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HIGH-LEVEL WASTE TANK CLEANING AND FIELD CHARACTERIZATION AT THE WEST VALLEY DEMONSTRATION PROJECT

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ABSTRACT

The West Valley Demonstration Project (WVDP) is nearing completion of radioactive high-level waste (HLW) retrieval from its storage tanks and subsequent vitrification of the HLW into borosilicate glass. Currently, 99.5% of the sludge radioactivity has been recovered from the storage tanks and vitrified. Waste recovery of cesium-137 (Cs-137) adsorbed on a zeolite media during waste pretreatment has resulted in 97% of this radioactivity being vitrified. Approximately 84% of the original 1.1×10^{18} becquerels (30 million curies) of radioactivity was efficiently vitrified from July 1996 to June 1998 during Phase I processing. The recovery of the last 16% of the waste has been challenging due to a number of factors, primarily the complex internal structural support system within the main 2.8 million liter (750,000 gallon) HLW tank designated 8D-2. Recovery of this last waste has become exponentially more challenging as less and less HLW is available to mobilize and transfer to the Vitrification Facility.

This paper describes the progressively more complex techniques being utilized to remove the final small percentage of radioactivity from the HLW tanks, and the multiple characterization technologies deployed to determine the quantity of Cs-137, strontium-90 (Sr-90), and alpha-transuranic (alpha-TRU) radioactivity remaining in the tanks.

In the past year, the WVDP has installed two remotely operated tool deployment systems in the primary HLW tank, 180° apart. From these two access points, remotely operated sluicers, guided by video cameras, have been used to wash the tank internal surfaces (e.g., walls, columns, and bottom reinforcing structures). The sluicers are unique in that they utilize submersible pumps to supply excess, dilute tank liquid to wash the internal surfaces. This recycles the tank liquid and avoids adding to the waste volume. To date, over 80% of Tank 8D-2's interior surfaces above the bottom support structure have been washed by the sluicers, as has the majority of the support structure. More detailed descriptions of sluicer use and their measured effectiveness in removing contamination that has accumulated over the past 35 years is described in the paper.

Innovative characterization technologies deployed in the HLW tanks include the use of a burnishing sampler that spot faces tank surfaces thereby drawing the residual surface contamination into a sample head for subsequent analysis. This direct sampling method has produced the most influential results. A specially modified gamma camera was also deployed to map the tank for areas of Cs-137 accumulation.

Deployment of the modified gamma camera is the first known use of this state-of-the-art technology within a HLW tank. Other technologies utilized in the past year include neutron detectors, gamma probes, color video cameras, and a custom-designed remote arm to obtain beta-gamma and gamma radiation measurements of tank surfaces.

Use of these types of advanced equipment is necessary to best establish what remains in each HLW tank - on the walls, structural supports, tank bottom, etc. Resulting information from equipment use and deployment techniques is expected to be invaluable to those sites currently planning for waste removal and retirement of HLW tanks.

This paper summarizes waste removal from one of the highest activity waste storage tanks in the DOE Complex, combined with one of the most elaborate internal structural support systems. The various methods of waste retrieval using mobilization pumps, remotely operated sluicers, and transfer pumps are discussed in more detail in the paper.

TANK CONFIGURATION AND CHARACTERIZATION TECHNIQUES DEPLOYED

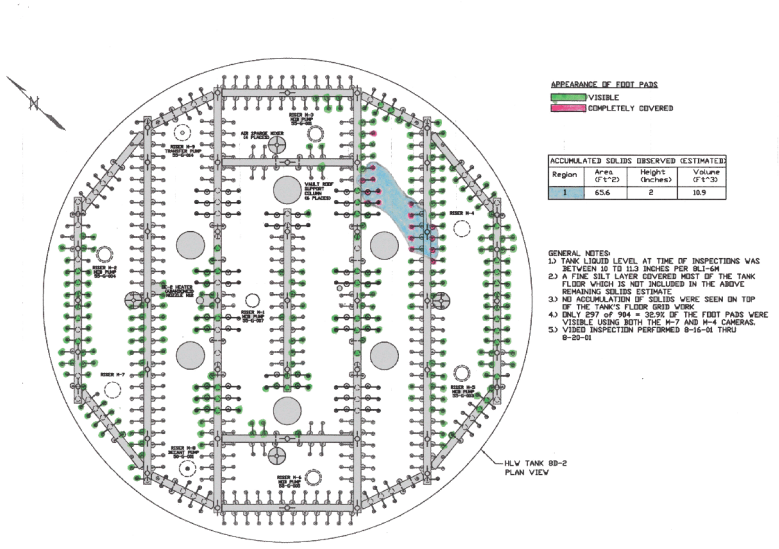
Tank 8D-2 is an underground carbon steel tank with approximate dimensions of 21.33 m (70 ft) diameter by 8.22 m (27 ft) high. Integral to the structure of the tank are forty-five 20 cm (8 in) diameter pipe columns that support the tank roof, six 1.21 m (4 ft) diameter support columns that support the vault roof, and a complex system of bottom support plates, beams, and grid work. Operational equipment internal to the tank includes four air circulators, four to six mobilization pumps, one steam heater, one density probe tree, one floating suction decant pump, and one slurry transfer pump. All of the above serve to complicate waste retrieval and cleaning efforts.

Waste retrieval and characterization techniques used in Tank 8D-2 are described below.

Video Mapping

Visual techniques were employed in Tank 8D-2 to aid in the characterization efforts. The volumetric determination and spatial distribution of residual waste on the tank floor were accomplished using remotely operated video cameras with pan, tilt, and zoom capabilities. Waste volumes were estimated by comparing the height of the waste to the known height markers on the bottom of the tanks, such as bottom grid work support pads, pins, and their welds. This data was used in conjunction with the zeolite cesium-loading estimates and Vitrification's concentrator feed makeup tank (CFMT) sample data as another method to quantify the tank floor source-term (see Fig. 1).

