# Remediation of Potentially Pyrophoric Mixed Wastes at the 618-7 Burial Ground, Hanford Site – 10399

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## ABSTRACT

The remediation of the 618-7 Burial Ground at the U.S. Department of Energy's (DOE's) Hanford Site in Richland, Washington presented a number of unique challenges including dealing with potentially pyrophoric and radioactive wastes originating from the former fuel fabrication facilities at the 300 Area. Washington Closure Hanford, LLC (WCH) and its protégé subcontractor TerranearPMC, LLC (TPMC) worked together to plan and execute a number of mitigation techniques to reduce the hazards to the workers, the public and the environment. The project was completed successfully on schedule with no recordable injuries or environmental releases. The two companies both received awards in recognition of the success of the project.

## INTRODUCTION

In early 2009, TPMC working under contract to WCH, operator of the DOE's River Corridor Closure Project in Richland, Washington, completed a year long, $14 million environmental remediation of the Hanford Site 618-7 Burial Ground. To address a number of unique challenges that would be encountered during this cleanup effort, the remediation project included a thorough hazard analysis and work planning effort, use of a variety of remote-sensing instruments and remotely-operated equipment, a range of fire prevention and control measures, and mockups and drills prior to startup.

### Site History and Background

The 300 Area, located a few miles north of Richland at the south end of the Hanford Site, was primarily used for research and fuel fabrication facilities. In 1943, at the beginning of the Manhattan Project, it housed the research and fuel fabrication facilities required to support the construction of the first production reactor. It later evolved to contain numerous research facilities for plutonium refining, irradiated fuel examination, and radioisotope research. Between 1944 and 1957, more than 1,000 research tests were performed in the 300 Area. Many of these tests produced unique waste that was sent to 300 Area solid waste disposal sites (known as "burial grounds").

The 300 Area fuel fabrication facilities produced fuel elements for the single-pass cooled reactors and N Reactor. Single-pass fuel was produced between 1944 and 1971. Its production consisted of the heating and extrusion of uranium billets into rods, out-gassing and straightening of the rods, cutting and machining of the rods into elements, cleaning and degreasing the elements, cladding, and then inserting the elements in aluminum jackets. On average, 30,000 fuel elements were produced weekly for the single-pass cooled reactors.

N Reactor fuel was produced from 1961 to December 1986. It differed from single-pass fuel in that the fuel consisted of two concentric rods of fuel (an inner and outer element) that was co-extruded with a zirconium alloy (Zircaloy-2) cladding. The extrusion process was performed by placing a Zircaloy-2 inner and outer shell around a prepared uranium billet. This assembly was heated and then pressed through an extrusion die. The high pressure exerted during the extrusion resulted in a strong bond between the cladding and the uranium metal. The extruded tubing was then cut to length, machined, and caps were welded over the ends to complete the fuel element. The end caps were vacuum brazed using a 5% beryllium/Zircaloy-2 alloy. N Reactor fuel production reached a peak of 250 elements per week in the mid-1980s.

The machining of the of the end caps of the fuel elements generated chips and turnings of the beryllium/Zircaloy-2 alloy. Because of their size, the chips and turnings were considered to be pyrophoric at the time of their generation and were stored and subsequently disposed in water-filled drums.

The 618-7 Burial Ground, located west of the Hanford Site 300 Area complex (see Figure 1), was a general purpose burial ground operated between 1960 and 1973. The original burial ground consisted of


**Fig. 1. 618-7 Burial Ground and the 300 Area Complex, Hanford Site**

one east-west oriented, flat-bottomed trench, approximately 198 m (650 ft) long, 30 m (100 ft) wide, and about 4 to 4.6 m (13 to 15 ft) deep. In 1965, a second trench, identical to the first trench, was constructed about 6 m (20 ft) north of the northern edge of the first trench and began receiving waste in 1966. These trenches received general waste (e.g. failed equipment, waste materials including drums of beryllium/Zircaloy-2 chips, and demolition waste) from uranium fuel fabrication operations.

Shortly after waste disposal began at the second trench, a third trench was constructed to the south of and parallel to the original trench. This third trench was "V"-shaped and was 140 m (459 ft) long and 9.1 m

(30 ft) wide. In addition to wastes similar to those disposed in the northern trenches, this trench, referred to as the "Thoria Pit", received contaminated waste from the production of Thorium-232 targets and other thorium-involved experiments. Between 1968 and 1970, approximately 300 tons of thorium oxide targets were fabricated and irradiated to produce U-233. The targets consisted of thorium oxide powder contained in aluminum alloy cans.

