sampler. The sampler was attached to the wall plate by electromagnets while samples were drilled from the plate.

SRNL Sampler Assembly

The main components of the sampler are the drill motor, the linear motor (drive motor), the vacuum eductor, sampler head, and controls. Material was machined from the wall, and passed through the sampler head where it was collected on the sampler filter. The SRNL modifications included changes in the controls, the mounting plate, springs, filter selection, and added electromagnets.

SRNL Test Results

Determinations of sampler collection efficiencies were considered for steel and hygroscopic salt coated steel surfaces. Collection efficiencies for steel were established above 97.4 %. Collection efficiencies for collecting only corrosion products, or rust, were not established, and the effect of salt liquefaction was not fully investigated. Efficiencies for collecting waste like that observed in Tank 18 were not directly evaluated because exact matching waste simulant coatings were not used on the test coupons

SRR MAST AND SAMPLER COMPONENTS

The mast design used supplied sampler and sampler heads, and the completed assembly consisted of several major components. The mast assembly was encased in a flexible plastic sleeve to maintain radioactive contamination control. Although not used in full scale testing, the sleeve connect\ed to a yellow plastic hut built for working with the sampler, and as the mast was lowered into a tank, the sampler was accessed in the hut. The base of the sampler was a 3 inch thick plate designed to cover 23 inch riser openings at the tank tops. The vertical mast was raised, or lowered through this plate and fixed in position to obtain required heights for wall samples. The cantilevered arm was hinged at the bottom of the mast, and the controls were connected at the top of the mast. The sampler was positioned near the end of the arm, and was lowered into position using a cable connected to a manually operated winch, which was located above the tank. When the arm was lowered, a level was observed on the arm with a remote camera to level the arm to the correct elevation in the tank at either FTF or during full scale testing. Once the arm was leveled, an air actuated cylinder then guided the sampler along the arm until the electromagnets touched the wall. A mast mounted camera was then used to ensure that the electromagnets were properly aligned before energizing the electromagnets. The level was re-checked, and sampling was performed. To obtain samples, the sampler control system was operated to collect a sample from the wall. A mast mounted camera and a fixed focal length camera mounted to the bottom of the sampler were used to determine that the sample was complete. Although a recommended time to machine a sample was used to direct the sampling effort, success was established by simply looking at the wall surfaces after drilling, to observe shiny steel. After collecting a sample, the mast was raised until the sampler head was accessible in the hut. Extended tools were then used to disassemble the captive hardware on the sampler head and minimize personnel radiation exposure. The head was then placed in a paint can for transport. The sampler head was then changed to repeat the process for another sample, or the mast was removed from the tank.

MAST AND SAMPLER FULL SCALE TESTING

To ensure sampling success in the waste tanks, the completed mast and sampler were evaluated during full scale testing. Evaluation at the mockup facility consisted of installing the mast by crane through a full scale riser opening, lowering the mast into position, operating the sampler, removing the mast assembly by crane, and removing and packaging a sample. These steps were performed using the same mast mounted camera equipment available to FTF. Other than the huts at the tank tops and contamination concerns, full scale testing conditions were comparable to FTF. A few minor changes were made to the mast, but it functioned as designed, and workers learned to operate the equipment efficiently before working in FTF. The first holes were drilled in a clean ground surface on the Full Tank wall. The initial attempts to drill rusted surfaces were ineffective ineffective.

Rust Effects on Drilling

The sampler was shown to drill unreliably on rusted surfaces, which meant that similar results could be expected in FTF. Typically, only one or two holes could be drilled before the bit became dull and drilling could not proceed. Occasionally, the mast was pushed by hand to obtain a sample. In one case, a tested sampler would not drill a hole, and the sampler was returned to SRNL where it successfully drilled a hole in the SRNL wall test plate, using the spare sampler. Also, a standard portable drill successfully drilled holes in the wall. SRNL investigated and resolved the problem.

Corrective Actions for Sampler Resonance

Materials testing and vibration analysis were used to resolve the issue of ineffective drilling. First, hardness testing showed that the hardness of the Full Tank wall was comparable to plate materials tested at SRNL, where portable Vickers hardness testing equipment was used to measure the force on a small striker. This data was converted to Brinnel hardness', and materials were eliminated as a major contributor to failure. Following hardness testing, vibration analysis was performed. The vibration of the drill bit chattering was measured, the natural frequency of the spring was measured, and the two frequencies were compared to show that the system was resonant. For resonance to occur, one of the natural frequencies of a structural component must be excited by a cyclic force of the same frequency. In this case, the frequency of drill bit chattering due to motor rotation equaled the spring frequency (cycles per second), and the system was resonant, or unstable. The soft rust material permitted chattering to start at the drill bit tip, causing the bit to oscillate on and off of the surface, which increased the wear rate of the drill bit.