Various video inspections were conducted using the cameras mounted on remote equipment in the M-4 and M-7 risers. Video mapping of Tank 8D-2 was valuable to identify locations of thicker deposits during mobilization and retrieval activities but was not very effective with an average of 1.0 cm (0.39 in) of solids spread over the tank bottom. Additionally, the remaining liquid heel and lighting limitations within the tank made support pad observation somewhat difficult. As a result, quantification of the small volume of solids remaining on the tank bottom is not possible. Instead, video inspection of Tank 8D-2 evaluated the homogeneity of the solids' distribution over the tank bottom and the cleanliness of the beam tops, webs, and gussets. It was encouraging that, based on this inspection, there appears to be few solids on the tank bottom since the grid work appeared clean and many support pads were visible.



Based on historical process knowledge from known mobilization pump cleaning radii, five operating mobilization pumps were expected to provide adequate agitation of the mobile tank bottom solids except under the area of the M-7 and M-8 risers where no mobilization pumps have existed. Mobilization of deposited solids in these areas has been more difficult and has been improved by periodically aiming or indexing the discharge nozzles of an adjacent pump toward excess solids (Reference 1). With video cameras installed in the M-4 and M-7 risers, video inspection at these locations was performed.

Fig. 1 - Solids Distribution on Bottom of Tank 8D-2.

The video surveillance conducted on August 19, 2001 indicated that most support pads in the field-of-view under the M-7 and M-8 risers were visible except for a small area of the tank bottom. However, due to the liquid heel depth, quantification of the depths of solids in that area was difficult. Only, the maximum depth of solids, therefore, is known, and is about 2 to 3 cm (0.78 to 1.18 in) in depth. This data, combined with the fact that the cleaning radii of the five operating mobilization pumps covers the entire tank area except that area visible with the installed video camera, supports the conclusion that the small quantity of mobile solids continue to be well-mixed over the tank bottom.

Pre-wash Beta-Gamma Probe

The predominant sources of beta and gamma radiation in the HLW tanks are Cs-137 and its daughter Ba-137m, and Sr-90 and its daughter Y-90. All Cs-137, Sr-90, and Y-90 emit beta radiation; Ba-137m emits gamma radiation. The purpose of the beta gamma probe system is to measure both the beta-emitting and gamma-emitting radioactivity fixed to the interior surfaces of the HLW tanks. See Fig. 2 for beta-gamma readings at various tank elevations. See Fig. 3 for a schematic detailing deployment of the beta-gamma probe. The system was designed with three ion-chamber detectors: gamma, beta-gamma, and background. All three detectors are housed in a box-like probe that provides shielding on all sides except the face of the unit. The probe face has two conical depressions leading to the end-windows of the two measurement detectors. The background detector is completely encased in shielding provided in the probe. The probe is comprised of a stainless steel shell and a lead-filled interior with detector cavities and cable chases for ease of initial placement, and potential replacement, of the three detectors.

All three Eberline® Model RO-7 probes in the beta-gamma probe system and read-out instruments were calibrated prior to deployment in the HLW tanks to correctly respond to the radiation exposure rate (in units of roentgen per hour or R/hr) attributable to a Cs-137 calibration source.

All of these ion-chamber detectors are sensitive to beta and gamma radiation. The shield configurations are what determines the type of radiation detected. The first detector has a 1 cm (0.39 in) thick Lucite™ or Plexiglas™ shield over the detector. This shield completely attenuates all the beta radiation including the 2.3 MeV beta associated with Y-90 decay. The shield window causes the detector to be sensitive to only the gamma component of radiation emitted from the tank interior surfaces. The second detector is shielded by a thin aluminum attenuator that passes gamma radiation but shields all but the 2.3 MeV beta particles emitted by the Y-90 and also eliminates most of the Cs-137 beta particles. The third detector is the background detector used to estimate the influence on the other two measurement detectors of gamma radiation from adjacent tank surfaces that are outside the field-of-view. The background measurements are subtracted from the measurement detector results in order to quantify the radiation intensity attributable solely to the surfaces under inspection, including a small incremental quantity from backscatter.

The aluminum attenuator over the beta-gamma probe was a modification to the system previously deployed in FY2000 for filtering the lower Cs-137 and Sr-90 beta energies from the higher Y-90 beta energy. This modification was made to address the effect of self-shielding within the contamination deposited on the wall. Since the Sr-90 and Y-90 are in equilibrium, all beta radiation measured is attributed to Y-90 and can therefore be used to predict Sr-90 areal concentrations.

The modified beta-gamma detector system, with the aluminum attenuator installed on the beta detector, was deployed in the M-7 riser of Tank 8D-2 in September 2000, prior to tank spray washing operations. M-4 riser pre-wash beta gamma detector readings were taken in September 2001, following removal of a mobilization pump at this location. The vertical tank wall scans were spaced approximately 0.61 m (2 ft) apart, and the beta gamma detector readings were collected vertically every 15.2 cm (6 in) and recorded on field data sheets. The tank liquid level was between 28 cm (11 in) and 33 cm (13 in) when the wall scans were collected.

A pre-wash, fixed waste inventory was determined from the Sr-90 concentrations based on the September 2000 beta-gamma detector surveys combined with subsequent burnishing sample Sr-90 ratios. The fixed waste contamination is assumed to be symmetric about the vertical axis of the tank. Estimates of the total inventories for each of the tank regions (vapor, area of elevated contamination, mid-liquid, and lower tank) were determined from the average Sr-90 areal concentration, the burnishing sample Sr-90 ratios, and surface area for each region of the tank. Since beta-gamma detector measurements of the lower tank region were not taken, the pre-washed lower tank fixed waste inventory was estimated based on the average mid-liquid Sr-90 areal concentrations and burnishing sample ratios.

