

REMOTE SYSTEM TECHNOLOGIES FOR DEACTIVATING HANFORD HOT CELLS

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ABSTRACT

Remote system technologies are being deployed by Fluor Hanford to help accelerate the deactivation of highly-radioactive hot cell facilities. These technologies offer improved methods for accessing difficult-to-reach spaces and performing tasks such as visual inspection, radiological characterization, decontamination, waste handling, and size reduction. This paper is focused on the application of remote systems in support of deactivation work being performed in several legacy facilities at Hanford (i.e., the 324 and 327 Buildings). These facilities were previously used for fuel fabrication, materials examination, and the development of waste treatment processes. The technologies described in this paper represent significant improvements to Hanford's baseline methods, and may offer benefits to other U.S. Department of Energy (DOE) sites and commercial operations.

INTRODUCTION

The U. S. Department of Energy (DOE) is implementing an aggressive strategy aimed at restoring the Columbia River corridor. The cleanup scope involves completing remediation of 50 burial grounds, 579 waste sites, 357 excess facilities, and 7 plutonium production reactors by 2012. The effort will result in reduced risk to the river, and a shrinking of Hanford Site operations. Due to the large quantities of radioactive material contained in the 324 and 327 Buildings, and their proximity to the Columbia River (i.e., less than ¼-mile) and the city of Richland, Washington, the DOE has placed a high priority on the deactivation of these facilities. There are many technical challenges associated with the accelerated deactivation of Hanford facilities, including high radiation levels that make human entry prohibitive. This paper highlights the application of several remotely deployed technologies that are enabling the deactivation tasks to be performed.

The 324 Building, constructed in the mid-1960s, houses the Radiochemical Engineering Cells (REC), and the Shielded Materials Facility (SMF) hot cells. The REC supported diverse studies on chemical and physical processing of high-level radioactive materials, including vitrification of high-level tank waste. Over the past three decades, approximately 70 million curies of cesium and strontium have been handled in the largest of the REC hot cells (B-Cell). As recent as 1996, B-Cell held nearly three million curies of residual radioactive material, and it was estimated that an unprotected worker could receive a lethal dose of radiation in less than a second. Since 1996, instrument racks containing a complex network of contaminated piping, tanks, valves, and

associated debris have been remotely disassembled, size reduced, packaged, and removed from the highly cluttered cells using a combination of the facility's standard (baseline) equipment and innovative technologies. In addition to hot cells, other deactivation challenges in the 324 Building involve the highly-contaminated vault tanks, ventilation ducting, and concrete-embedded process piping. From a deactivation perspective, the 324 Building is considered one of the most challenging facilities on the Hanford Site.

The 327 Building, constructed in the early 1950s, contains nine specialty hot cells centrally positioned along the length of its canyon. Since 1953, highly radioactive materials (e.g., fuel elements and materials for the Hanford Production Reactors, Plutonium Recycle Test Reactor, EBR-II, Fast Flux Test Reactor, the Nuclear Development Corporation of Japan, and the Space Reactor Program) have been examined and tested within the 327 Building hot cells. The facility has also been used to analyze sludge materials from the Hanford waste storage tanks. These activities were conducted in the building's nine hot cells, centrally positioned along the length of its canyon, fabricated of cast iron material up to 18 inches thick, and weighing as much as 155 tons. To support the Hanford Site's vision to restore the Columbia River corridor by 2012, the 327 Building must be deactivated, decontaminated, decommissioned, and demolished. The building's large, radioactively contaminated hot cells and ancillary equipment must also be appropriately dispositioned. New technologies are being deployed to improve upon the baseline and demonstrate that an innovative and more cost effective deactivation and decommissioning (D&D) approach may be feasible. This new approach involves characterization, decontamination only where necessary to achieve a less-than-TRU waste designation, and the transportation/disposal of entire hot cells as monolithic waste units.

The following subsections in this paper are focused on remote access and characterization technologies that are providing improved methods to accomplish deactivation scope. These technologies are allowing workers to remotely access spaces that were once very difficult or impossible to reach. These technologies are also helping to reduce down-time associated with failure of older/baseline equipment by handling significantly heavier payloads and a broader variety of cleanup tools. Improved characterization methods are also providing information that allows for considerably better planning and management of hazards.