**Project Scope**

This project involved the remediation of the three trenches within the burial ground. The scope included the planned excavation of approximately 19,000 cubic meters (670,000 cubic feet) of uncontaminated overburden material; excavation, sorting, and loadout of 50,000 meters or about 114,000 metric tons (1,800,000 cubic feet or about 126,000 U.S. tons) of contaminated soil and debris for disposal at the Hanford onsite disposal facility; and processing of up to 75 anomalous waste items, which required further investigation, characterization, and stabilization/treatment prior to disposal. The anomalous items were expected to include drums, small containers containing powders or fluids, process vessels, discolored soil, and other materials that required further investigation, characterization, and treatment prior to disposal.

**Concerns**

Prior to remediation activities, WCH prepared a waste evaluation that summarized historical records in an effort to determine the types and quantities of chemical and radiological material sent to the burial ground. The most notable concerns identified in the waste evaluation were that the burial ground had the possibility of containing:

- Potentially pyrophoric material, which included:
  - Drums containing uranium metal chips covered with oil
  - Drums containing uranium oxides
  - Drums containing chips of Zircaloy-2/beryllium alloy covered with water or water-soluble oil
- Deteriorated containers of chemicals
- Discarded containers, shipping casks, and equipment with radioactive residues including labware contaminated with trace amounts of plutonium and other radionuclides
- Several drums of powdered thorium oxide (which has airborne contamination limits that are more restrictive than plutonium)

The pyrophoric material presented a significant issue because of the potential for it to spontaneously ignite at ambient temperature when exposed to air. Once ignited, it would be extremely difficult to extinguish. In addition, burning of the Zircaloy-2/beryllium alloy chips would release smoke containing beryllium with the potential for downwind exposures. Because of the proximity of this burial ground to both a major highway providing access to the Hanford Site and to the Columbia River, minimizing the potential of a drum fire was a major objective of the burial ground remediation.

## TECHNICAL SOLUTIONS

### Risk Identification and Mitigation Workshops

The project team recognized that there were many hazards associated with the remediation of the 618-7 Burial Ground including sampling and disposal of drums of potentially pyrophoric material, the potential to encounter the same pyrophoric materials in a loose form (either because they were not disposed in containers or because the containers had corroded severely), and the possibility of encountering loose plutonium contamination.

In order to address these risks, the project team took advantage of the unique mentor-protégé contracting relationship between WCH and TPMC, and was able to hold a series of risk identification and mitigation workshops with WCH and TPMC personnel during the planning phase, and before the task order for the 618-7 Burial Ground was released for bid.

Workshop participants considered the hazards associated with the expected waste streams and examined events that occurred at other DOE sites including drum fires and pyrophoric material fires. The project team also considered the applicability of DOE safety bulletins involving drum lids being ejected from unstable drums and Defense Nuclear Facilities Safety Board (DNFSB) recommendations for handling drums with flammable or explosive headspaces.

The workshops sought to achieve the mitigation of hazards with a preference for those methods that could be implemented with a short lead time and were relatively inexpensive. The workshop recommendations were thus biased toward commercially available materials and equipment and standard construction practices.

### Separation and Protection of Workers from Excavated Materials

During remediation, several key safety measures were employed including:

- Workers in the immediate vicinity of the excavated materials were generally limited to heavy equipment operators who were dressed in Level B PPE that included full-face respirators with supplied air.
- The heavy equipment was fitted with transparent blast shields that were mounted over the windshields.
- During excavation, dust control was maintained by use of remote-operated water cannons that allowed the operators to remain at a safe distance from the excavation.

When drums were removed from the excavation, they were overpacked in larger drums using only the excavator. Support personnel were kept at least 50 ft away from the active excavation and material handling areas through the use of an exclusion zone. When overpacked drums were moved from the active excavation area for further investigation, a long-reached forklift equipped with a drum grappler was used. The forklift was equipped with a blast shield in front of the windshield and the operator was dressed in Level B PPE with full-face respirator and supplied air.

**Initial Monitoring Using Remote Instrumentation**

Excavated materials and anomalies were initially monitored using radiation detectors and a photo-ionization detector (PID) mounted on the arm of the excavation equipment. These instruments were connected to remote readouts via radio telemetry. An infrared thermometer was also mounted on the excavator arm with a readout that could be seen by the operator to monitor for elevated temperatures of drums and other anomalous materials to provide an early indication of a pyrophoric reaction (Figure 2).