An estimate of approximately 150 curies of alpha-transuranic fixed waste was reported from beta gamma measurements combined with burnishing sample Sr-90 ratios. This estimate is believed to be biased low by a factor of three because of uncertainties in the geometry of the detector. The 95% upper confidence limit reflects this uncertainty. Further enhancements of the measurement technique and dose-to-curie modeling, such as calibration of the beta-gamma detector system, could improve the quantification methodology. Currently, each probe is calibrated individually outside the detector shield housing. An in-tank calibration, by correlating beta-gamma detector measurements with physical burnish samples, is being evaluated.

Since the initial inventory analyses performed during FY2000, it has been determined that calculation of Cs-137 concentrations using the beta gamma probe surveys is difficult due to possible bremsstrahlung effects on the gamma measurements. Even with modeling or calibration, determining the magnitude of this effect was thought to be a nontrivial task. As a result, the Cs-137 areal concentrations are not derived from the beta-gamma probe readings. Instead, the Cs-137 areal concentrations are calculated by using the Sr-90 concentration measured by the beta-gamma probe and the Cs-137/Sr-90 ratios from fixed waste samples obtained from actual tank surfaces in the different tank regions.

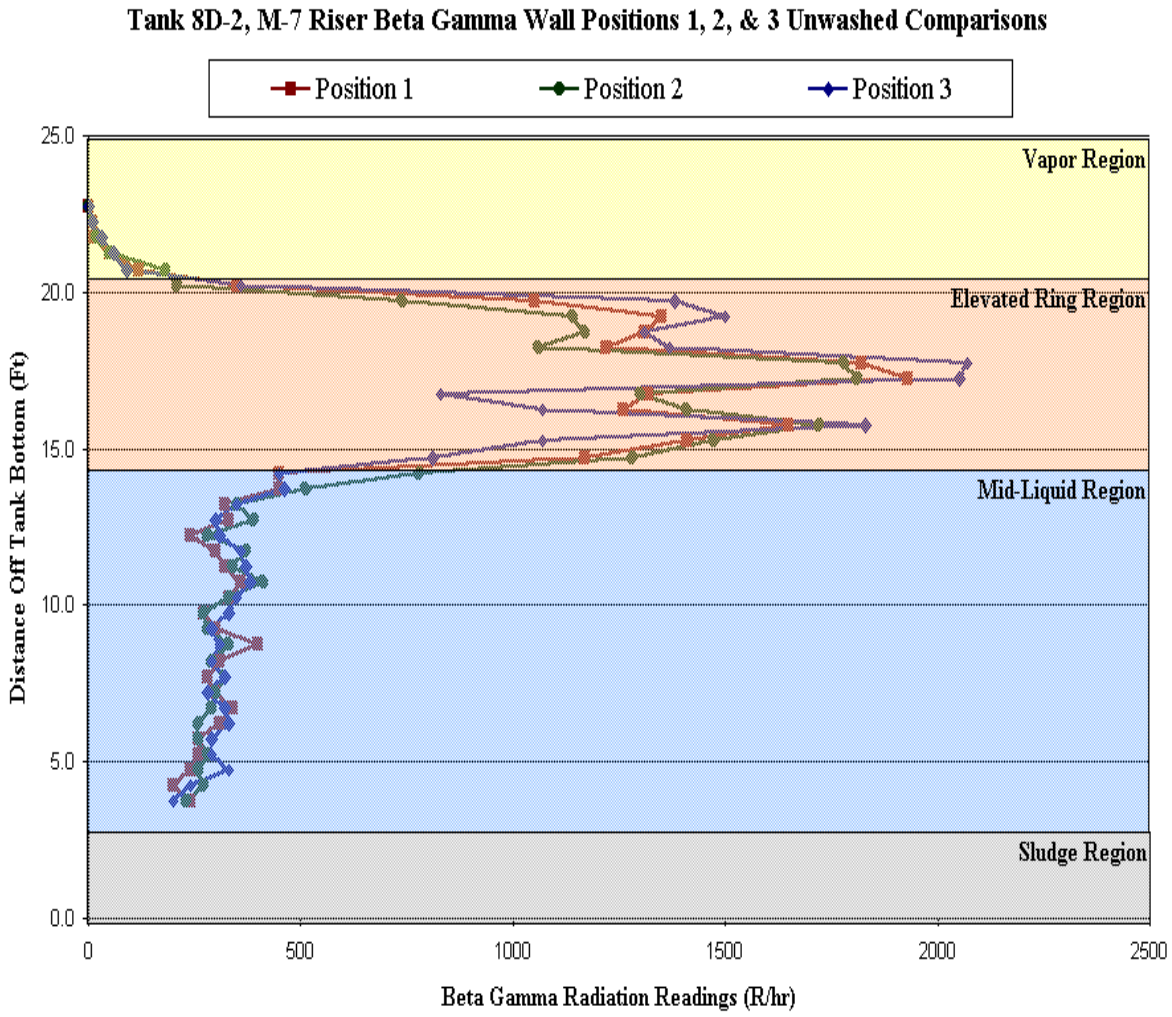


Fig. 2 - Beta-Gamma Readings at Various Elevations.