ROBOTIC ARM AND CRAWLER TECHNOLOGIES

The Cybernetix Robotic Work Platform

The 324 Building organization has procured and deployed a robotic work platform that is designed to provide remote access to hot cell floors, walls, ceilings, and below-grade pits. The work platform and its SAMM™ robotic arm can be deployed via an overhead crane, a 16-foot tall TOTEM™ mast, or a rectangular support structure. Deactivation tools and end-effectors can include grippers, impact wrenches, shears, saws, pipe cutters, decontamination equipment, grinders, and characterization sensors.

The need for this technology was based on the shortcomings of the 324 Building's older, baseline equipment. During early phases of planning the hot-cell deactivation scope, it was

recognized that while the existing overhead cranes and master-slave manipulators (MSM) in the 324 Building had performed well during the building's earlier research missions, they were never intended to support the demands associated with deactivation work scope. The overhead cranes cannot reach all spaces within a hot cell, and the MSMs have limited payload capacity. The MSMs are also unable to reach the hot cell floors. Both of these baseline systems are decades old and experiencing significant downtime due to equipment failure and repair.

Figure 1 depicts the robotic work platform as mounted on the 16-foot tall TOTEM™ mast and the rectangular support structure, respectively. The work platform can travel up and down the TOTEM™ mast to access the floor, walls and/or ceilings in the 324 Building's largest and most contaminated hot cell (i.e., B-Cell). The SAMM™ robotic arm can handle horizontally extended payloads of up to 200 pounds, unlike the MSMs (that are limited to about 25 pounds). Onboard lighting and video capability also provide the operator with visual access to nearly every area in the workspace.



Figure 1. Cybernetix Robotic Work Platform on the TOTEM™ mast (left), and on the rectangular support structure (right).

The rectangular support structure for the robotic work platform was specifically designed to support the Phase-I cleanout of the 324 Building's pipe trench. Following nearly three months of operations and maintenance proficiency training on the Cybernetix system, the team began the

pipe trench cleanout task in late 2001. The scope involved cutting and removing process piping, block connectors, drip pans, and condensers as well as scraping/scooping and removing contaminated debris from the pipe trench floor. This technology will now be used to supporting additional cleanout work in B-Cell and other 324 Building areas over the next several years. The robotic work platform was purchased from Cybernetix of Marseille, France.

The ARTISAN™ Telerobotic Manipulator Arm

During the early phases of deactivation in the 324 Building, the project relied on existing manipulators that were previously used for hot cell research. However, demands associated with deactivation (e.g., waste materials size reduction, handling, packaging) can often exceed the designed stress limits of these standard manipulators. Unfortunately, this lack of robustness, results in manipulator failures, unproductive time associated with the manipulator removal/decontamination/repair/reinstallation sequence, as well as increased radiological exposure to workers involved in repairing the manipulators. These original manipulators are typically installed in the hot cells via 10-inch-diameter ports accessed from the hot-cell operating gallery and run through the 4-foot-thick concrete walls. These manipulators can extend about 10 feet into the hot cell's interior. These older manipulators also have a maximum load capacity of 100 pounds when in a vertical configuration, and only 20-25 pounds when horizontally extended.

Fluor Hanford recently acquired an ARTISAN™ robotic manipulator arm system to support the heavy-duty deactivation tasks in the 324 Building's SMF hot cells. The ARTISAN can handle payloads of 220 pounds (nearly 10 times more than the facility's existing manipulators) at full extension, and can be configured to reach over 15 feet.