Although resonance was not previously identified, the chattering problems at West Valley, Oak Ridge, and now SRS were clearly related to system resonance of the drill / spring system. Once the springs were changed, which permitted drilling of six holes in the rusted tank wall surfaces during full scale testing. Since only two holes were planned to be drilled with each sampler head, this improvement was adequate to move the sampler assembly to FTF. Further improvements to drill bit life could have been made by modifying the drill bit relief, rake, and point angles; using a different spring design; or other alternatives; but the design was complete. Holes were successfully drilled in rusted surfaces.

MAST AND SAMPLER INSTALLATION IN FTF

The mast assembly was lowered by crane into the two tanks until the desired sampling elevations were reached in each tank. Sampler operations were similar to those performed during full scale testing, but an additional video camera was installed in another tank riser to provide an overall view of the mast and sampler.

FTF SAMPLES

The performance of the sampler varied between Tank 18 and Tank 19. Even so, adequate samples were collected from each tank at the required elevations. The initial unsuccessful samples are simply referred to as first sampler and second sampler. Results that completely fulfill sampling requirements are referred to as Tank 18 upper sample, Tank 18 lower sample, Tank 19 upper sample, Tank 19 lower sample, and scale sample.

While water washed in 2003, the Tank 18 walls had accumulated waste coatings that prevented the electromagnets from operating properly. Several attempts to collect a sample failed, but at least one sample was obtained at each of the required elevations, and sufficient material was collected for SRNL analysis. Surface areas were conservatively estimated to be less than the actual surface areas, where the actual surface area of collected material may exceed the calculated surface area by as much as 75%, or more. That is, more material may have been collected in the sample head than that which was collected on the bare metal surface. Surface areas were estimated to determine the activity (μCuries) per unit area for the sample areas only.

When the upper sample was collected, the sampler and arm were wedged between the tank wall and the transfer pump. When the sampler was operated to collect the upper sample, a large vibration response due to drill bit chattering at the wall vibrated the sampler violently between the wall and the transfer pump. The fact that the effects of resonance had been reduced, but not eliminated, indicated that the sampler would have vibrated with forces many times higher if the spring design had not been changed, and a sample would not have been collected. Even so, a sample was ground from the wall steel surface as the drill bit scraped horizontally along the tank wall.

For the lower steel sample, the sampler did not initially collect material. The mast was shaken at the tank top, and the drill bit scraped down along the wall and ground off a sample, which included surface steel from the tank wall.

In Tank 19, the walls were cleaned by pressure washing prior to initiation of sampling and the sampler drilled holes as expected. Two holes were drilled with each of two samplers and the samplers were transported to SRNL. Surface areas were simply equal to the area of the drilled hole. After delivery to SRNL, all returned sampler heads were disassembled and carefully cleaned to ensure that all material was collected for further analysis.

SAMPLER MATERIAL COLLECTION FOR TANKS 18 AND 19

In Tank 18, material thicknesses affected material sampling and varied from 1/16" to approximately 3/8" during testing, where the exact thickness was not determined. Sample results varied for each sampler head. Five discrete locations were sampled with the first sampler head, and two locations were selected for each of the other three heads. The first sampler head collected a scale material which looked like small, reddish brown, dried clay like, pebbles about 1/8 of an inch in size which was easily cleaned from the sampler head surfaces (2000 mRem extremity). This sampler head was used at multiple locations and both higher and lower sample elevations. The second sampler head collected negligible material even though chips appeared to be removed from the waste during sampling. The third sampler head collected a fine, brown, dust like material which could not be brushed from the sampler head surfaces and steel chips from machining the surface (1500 mRem extremity). The fourth sampler head collected a small amount of black, dust like, perhaps crystalline, material in addition to some steel chips machined from the surface (4000 mRem extremity). In other words, the material was visually distinct in each sample. Also, negligible radiation rates were expected from the corrosion layer, and dried waste on the tank wall surfaces varied up to perhaps 3/8 inch or more at different wall locations. While a hole was not properly drilled like holes that were drilled at SRNL and during full scale testing, Tank 18 sampler heads clearly collected corrosion products from the tank wall. Sampling occurred on several days over several weeks in FTF.