Gamma Camera

The gamma camera radiation detector (gamma camera) is based on AIL Systems, Inc. GammaCam® M31. The gamma camera is an imaging system that provides two-dimensional spatial mapping of gamma-ray emitting nuclides in real time. The electronics have been repackaged with a radiation shield and a laser range finder (for distance measuring and target spotting) added. The software program was modified to

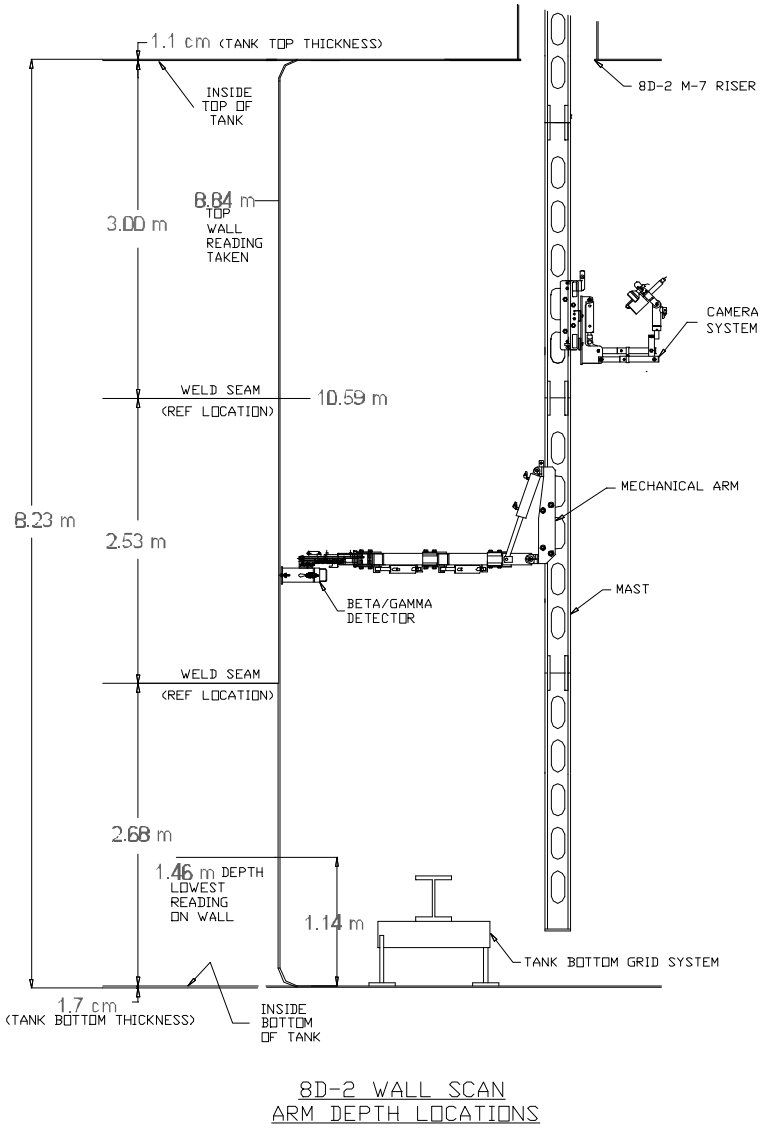


Fig. 3 - Deployment of the Beta-Gamma Probe.

WVNSCO's requirements. The gamma camera provides a closed circuit black and white television (CCTV) image with an overlay of graduated colors representative of the target's gamma radiation levels.

In addition, the software provides the laser range finder distances to the target, the amount of Cs-137 activity in each colored region, and the amount of gamma curies per 100 cm^2 (15.5 in^2). The gamma camera has a field of view of 26.7 degrees. This results in a nominal 0.27 m (2.9 ft) square image at the minimum 1.8 m (6 ft) range and a nominal 5.8 m (19 ft) square image at a 12 m (40 ft) range.

The system consists of a sensor head, control box, operator control panel, and connecting cables. The head enclosure is constructed of stainless steel and is shielded to withstand an integrated gamma exposure of 10^7 Rads. The sensor head is 71 cm (28 in) long by 28 cm (11.5 in) high by 46 cm (18.3 in)

wide, weighs 295 kg (650 lb), and is deployed via the mast tool delivery system in Tank 8D-2. The control box is located outside the tank near the mast (this keeps most of the electronics out of the radiation field) and the operator control panel is located in a low radiation area. A four-light CCTV camera was deployed above the gamma camera and was used to assist in orienting the gamma camera for imaging.

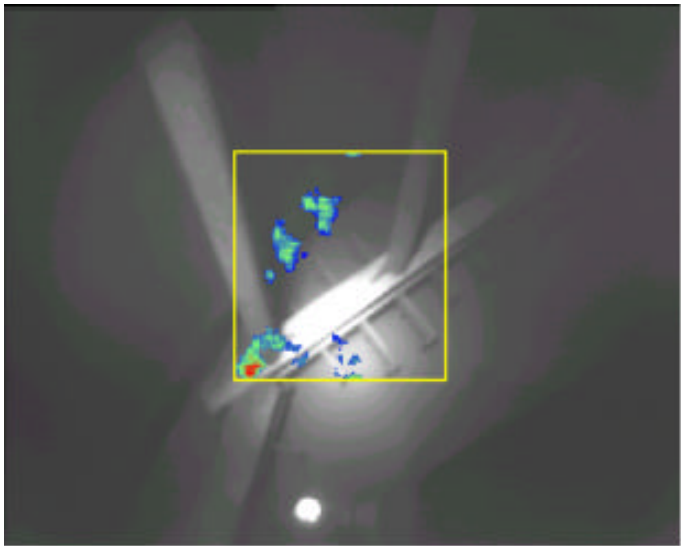


Fig. 4 - Gamma Camera Image of Tank Bottom.