The ARTISAN™ arm (Figure 2) is designed to be considerably more robust than the facility's standard manipulators, and is expected to result in significant improvements in operating efficiency during SMF hot cell deactivation. The SMF hot cells are arranged in an L-shaped configuration and are typically 16 feet wide and 18 feet tall. Overall, SMF hot cells have 22 leaded-glass/oil-filled windows and 36 manipulators (or manipulator ports) at, or near, the windows. These baseline manipulators will continue to be used during the approximately two-year deactivation process. However, during this process, the ARTISAN™ will be strategically repositioned in various ports to align with the work scope demands at a given window/work station. Supported by a specially-designed structure, the 1,100-pound robotic arm can be removed and reinserted in different ports in a straightforward manner. The overall reach capability with the hot cells can range from 11 feet to more than 15 feet by installing various extension tubes between joints. The ARTISAN has six degrees of freedom and a payload limit of 220 pounds when horizontally extended. The ARTISAN arm is hydraulically powered, joystick controlled with position feedback, and has a "teach and repeat" function that can be used to reduce the time necessary to carry out complex or repetitive maneuvers.



Figure 2. ARTISAN manipulator arm system

The ARTISAN™ system has passed the factory-acceptance testing, and has been shipped to Hanford's 324 Building. The deployment of this arm in 2003 is expected to reduce cost and expedite cleanup. DOE's Office of Science and Technology (EM-50) supported the development of the ARTISAN™, which is manufactured by AEA Technology and Engineering Services, Inc.

The Dispersible Removal System

As an aid in achieving a significant cleanup milestone in the 324 Building, an electrically driven crawler known as the Dispersibles Removal System (DRS) proved to be a highly versatile tool for negotiating obstacles and removing light debris and dispersible materials from the 324 Building's B-Cell floor.

Just prior to deployment of the DRS, the bulk volume of B-Cell's equipment (e.g., tons of instrument racks, piping, small tanks) had been size-reduced, packaged, and removed from the cell. However, the cell's floors and walls still contained a significant amount of highly radioactive dirt, dust, dried chemical residues, vitrified glass, and concrete-like material. The B-Cell also contained several racks for storing spent nuclear fuel, work-tables and other obstacles that needed to remain in the cell while this dispersible material would be removed. This task was further complicated because the existing hot cell manipulators were not able to reach the floor level. Furthermore, in-cell cameras were fixed to the walls at higher elevations and offered only partial viewing of the surfaces to be cleaned, radiation levels in the cell had been measured up to 20,000 R/hour, and the process of suspending scrapers and clamshell devices 30-feet from semi-reliable overhead cranes would not likely be very effective or efficient. Based on these factors, performance specifications were written (Ref. 1), and the DRS was competitively procured from R.O.V. Technologies, Inc., to ensure that the cleanup schedule could be met.

The DRS is a small crawler (about 24 inches wide by 24 inches long, weighing approximately 150 pounds) equipped with stainless steel tracks, lighting, a light-duty telescoping boom and two-jaw gripper, a wrist-tilt mechanism, and suite of end-effectors that can be remotely changed using a motor-driven coupler. A joy-stick and push-button console controls the crawler via a 75-foot-long electrical connection.

In addition to the successful removal of dispersible material from B-Cell, the DRS was later used to remove dispersibles from the bottom of 324 Building's Pipe Trench. The DRS should continue to be used in B-Cell, other Hanford hot cells and areas where contaminated debris and dispersible materials are present.

The Gamma-Rover (Grover) Crawler for HVAC Duct Characterization

A remotely-operated, mini-tracked crawler has been assembled to obtain visual characterization and dose profiling data in contaminated ventilation ducting that exhausts air from hot cells. Data from deploying this equipment will be used to determine the appropriate method(s) of duct decontamination and/or stabilization that is necessary before the facilities are demolished.

As noted earlier, waste vitrification process development and other physical and chemical processing studies involving high-level radioactive materials were performed in the 324 Building hot cells from the mid-1960s until the early 1990s (with B-Cell alone handling about 70 million curies of cesium and strontium). Based on this history, the interior wall of the 24-inch diameter exhaust ductwork that exits B-Cell may hold high levels of loose or loosely bound contamination along its pathway to the HEPA filters. To support safe demolition of the 324 Building, the existing contamination in the exhaust ducting needs to be assessed and removed and/or stabilized.