**Fig. 2. Excavator bucket and arm showing infrared thermometer and radiation meter mounted on end of white metal pole and photoionization detector intake tube running along length of arm.**

In addition to an initial visual inspection of anomalies by the excavator operator, personnel were stationed outside of the exclusion zone boundary with binoculars to provide additional inspection and monitoring.

**Minimization of In-Process Material**

Because of the close proximity of the project to the general public, WCH performed computer simulations to determine the magnitude of potential airborne emissions under various accident scenarios. The results were used to define limits and controls for the in-process material excavation and handling so that if an event did occur, it would not affect the general population. For example, these design controls included not allowing more than five drums or drum equivalents (defined as one B-25 box or two B-12 boxes) to be exposed during excavation (combined total of drums in the excavation face or stored on the edge of the excavation).

During initial characterization and stabilization, no more than three drums or drum equivalents were allowed to be in process and were stored between characterization stations in an interim storage area constructed of three-sided cells built with ecology blocks stacked two high. After initial characterization and stabilization, drums were stored in a material release area pending sampling results. The material release area was constructed with open ended rows of ecology blocks stacked two high. No more than five drums were stored in each row and each drum was separated by a distance of at least three ft. Once sample results were received, drums were moved to a long-term storage area prior to transport offsite for disposal. The long-term storage area was limited to groupings of no more than five drums with each drum separated by at least three ft and each group separated by at least 25 ft.

**Integration of Fire-Suppression Capability**

Fire-suppression capabilities were included in each step of the material handling process. Upon uncovering an anomaly (drum, container, anomalous debris, discolored soil, etc.), the excavator operator working the excavation face would suspend work and the anomaly would be monitored with the instrumentation mounted on the excavator arm. During monitoring, any indications of a chemical reaction (visible emissions, hissing, discoloration, blistering, smoke or an elevation of temperature) would trigger a response action of the excavator covering the anomaly with soil.

Once the anomaly was containerized (overpack drum, B-12, B-25), it was transported from the excavation to characterization stations by the blast-shielded, long-reach forklift. Along this route, several piles of fire suppression sand were strategically placed and a front-end loader with an operator in Level B PPE remained on standby. If there was any indication of a reaction in the container at any point along the route, the container was placed on the ground and the front-end loader responded by covering the container with sand.

**Use of Remotely Operated Equipment for Drum Investigation**

Intact drums were opened for sampling in a remotely operated facility. Characterization of drums was planned as a three-stage process: a radiological assay and determination of drum weight; an assay of zirconium and beryllium content; and opening, evaluating and sampling the drum contents. In each stage, equipment was remotely-operated to maintain a separation of field personnel from the drums.

The radiological assay was performed using high resolution gamma ray spectroscopy to identify and differentiate drums containing thorium, uranium and plutonium. The drum was placed by the blast-shielded, long-reach forklift onto a scale to first determine the weight of the drum. While on the scale, the radiological assay instrument was moved close to the drum via a cable and pulley system. Readouts for both the scale and the radiological assay instrument were obtained via radio telemetry in a nearby trailer.

The second stage of the drum characterization was to determine if the container contained any detectable zirconium or beryllium. This assay was attempted using a portable isotopic neutron-spectroscopy instrument. Although this technology had been successfully used in the past by the U.S. Army for identification of suspect munitions, the results for zirconium and beryllium detection during this project were inconsistent, due mainly to the presence of water in the drums that effectively shielded the zirconium from the neutron source.

The last stage of drum characterization was to puncture the top of the drum; remotely evaluate the stability of the drum contents; and, if the drum was determined to be safe to approach, to sample the contents. The design of the drum punch facility (DPF) was a product of the pre-project workshops. The DPF consisted of a Hazmat building with a hydraulic lift table and a brass-tipped punch attached to the ceiling. A negative pressure ventilation system with a HEPA filter was connected to the building. The pneumatically-operated doors of the DPF could be opened and closed remotely to allow drum placement and removal by the blast-shielded, long-reach forklift (see Figure 3).

**Fig. 3. Blast-shielded forklift transporting overpacked drum into drum punch facility.**

The inside of the DPF was monitored with a watertight/submersible camera with zoom lens, attached lighting, and a pan and tilt mount; a multi-function gas monitor capable of monitoring volatile organics, oxygen level, carbon dioxide level, and explosivity; a radiation meter; and an infrared thermal detector. For fire control, a sand hopper was positioned directly above the building. The hopper was equipped with a pneumatic valve that could be opened to dump either a portion or the entire contents of the five cubic yard hopper through a large opening in the ceiling of the building that connected to the hopper. The sand hopper was also equipped with a vibrator that actuated automatically when the hopper valve was opened to prevent sand bridging in the hopper from any accumulated moisture.