The gamma camera indicates the radiation level using colors superimposed on a CCTV image and calculates the dose level (in millirem/hr) and the curie content (curies per 100 cm^2) of hot spots shown in the image to an accuracy of ±20 percent at any distance for curie levels and up to 9 m (30 ft) for dose levels. The software also identifies the amount of Cs-137 activity in curies in each color-highlighted region. The gamma camera assumes that the target is in a plane at a right angle to the camera's line of sight and all radiation components are equidistant in this plane. This is an oversimplification in the tank deployment and has its greatest effect on the floor and beam flange images because of the angles and in any image with a hot spot in the foreground of the image target.

The gamma camera collectively measures the sum of all gamma-emitting radionuclides present on the tank surfaces and was used to characterize the tank walls, grid work, support columns, floor, and in-tank equipment. The primary purpose of the gamma camera is to detect localized accumulation of radioactivity in the HLW tanks. Identification of such "hot-spots" was made through analysis of the dose rates observed in various areas throughout the tanks. Significant fluctuations in the measured results would be an indication of relative heterogeneity of waste distribution in the tanks. A relatively uniform set of dose rate results would indicate the presence of general homogeneity and uniform distribution of residual zeolite/sludge throughout the tanks. The camera can be positioned to take an image (with radiation levels displayed) of any area visible from the access riser mast. Support columns block some areas of the walls and grid work from view. Tank liquid levels were adjusted to minimize the background radiation attributable to the waste remaining on the tank bottom.

The gamma camera was installed in the Tank 8D-2 M-7 riser and the cesium test source was checked on October 16, 2000. The tank was decanted to its lowest level (7.6 cm [3.0 in]) and tank floor readings were taken on October 17, 2000. This set of images showed small deposits of zeolite in various locations and confirmed regions where mobilization pumps have difficulty reaching (see Fig. 4).

Liquid was added from Tank 8D-1 to bring the Tank 8D-2 level to 64 cm (25 in) of water. This brought the liquid level in the tank to the midpoint of the beams, which provided shielding from deposits on the tank floor. Top-of-beam flange readings were taken on October 19, 2000. This set of images showed radiation on top-of-the beam flanges; probably from zeolite deposits. Unexpected zeolite deposits on

top-of-the-tank air circulator units were also discovered during this deployment. Another 69 cm (27 in) of liquid was then added to the tank. This brought the liquid level in the tank above the beam flanges, providing shielding from deposits on the tank floor and beam flanges. Tank wall readings were taken on October 20, 2000. Images were taken of the wall ring zone of elevated contamination and confirmed the success of the prototype spraying operation in cleaning Cs-137 from the tank walls.

The gamma camera was originally conceived as a qualitative measuring device for use in the tanks, locating piles of zeolite for mobilization. Extensive testing was done at the factory and on site, confirming the gamma camera's operation. The local testing used radioactive weld inspection sources to evaluate the unit's functionality and its ability to quantify gamma source activities with high-level background radiation. On-site testing confirmed the operation of the gamma camera with higher level cesium sources and established that a test source can be used to confirm the functionality of the gamma camera before and after tank deployment.

The greatest correlation between the gamma camera readings and other radiation measurement readings occurred in a narrow band during the wall scans without any columns in the foreground. This initial deployment allowed development of the imaging technique and lessons learned for future deployments.

Solid State Neutron Track Recorders

Five sets of neutron track recorders were deployed into Tank 8D-2 for one week in October 2000. The cadmium (Cd)-covered recorders are sensitive primarily to high-energy neutrons (fast) that have not interacted with water. The aluminum (Al)-covered recorders are sensitive to neutrons of any energy (fast and slow). From the number of tracks, the time in the tank, and the size of the U-235 foil, a fast and thermal (slow) neutron flux is developed for each of the track recorders. Process data on relative isotopic concentrations, physical geometry of the tank, and a neutron transport model were used to develop an inventory from the neutron fluence.

In Tank 8D-2, the analysis concludes that there are sources that yield 1.9×10^7 neutrons/second. Based on simplified modeling, this corresponds with 130 curies of Cm-244. The inventory of other radionuclides can be estimated from the Cm-244 inventory and ratios established by direct tank sampling.

These results appear to indicate a larger alpha-emitting transuranic source-term than other measurements. Discussions with both the supplier and data analyst suggest that further investigation and refinement of the data on the $(\alpha, {}_0n^1)$ contribution to the source would likely result in a lower revised estimate of the contribution from Cm-244. Review of the literature on $(\alpha, {}_0n^1)$ reactions suggests that there are target molecules in the tanks that would yield more neutrons than the actinide oxide mix assumed in the calculations. This would substantially reduce the estimated Cm-244 inventory and the other corresponding radionuclides.

Pre-wash Burnishing Samples

The burnishing sampler end effector is a device used to remotely collect in-tank fixed waste burnished samples from the internal surfaces of Tank 8D-2. The sampler unit is comprised of a removable sample head that contains a filter assembly, spring-loaded shroud, and a rotating end-mill. The end-mill contacts the surface to be sampled and machines a 1.27 cm (0.50 in) diameter shallow spot face (burnish). Stand-

offs on the sample head faceplate limit the penetration of the end mill into the surface to be sampled. A venturi-type vacuum connected to the sample head is used to draw the sample millings into the sample head where they collect on the HEPA filter medium. Air motors are used to move the sample head forward into the surface to be sampled and to rotate the end-mill. A spring-loaded tool platform positions the sampler unit against the sample surface. The sample unit is retrieved from the tank via the mast tool delivery system and the sample housing is remotely removed and transported to the on-site Analytical and Process Chemistry (A&PC) Laboratory for analysis. Each sample head is used only once.

The purpose of the burnishing sampler is to remotely obtain fixed waste samples of representative material that is adhering to the wall, columns, and other vertical or horizontal surfaces within the HLW tank by spot-facing and capturing the removed material. The samples obtained are analyzed to establish the radiological constituents contained in a known sample area. Based on the sample radionuclide inventory and a measured sample diameter, the areal concentration is obtained for that region of the tank sampled. The radionuclide ratios of fixed contamination from each region of the tank sampled are also determined from the burnishing samples.