The B-Cell duct run is nearly 100 feet in length, mostly horizontal, and constructed from welded-seam 304-L stainless steel. Three 90-degree bends are positioned at about 8, 32 and 73 feet from the exhaust duct inlet. Given this configuration, the highest levels of contamination are expected to be deposited upstream of the second 90-degree bend (Ref. 2). Given this expectation and accounting for the additional complexity necessary to negotiate more than one 90-degree bend with a tethered crawler, a decision was made to acquire a remotely operated crawler that can perform both dose and visual characterization of the duct's interior up to the second 90-degree bend (i.e., to about 32 feet downstream from the exhaust duct inlet).

The technology assembled to meet the needs for dose profiling and visual characterization was named by the Pacific Northwest National Laboratory (PNNL) design team as the "Gamma-Rover." The Gamma-Rover is an electrically powered, dual-tracked crawler equipped with gamma radiation sensors and video cameras. The deployment platform is made of 1-inch steel to provide radiation shielding. Gamma Rover is a skid-steered vehicle, whereby turning is accomplished by having one track move forward while the other track moves backward or remains stationary. The crawler has been designed to drive and automatically track in round duct. However, to provide an indication of stability, a white-line dangle meter is provided in the forward directed camera; if the vehicle should tilt, this line moves to either the lower right or

lower left. A hand-held pendant has rocker switches for vehicle/camera control and a master on-off switch. A second pendant provides controls for a winch/tether drive.

The Gamma Rover has passed acceptance testing for the 324 Building, and will be deployed in 2003 during the next in-cell filter replacement in the B-Cell exhaust ducting.

REMOTE VISUAL TECHNOLOGIES

The iPIX[®] 360-Degree Camera

The Hanford Site has hundreds of radioactively and/or chemically contaminated facilities that must be entered for operations, maintenance, or D&D purposes. Before beginning work in any such facility, project planners and workers must know the layout, condition, and potential hazards of the area in order to mitigate risks. To familiarize themselves with the area and associated risks, they may make multiple entries to map each room and attempt to locate all hazards. Each entry increases overall exposure time and escalates both the potential for accidents and the overall cost.

Engineering drawings, reports, and “flat” photographs have traditionally been used to document the condition of these contaminated indoor areas. These resources can have limitations; it is not always easy to visualize the physical situation and condition from engineering drawings or written text, two-dimensional graphics and photos offer limited perspective, and personnel often find it difficult to orient themselves in a room based on these depictions alone. Items of interest are often not visible in a given photo and may not be described in sufficient detail in existing documentation. Videos tend to quickly pan across areas, and often miss items of significance.

Based on a technology that has been recently and more commonly used by the real estate and automotive sales industries, “virtual tours” have been created for a number of areas in the 324 Building and other Hanford facilities with 360-degree photos.

For less than \$2500, a high-resolution digital camera and special software, developed by the Internet Pictures Corporation (iPIX[®]), were purchased “off the shelf.” The cost for processing each set of photos has been about \$25. The iPIX[®] software allows different sets of 360-degree photos to be grouped together to create a virtual room-to-room tour of a given building. Additional information (e.g., audio files, flat photos, or text information to identify hazards that are not readily visible) can also be attached to the 360-degree photo. The user can zoom in and study areas of interest at any time. Low-resolution versions of the tour can be placed on the Internet.

Fluor Hanford’s use of the iPIX[®] software has realized many as-low-as-reasonably-achievable (ALARA) benefits in recent years by helping to minimize the number and duration of entries into contaminated areas for touring, training and pre-job planning purposes.

The Fiberoptic Video Borescope

A very small diameter, fiber-optic, video borescope was just recently procured to support the need for remote visual characterization of hard-to-reach spaces in Hanford's 324 and 327 Buildings. The purchase was based on a vendor's success at meeting a very challenging set of performance criteria.