To open a drum, the non-sparking brass punch created a 4-inch diameter opening in the top of the drum. A flexible rubber skirt was mounted near the tip of the brass punch to deflect any liquids or splash down onto the lid of the drum during opening (see Figure 4).


**Fig. 4. Pre-project testing of the drum punch facility using an empty drum.**

If a drum required stabilization after opening, hoses attached to the sides of the punch could deliver either water or mineral oil into the drum from reservoirs equipped with pneumatic pumps outside the DPF. If the drum became stuck to the punch during opening, a plunger mounted to the side of the punch could be actuated to push the drum off of the punch. All of the mechanical systems were pneumatic with the exception of the lift table which was hydraulic. All of the systems and instrumentation were operated and monitored from a control trailer located 50 ft away from the Hazmat building. The control trailer was also equipped with a video recorder to record the video feed from the camera in the Hazmat building.

Each drum was observed and monitored after punching until a response team consisting of project supervisory, engineering, safety, and radiation protection personnel determined that the drum was safe to approach. The initial approach by sampling personnel (in Level B PPE) was to inspect the drum from outside of the DPF using a long-handled, goose-necked, waterproof, lighted camera inserted through a port in the back wall of the DPF. Using a hand-held viewing screen, the samplers observed the contents of the drum. After viewing the drum contents, the samplers prepared the inside of the DPF for sampling activities by operating a cable system from the outside that unhooked the punch assembly mast and allowed it to be swung up to the ceiling, providing more room for the suited-up samplers to enter the DPF and work with sampling equipment above the drum.

Once permission was given to the sampling team to enter the DPF, the doors were opened remotely and the operator in the control trailer placed all controls in a "safe to enter" position. After the samplers had completed their activities and left the DPF, the drum was removed, the punch mast was reattached, and the doors were closed until the arrival of the next drum.

**Mock Ups and Drills Prior to Startup**

Mobilization included a number of training drills and full-dress rehearsal mock-ups of each step of the excavation, material handling, and anomaly characterization process to ensure understanding of the work and safety implications. These included:

- moving and overpacking drums using only the excavator bucket,
- transporting drums between excavation and characterization stations,
- covering drums with sand using the response front-end loader,
- operating the drum punch facility and penetrating empty drums,
- performing sampling drills of the opened drums, and
- practicing emergency site evacuations.

## RESULTS

At project completion in early 2009, a total of 161,000 metric tons (178,000 U.S. tons) of waste material had been removed from the 618-7 Burial Ground and disposed at the Hanford Environmental Restoration Disposal Facility (ERDF) or offsite. This represented a 41% increase over the baseline quantity of 114,000 metric tons (126,000 U.S. tons). Of this amount, 27,600 metric tons (30,400 U.S. tons) were classified as lead and lead-contaminated soil that was not anticipated during the planning of the project scope, and which required treatment at ERDF prior to disposal.

Over 800 anomalous items were found and processed during the project. This included:

- 624 drums or other large containers consisting of:
  - 3 drums of uranium oxide
  - 279 drums of miscellaneous materials
  - 117 drums of Zircaloy-2/beryllium alloy chips
  - 190 drums of vermiculite
  - 4 casks
  - 31 five-gallon buckets
- 65 pipes, tanks, process vessels or process equipment including 20 large stainless steel tanks, each about 10 feet tall
- 100 small containers (less than one gallon) including bottles and cans
- 8 compressed gas cylinders including 4 fire extinguishers

- 36 miscellaneous anomalies including debris, powders, and spilled liquids

Over the course of the project, there was one flash fire that occurred on the open bottom of the excavation and that was not associated with a drum or other container. As planned and practiced, the project contingency plans were implemented immediately to respond to the fire with no release of contamination.

Despite a late start and an increase in excavation quantities, the project team was able to complete the project on schedule to meet the Hanford Tri-Party Agreement milestone. Although there were challenges along the way, the project was successfully completed with no recordable injuries or environmental releases.

The success of this project can be attributed to the professionalism and diligence of both TPMC and WCH. As a result of the outstanding performance, TPMC was nominated by WCH, and selected by the DOE, as the DOE Protégé of the Year for 2008. Likewise, WCH received the "Project of the Year" award by the Columbia River Basin Chapter of the Project Management Institute.