In Tank 19, drilling of samples was performed similar to SRNL testing. Sample s had lower radiation rates (13 and 37 mRem extremity) All Tank 19 sampling was completed in less than a day.

SUMMARY OF TANK 18 AND TANK 19 WALL SAMPLING

The FTF sample collection results are summarized in Table 2. Several conclusions may be drawn:

1. Initial sampling attempts failed, and drill site characteristics varied at different locations, i.e., no evidence of drilling; small chips were removed from the waste on the wall; shallow holes were drilled, where in one case the shallow hole was drilled down to the wall surface as evidenced by black material in the bottom of the hole, where the material

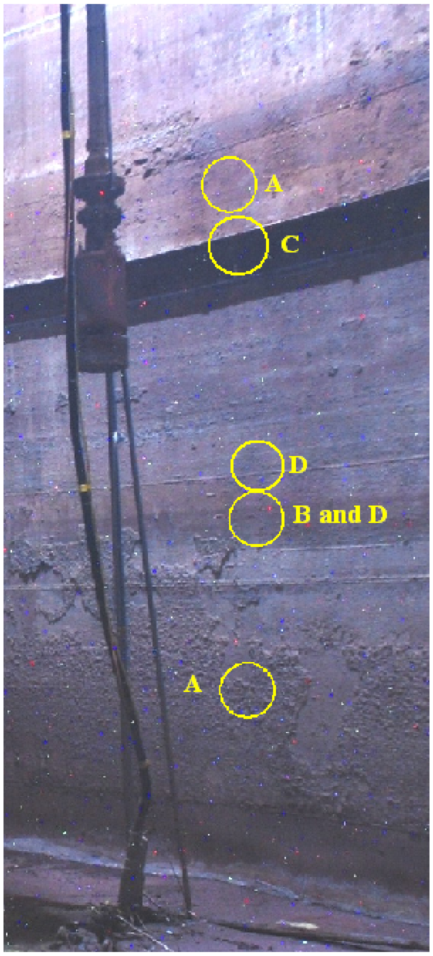
characteristics changed from waste attached on the wall to corrosion at the surface. In some cases, the sampler was pushed from the wall when the drill bit was advanced.

2. In Tank 18 final sampling results, bare steel was successfully machined at both required elevations.
3. A sample of the scale material was collected from the wall.
4. The Tank 18 sample surface areas were ill defined since the samples were ground from the wall, rather than drilled. Surface area determination therefore required additional calculation.
5. The materials were visually different at different sample locations in Tank 18.
6. In Tank 19 final sampling results, two holes were drilled at each required elevation, and the holes were similar to those drilled during testing.
7. The surface areas of the Tank 19 samples were well defined by the diameter of the drilled holes.
8. Radiation rates were expected to be negligible but were as high as 4000 millirem extremity, measured within approximately two inches of the sampled materials on the filters. Rates were measured for a disassembled sampler.
9. The sampler apparently did not drill through the corrosion layer of the tank walls at West Valley. Material was sample down to the corrosion layer. According to the West Valley report, the researchers assumed that the black circle at the bottom of the hole was exposed steel, and SRS sampling clearly showed that exposed steel was bright and shiny as expected. The black circles were the corrosion layer on the wall surface. West Valley did not drill down into the steel. Although they recognized that the drill chattered, and numerous changes were investigated and implemented in the West Valley design, resonance was not identified as a principle design flaw of the sampler.

How can sampling be improved on waste coated walls? One recommendation is to locally clean the area where the electromagnets are mounted. Only a few hundred gallons of water would be required to pressure wash the areas to be tested, and the design issues for drilling through waste would not need to be further resolved.

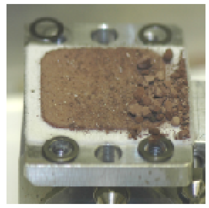
CONCLUSION

The sampler described in this report successfully collected wall samples from waste tanks at SRS. The sampler equipment performed well when only a thin layer of waste covered the wall, but performance deteriorated rapidly when a thick layer was present on the tank wall. Experience indicated that residual waste on the tank wall has a significant effect on sampler performance. Collecting a sample from tank walls with a thick layer of dried waste proved to be very challenging. The thickness of residual waste on waste tank walls should be a major consideration for any wall sampling planned for the future.