Between February and October 2001, 23 pre-wash samples were taken at the M-7 riser location and 16 pre-wash samples were taken at the M-4 riser location, on the opposite side of the tank. The samples were obtained from various tank surfaces such as tank roof pipe columns, side walls, and beams, and at different elevations or contamination regions of the tank (see Table I). The regions include: vapor region (approximately 6.25 m [20.5 ft] and up from the tank bottom), elevated zone of contamination region (approximately 4.27 m [14 ft] to 6.25 m [20.5 ft] from the tank bottom), mid-liquid region (approximately 0.91 m [3 ft] to 4.27 m [14 ft] from the tank bottom), and the liquid/sludge region (approximately 0 m [0 ft] to 0.91 m [3 ft] from the tank bottom).

The burnishing sampler data was evaluated using two methods. The first method was in conjunction with the beta gamma detector. The second method was to establish total quantities of radionuclides per sampled area and calculate the tank inventory by multiplying the sample concentration by the area of the tank surfaces. The burnishing samples were analyzed on site by the A&PC Laboratory.

Battelle Pacific Northwest National Laboratory used this second method to model the Tank 8D-2 fixed waste. The burnishing samples were the primary data source in the estimation model, with the beta gamma scan data used only to weight the burnishing sample data within the elevated zone of contamination region of the tank where the data is most variable. The areal concentrations of the radionuclides were multiplied by the surface area of each of the zones and summed together to arrive at the total curies of fixed waste in Tank 8D-2. Burnishing sample ratios from the M-7 riser area result in the radionuclide inventories shown in Table II.

The pre-wash burnish sample sizes appeared to vary considerably depending on the surface being sampled. Ideally, all the sample sizes would be equal and approximately 1.27 cm (0.50 in) in diameter, consistent with the end-mill/cutter size. This was not the case during pre-wash burnishing sampling due to different surface configurations (curved wall, 20 cm [8 in] column, beam top, etc.), varying depths of penetration into the surface due to different amounts of the much harder corrosion deposits, the alignment of equipment against the surface, and the differing preload on the surface and end-mill/cutter at different elevations along the long, and somewhat flexible, vertical mast support.

Table I. Tank 8D-2 Pre-Washed Fixed Waste Samples

February/March 2001 at the M-7 Riser							
Sample No.	**Sample ID**	**Tank Region**	**Sample Location**	**Sample No.**	**Sample ID**	**Tank Region**	**Sample Location**
1	BS-1A	Vapor	Column	13	BS-11	Deposit Ring	Wall (washed)
2	BS-1B	Vapor	Wall	14	BS-12	Deposit Ring	Wall
3	BS-2	Mid-Liquid	Column	15	BS-13	Deposit Ring	Wall
4	BS-3	Mid-Liquid	Column	16	BS-14	Deposit Ring	Wall
5	BS-4	Mid-Liquid	Column	17	BS-15	Deposit Ring	Wall
6	BS-5	Mid-Liquid	Column	18	BS-17	Lower Tank	Beam Web
7	BS-16	Mid-Liquid	Wall	19	BS-18	Lower Tank	Plate
8	BS-6	Deposit Ring	Column	20	BS-19	Lower Tank	Plate
9	BS-7	Deposit Ring	Column	21	BS-20	Lower Tank	Beam Top
10	BS-8	Deposit Ring	Column	22	BS-21	Lower Tank	Beam Top
11	BS-9	Deposit Ring	Column	23	BS-22	Lower Tank	Beam Top
12	BS-10	Deposit Ring	Wall (washed)				
October 2001 at the M-4 Riser							
Sample No.	**Sample ID**	**Tank Region**	**Sample Location**	**Sample No.**	**Sample ID**	**Tank Region**	**Sample Location**
24	BS-39	Vapor	Wall	30	BS-45	Vapor	Column
25	BS-40	Vapor	Wall	31	BS-46	Deposit Ring	Column
26	BS-42	Mid-Liquid	Wall	32	BS-47	Deposit Ring	Column
27	BS-41	Mid-Liquid	Wall	33	BS-48	Deposit Ring	Column
28	BS-43	Mid-Liquid	Wall	34	BS-49	Mid-liquid	Column
29	BS-44	Mid-Liquid	Wall	35	BS-50	Mid-liquid	Column

Estimation of burnish sample size is complicated by the presence of up to three different layers in the samples (chemical deposits that wash away easily, the corrosion layer, and the base metal itself) with the actual distribution of activity within the various regions unknown. If nearly all the activity is contained in the outer chemical deposit, the sample sizes in the ring deposit region would be from 0.97 cm (0.38 in) to 1.35 cm (0.53 in) in diameter. However, if most of the activity is contained in the harder corrosion deposits underneath the chemical deposit, where the end-mill did not always penetrate fully, the sample sizes would be much smaller, typically 0.30 cm (0.12) to 0.97 cm (0.38 in) in diameter, due to the slight taper on the end on the end-mill/cutter.