One of Fluor Hanford's near-term applications and most challenging needs for this technology is to gain access to the 324 Building's High Level Vault tank T-105. The High Level Vault contains four below-grade waste receiver tanks that are shielded by 6-foot-thick concrete walls and cover blocks. Each of the four tanks has a capacity of 10,000 gallons or less, has no vertical riser access, and can be internally accessed only via small diameter piping (0.5 to 2.0 inches in diameter) with multiple 90-degree bends and welded connections to the tank dome. Each tank received a mild-acid rinse in the mid-1990s. However, based on subsequent survey readings within the vault, tank T-105 still has some form of residual waste, estimated dose rates of 1,500 Rad/hr at two feet above the tank bottom, and 14,000 Rad/hr at the tank bottom. Manned access into the vault is prohibited. Tank T-105, which contains about 70 percent of the total curie inventory of waste in the vault is located directly beneath the 6-foot-thick, concrete shielding cover/access blocks, and has a very high source term (i.e. 10,000 curies of cesium-137/barium-137 with an estimated equivalent amount of strontium-90/yttrium-90). Due to the high levels of contamination, it is believed that some form of further decontamination may be necessary in order to safely remove, package, possibly size reduce, and transport this tank to a waste disposal site. A visual inspection of the waste location and physical characteristics (e.g., "bath tub ring," crystalline nugget, residual powder, etc.) would therefore be very helpful for evaluating tank remediation alternatives.

Following an evaluation of the 24 individual pipes that connect to the dome of tank T-105, it was determined (based upon pipe length, diameter, and number of tees and 90-degree bends) that pipe number T-71 offered the most likely chance of gaining access to the tank internals. Pipe T-71 is 27 feet in length, has four 90-degree ells, and is made of ½-inch Schedule 40 stainless steel (i.e., 0.62 inch diameter).

A competitive procurement was initiated by Fluor Hanford whereby multiple vendors were invited to prove that their video borescope technology could negotiate the diameter/length/bend challenges associated with pipe T-71. Additional challenges included the ability to handle the high radiation environment within tank T-105, and to provide sufficient lighting and image quality to support characterization of the tank internal surfaces. As part of the procurement process, a full-scale mock-up of pipe T-71 was fabricated at Hanford and made available to prove vendor equipment capability. A company named Everest VIT[®] devised a technique for successfully pushing their video borescope through the entire pipe T-71 mockup routing.

The video borescope system (Figure 3), as purchased, includes a 40-foot long, less than ¼-inch diameter, insertion probe that utilizes quartz fibers for radiation resistance. The front end of the insertion probe includes a two-way articulated camera (controlled via remote joy stick) that can accept different tip adapters for varying field of view, depth of view and magnification. This system is expected to arrive at Hanford in February 2003.

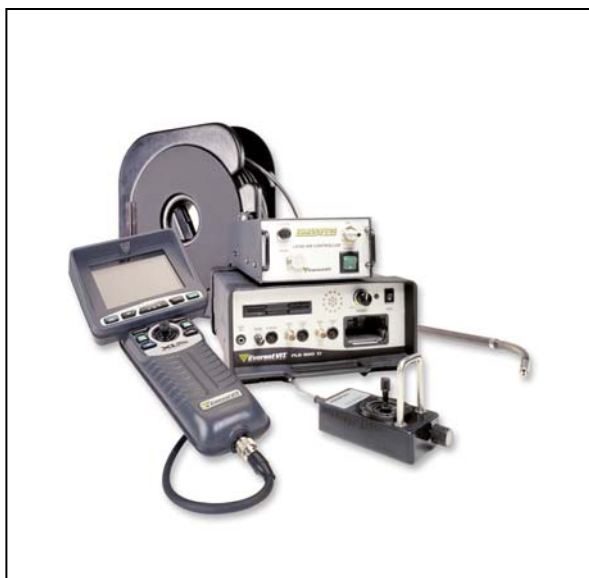


Figure 3. LongSteer® VideoProbe®

It is expected that this new tool will prove to be highly valuable for inspection of other concrete-imbedded piping, tanks, ventilation ductwork, abandoned pool-basin access pathways, and to support remote troubleshooting of facility equipment in a variety of highly contaminated spaces.