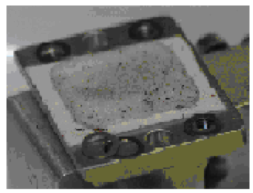


Tank 18 Northeast Wall
Approximate sample locations

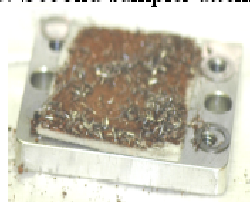
Sampled solids on collection filter



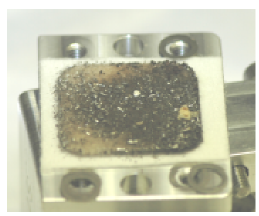
A. First sampler attempts



B. Second sampler attempts



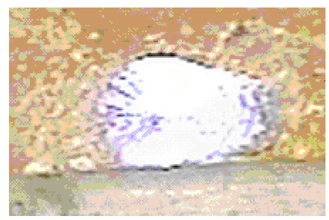
C. Tank 18 upper samples



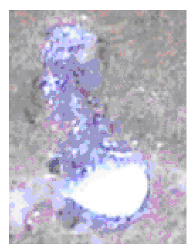
D. Tank 18 lower samples

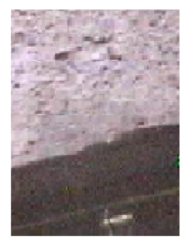
Material removed from wall

B. Failed attempt with second sampler



C. Completed upper samples

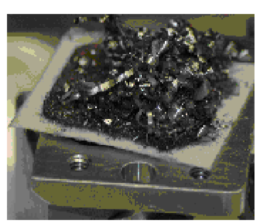




D. Completed lower samples

Tank 18 Sample Results

Tank 19 wall and floor



Upper and lower sample results

Tank 19 Sample Results

Figure 4: Tank 18 and Tank 19 Sample Results

Table 2: Tank 18 and Tank 19 Sample Results

Sampler Head Number	Tank	Elevation from tank floor ft	Drill time, min	Rad rates, mrem, extremity	Results
TK 18-2	18	19' 8-7/16"	0.17	2000	**Scale Sample**: Brown material, 1/16" – 1/8" diameter stone shaped material, similar to dried clay. Two shallow holes and some chips from the waste on the wall. One shallow hole appeared black at the bottom of the hole.
		6' 3"	2		
		6' 6 "	5		
		6' 9"	4.5		
		7' 0"	6		
SP3	18	10' 3-7/16"	4	---	Second sampler for attempted holes: Two waste chips removed. Negligible material.
		9' 9-7/16"	13		
TK 18-1	**18**	17' 0"	8	1500	**Tank 18 Upper Sample:** Bare metal on one hole. Exposed corrosion in the bottom of the second hole. Reddish brown dust like material and some metal chips.
		17' 1"	0.82		
SP4	**18**	10' 7/16"	10.5	4000	**Tank 18 Lower Sample**: Bare metal on one hole, black crystalline material and some metal chips, small chip on second hole.
		11'6-7/16"	24		
TK19-1	**19**	7' 3"	4.32	13	**Tank 19 Upper Sample:** Two complete holes drilled, numerous metal chips.
		8' 0"	4.45		
TK 19-2	**19**	6' 9"	4.43	37	**Tank 19 Lower Sample**: Two complete holes drilled, numerous metal chips.
		7' 0"	4		

REFERENCES

1] Leishear, R. A. and Fowley, M., "Tank 18 and Tank 19 Wall Sampler Performance", SRNS-STI-2009-00416, Savannah River National Laboratory, Aiken, S. C.

2] S. Killough, 2001, "A Sampling End Effector for Steel Waste Tank Walls", Proceedings of the American Nuclear Society, 9th Topical Meeting on Exhibition of Robotics and Remote Systems Conference.

3] T. R. Thomas, 2002, "Review of Analytes of Concern and Sample Methods for Closure of DOE High Level Waste Storage Tanks", Idaho National Engineering and Environmental Laboratory.

4] J. Drake, C. McMahon, 2002, "High Level Waste Tank Cleaning and Field Characterization at the West Valley Demonstration Project", Waste Management Conference.