Table II. Preliminary Estimate
Remaining Tank 8D-2 Fixed Wall Inventory

Radionuclide	Entire Tank Inventory Prior to Vitrification (Ci)	Prewash Fixed Wall Estimate (Ci)
Sr-90	5,200,000	39,000
Cs-137	6,700,000	4,600
Alpha-TRU >5-Year Half-Life	70,000	360

The sample sizes used in the model were estimated from observing the actual burnishing operations via video camera, as well as reviewing the corresponding videotape recorded and producing still photos from the videotape. The sizes were estimated by two different individuals with similar results. A key assumption used by both individuals was that the dark center of the burnish indicated penetration into the base metal since very little of the burnish locations appeared to reflect light as a shiny surface would with the optimal lighting and camera angle. The sample size measurements assumed a uniform distribution of activity through both the chemical deposit and the corrosion deposit, with an insignificant amount in the base metal. Consequently, the sample size resulted from averaging the estimated diameter in the outer deposit and the diameter into the base metal. Based on engineering judgement, if the radioactive contamination is indeed uniform throughout both the chemical layer and corrosion deposit, and the dark centers do indicate penetration into the base metal, then the method is estimated to have sample size uncertainty of less than ±0.30 cm (0.12 in) at a two sigma range. If the contamination is primarily contained within the corrosion deposits or the dark center does not represent penetration into the base metal, then the sample sizes reported would be too large by up to a factor of two, depending on the region sampled. The amount of iron in each sample was also used as an independent method to establish diameters.

TANK WASHING

Between March and December 2001 washing operations were conducted to reduce the transuranic activity fixed on Tank 8D-2 internal surfaces. The washing process was accomplished using two mast tool delivery systems, installed 180° apart in the M-4 and M-7 risers. Each mast is connected to a bearing capable of rotating the mast 360° and is equipped with a 1.2 m (4 ft) long folding arm and sluicing end effector. A submersible pump with variable frequency drive supplies the recirculated tank liquid to the sluicer. Flow and pressure for the sluicer are a maximum of 380 L per minute (100 gpm) and a maximum of 6.9 bars (100 psig), respectively. The sluicer nozzle spray configuration and operating parameters were determined and optimized during weeks of on-site, out-of-tank testing.

Positioning the arm and sluicer nozzle is accomplished using the in-tank video cameras and lights. The arm swing radius is approximately 2.1 m (7 ft). The spray nozzle has 180° of pan and 135° of tilt movement. Washing is usually performed with the arm positioned horizontally approximately 6.55 m (21.5 ft) off the tank floor. This is slightly above the fixed contamination region, thereby keeping the spray nozzle usually pointed downward from horizontal and serving to wash contamination down the surface being washed. The nozzle is positioned anywhere from 1.5 m (5 ft) to 9.1 m (30 ft) from the target surface, 3.0 m (10 ft) being the optimum distance from the target to be washed.

The six 1.2 m (4 ft) diameter columns were washed first since they were relatively large targets. Washed surfaces were easily discernable from unwashed surfaces using either the black and white or color video cameras. It should be noted that although there exists the capability to spray liquid the entire width of the tank, there is no direct visual access across the same distance. Viewing abilities are limited by the supporting columns and in-tank equipment. Columns were washed first moving the sluicer in the horizontal direction (side-to-side motion) then washed a second time in the vertical direction (bottom to top). The sluicer was operated at pressure and flow maximums during washing unless the target was closer than about 3.0 m (10 ft). At this distance, pressure and flow were reduced to minimize the amount of water atomized into the air which would impair viewing capabilities. Washing operations lasted anywhere from 20 minutes to one hour for each application, depending upon apparent contamination removal and tank viewing conditions.

Tank walls were washed after washing of the columns was completed. Sections of the tank wall, usually sections viewed between two columns, were washed starting at the base and moving the sluicer up the tank wall. This action created less fogging in the upper elevation of the tank near the video cameras. The wall washing was accomplished systematically with the washing overlapping each previously washed section and gradually working the sluicer around the tank perimeter.

The tank bottom structural grid work was washed last. Sediment was removed from the beam tops, which are approximately 0.91 m (3 ft) off the tank bottom, and from the tops of other internal equipment. The tank liquid level during most of the washing activities was kept between 30 cm (12 in) to 61 cm (24 in). Approximately 80% of the tank surfaces above the bottom grid work were washed, which includes 99% of the wall surfaces and 60% of the internal columns. During all washing operations, approximately 908,000 l (240,000 gal) of tank liquid were used and recycled.

EFFECTIVENESS OF TANK WASHING

Additional characterization activities were performed to establish the effectiveness of tank washing. Beta-gamma probe measurements were obtained and the burnishing sampler was deployed again to take additional tank samples.

Post-wash Beta-Gamma Probe

Post-wash beta-gamma detector measurements were taken from July to October 2001, to evaluate the effectiveness of Tank 8D-2 spray washing operations. The pre-wash dose rate profile was compared to the post-wash dose rate profile indicating that wall washing was effective in reducing the beta gamma dose rates in the elevated contamination region. Assuming no preferential removal, this would correspond to about a 52% removal of alpha-transuranics in the elevated wall contamination region and no removal in the mid-liquid and vapor regions. The gamma dose rates showed a reduction in all three regions on the tank wall. This would correspond to an overall tank Cs-137 removal of 54%.

Post-wash Burnishing Samples

After washing activities in Tank 8D-2 were completed, 16 post-wash samples were collected from the M-7 riser location in August 2001. An additional 15 post-wash samples were collected from the M-4 riser location between October 12 and 14, 2001 (see Table III). Again, the sampling was performed in various

tank contamination regions and samples obtained from different internal surfaces (see Fig. 5).

Prior to the second deployment of the burnishing sampler to collect the post-wash samples, several modifications were made to the unit to optimized the type of cutting tool, tool material and coating, and tool point contour. In addition, the amount of spring force applied to the end-mill and the motor speed (rpm) were other factors evaluated. Test plates of mildly rusted and heavily rusted low carbon hot-rolled steel were used during this evaluation. End-mills and drills of high-speed steel with a titanium carbon nitride coating, cobalt steel with a titanium carbon nitride coating and carbide materials; and two-fluted end-mills were additionally evaluated. Conical point contours of 135° and 150° for the drills and 168° and 180° (flat) for the end-mills were part of the evaluation.