RADIOLOGICAL CHARACTERIZATION TECHNOLOGIES

Four new applications for characterization technology were recently deployed in Hanford's 327 Building hot cells. These characterization tools are helping to prove that the baseline methods for hot cell D&D in the 327 Building can be accelerated and accomplished in a more effective manner.

Previous plans for D&D of the 327 Building hot cells have involved extensive decontamination, section-by-section disassembly of the hot cell structural components, as well as costly waste handling/packaging, transportation and disposal. Under the new concept, however, each of the nine hot cells will be characterized, and decontaminated only to the extent necessary to achieve a "less-than-TRU" waste designation. The hot cells, each weighing between 60-150 tons, would then be individually removed from the facility as monolithic waste units, transported over Site roadways, and buried in Hanford's Low-Level Burial Ground or Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA) landfill.

To help prove that this new D&D approach is viable, four new characterization technologies have recently been deployed: (1) the CARTOGAM gamma camera is used to locate hot spots and make qualitative assessments of the contamination within the hot cells; (2) the In-Situ Object Counting System (ISOCS) is providing gamma spectral analyses; (3) the Neutron Instrument Pod is used to detect and quantify neutrons and identify TRU levels in the cells; and (4) a Copper Foil Activation technique is used for quantitative determination of TRU levels in a high gamma background. The Neutron Instrument Pod and the Copper Foil methods provide the same data

(based on different methodologies) and allow for confirmation of results from each other. All technologies were remotely deployed through the hot cell's 7.5-inch-diameter ports. Brief descriptions of these in-situ characterizations methods are provided below:

CARTOGAM Gamma Camera -- The CARTOGAM is a relatively small (3.2 inches diameter by 16 inches long) and relatively lightweight (approximately 35 pounds), real-time, gamma camera that provides two-dimensional mapping of gamma emitting sources. The characterization data is depicted as concentric and colored iso-contours (Figure 4) that are overlain on a two-dimensional photographic image of the waste object or surface area in order to identify the location of gamma emitting hot-spots. Dose rates associated with each of uniquely colored iso-contours are also indicated on each image by a color-coded scale. Specialized software (GammaViewTM, which operates under Windows NT) is used to analyze the data. Using a thin connecting cable, the system is capable of operating with a PC-to-camera distance of up to 275 yards. This portable technology was purchased from Canberra Industries, Inc.

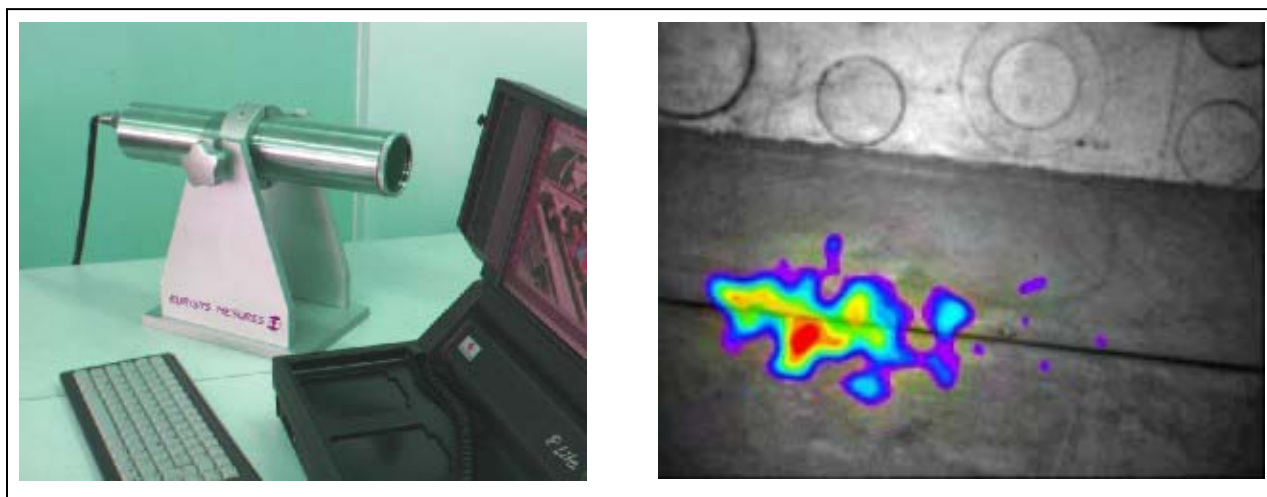


Figure 4. CARTOGAM gamma camera (left), and data image of “hot spot” (right).