Table III. Tank 8D-2 Post-Wash Fixed Waste Samples

August 2001 at the M-7 Riser							
Sample No.	**Sample ID**	**Tank Region**	**Sample Location**	**Sample No.**	**Sample ID**	**Tank Region**	**Sample Location**
1	BS-23	Vapor	Wall	9	BS-31	Mid-liquid	Wall
2	BS-24	Deposit Ring	Wall	10	BS-32	Vapor	Wall
3	BS-25	Deposit Ring	Wall	11	BS-33	Deposit Ring	Wall
4	BS-26	Mid-liquid	Wall	12	BS-34	Mid-liquid	Wall
5	BS-27	Mid-liquid	Wall	13	BS-35	Vapor	Column
6	BS-28	Vapor	Wall	14	BS-36	Deposit Ring	Column
7	BS-29	Deposit Ring	Wall	15	BS-37	Mid-liquid	Column
8	BS-30	Deposit Ring	Wall	16	BS-38	Deposit Ring	Column
October 2001 at the M-4 Riser							
Sample No.	**Sample ID**	**Tank Region**	**Sample Location**	**Sample No.**	**Sample ID**	**Tank Region**	**Sample Location**
17	BS-58	Deposit Ring	Column	25	BS-53	Deposit Ring	Wall
18	BS-57	Vapor	Column	26	BS-54	Deposit Ring	Wall
19	BS-59	Deposit Ring	Column	27	BS-55	Mid-liquid	Wall
20	BS-60	Deposit Ring	Column	28	BS-56	Mid-liquid	Wall
21	BS-61	Mid-liquid	Column	29	BS-65	Vapor	Wall
22	BS-62	Mid-liquid	Column	30	BS-63	Lower Tank	Beam Web
23	BS-52	Deposit Ring	Wall	31	BS-64	Lower Tank	Beam Web
24	BS-51	Vapor	Wall				

Performance was judged by how well the tool penetrated the severely corroded test plates, how much vibration (chatter) was observed, how consistent was the sample diameter, and what damage or wear was observed on the tool. The best performance was obtained when using cobalt steel end-mills with titanium carbon nitride coating and a 168° conical point at 138 newtons (31 lb) spring force and operating

at approximately 675 rpm. The carbide end-mills operated satisfactorily but were more susceptible to chipping. The end-mills performed best at a lower spring force and a higher rpm, while the drills required higher spring force 236 newtons (53 lb) and a lower rpm (225 rpm).

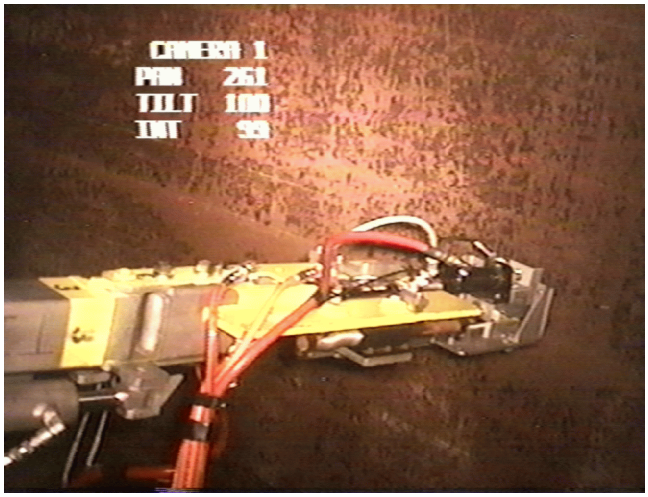


Fig. 5 - Burnishing Sampler Positioned Against Tank Wall.

The changes made to the sampler prior to obtaining the post-wash samples were the installation of a higher rotational speed air motor (750 rpm, no-load speed), use of the cobalt steel end-mills with the titanium carbon nitride coating, incorporation of a tachometer and chart recorder to monitor the cutting speed, and the use of a single stand-off (stop pin) on the vertical centerline of the sample head. Additionally, the black and white, in-tank video camera was replaced with a color camera having a higher power zoom. Subsequent video inspection of the actual sample locations showed very consistent sample areas.

Visual inspections of the areas sampled using the modified Burnishing Sampler indicate that the sampler was effective in retrieving surface contamination from the HLW waste tank for analysis. Although this type of sampler cannot differentiate between how much contamination is contained in each of the various layers (e.g., chemical deposits on the tank surface, the corrosion layer, or in the base metal) and there may be some uncertainty due to sample size, it is the most direct technique for characterization of the remaining radionuclides within the tank on vertical or horizontal surfaces above the liquid level.

PATH FORWARD

Washing operations in Tank 8D-2 concluded December 2001. Characterization of Tank 8D-2 will continue through most of CY2002 to further establish the quantity of the various radionuclides, important to future tank closure, that remain in the tank. Also in December 2001, a nitric acid flush of stainless steel Tank 8D-4 was performed. It is expected that nitric acid flushes of HLW pretreatment processing systems: the Supernatant Treatment System (STS), and the Liquid Waste Treatment System (LWTS) and evaporator, will begin May 2002. Zeolite and sludge transfer lines from the waste tanks are currently being flushed with nitric acid and water. Final waste transfers from Tanks 8D-2 and 8D-4, and from LWTS to the Vitrification Facility are expected to be completed during mid-2002. The planned shutdown of the vitrification production melter in September 2002 will occur after completion of all flushing operations. Vitrification Facility characterization will begin shortly thereafter.

REFERENCES

1) W. F. HAMEL, JR., C. L. MCMAHON, D. C. MEESS, "Waste Removal from the West Valley Demonstration Project High-level Radioactive Waste Storage Tanks," WM'00 Symposium, Paper #390, (2000).