In-Situ Object Counting System (ISOCS) -- The ISOCS utilizes a high-purity Germanium detector to identify and report quantitative activity of specific gamma emitting isotopes. Earlier methods for obtaining similar characterization data had involved the collection of a statistically-representative number of physical samples from a waste object or potentially contaminated surface/wall/floor surface area, then packaging and transporting these samples to some other facility for laboratory-based gamma spectrometry analyses, and eventual sample disposal. The ISOCS, however, is a field portable unit that is capable of collecting data from very large surfaces in-situ, and can average any non-homogeneity of the contamination over the entire object or surface area of interest. Use of an ISOCS shield and/or selected collimators (allowing for 30-, 90- or 180-degree fields of view) is also available to assure that other nearby sources do not influence the data received for the specific area or objects of interest. This technology was also purchased from Canberra Industries, Inc.

Neutron Instrument Pod -- The portable Neutron Instrument Pod incorporates fission chamber detectors for neutron detection, a Cadmium/Tellurium detector for gamma spectroscopy, and an

Eberline RO7 ion chamber for measuring gamma dose rates. Neutron detection is a useful method for measuring TRU, since neutrons are not emitted by the non-TRU isotopes that are likely present in the 327 Building hot cells. The fission-chamber neutron detector chosen for the Instrument Pod is a proportional counter containing a thin coating of highly-enriched uranium on the inside surface of its cylindrical wall. Fission chambers are less sensitive to neutrons than commonly-used neutron detectors such as helium tubes, but they were chosen for this application because they are insensitive to gamma radiation. The Neutron Instrument Pod hardware and deployment support was provided by PNNL.

Copper Foil Activation – Copper foil activation is used to confirm neutron flux data as well as fission chamber results. Small bars of copper are wrapped in plastic and strategically positioned on the hot cell floor for measured period (typically 24-hours or more). Neutrons are emitted from any TRU isotopes in the cell either by spontaneous fission, or by (alpha, neutron) reactions with low atomic number elements nearby. After removing the copper bar from the hot cell, a pulse-height spectrum is then obtained in the laboratory. This spectrum is analyzed to determine the total number of counts resulting from neutron interactions, as opposed to background counts caused by gammas or alphas emitted by uranium. The final measurements are then used with assistance from process knowledge, in-cell characterization data, and other radiation transport modeling to arrive at a measurement of the distribution and quantity of TRU in the cell. The copper foil data is intended to complement the assessments made by ISOCS, CARTOGAM, and the Instrument Pod. Technology hardware and deployment support was provided by PNNL.

At the time of this writing, each of the four characterization technologies had been deployed in hot cell G and hot cell H. While final analyses and reporting is expected in March 2003, preliminary analyses indicate that cells G and H could likely be designated as “less-than-TRU” waste. Higher levels of residual contamination are expected in the remaining seven hot cells. If this new D&D concept (involving characterization, decontamination only where necessary to achieve a less-than-TRU designation, and monolithic disposal at Hanford) can be applied to all nine of 327 Building’s hot cells, a cost avoidance greater than \$10M may be realized.

CONCLUSIONS

The decision to invest in technologies is difficult and must be driven by project needs and life-cycle costs. The experience gained by Fluor Hanford has shown that investments in the adaptation of remote access and characterization technologies are essential to project success. With the adaptation of remote systems, Fluor Hanford is reducing personnel exposure, reducing D&D costs, and accelerating schedules. Similar benefits may be realized at other Hanford facilities and sites throughout the DOE complex. Special appreciation is extended to the U.S. Department of Energy’s Office of Science and Technology (EM-50) for the support provided through the Accelerated Site Technology Deployment initiative, and the programs aimed at the development and adaptation of D&D technologies.

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