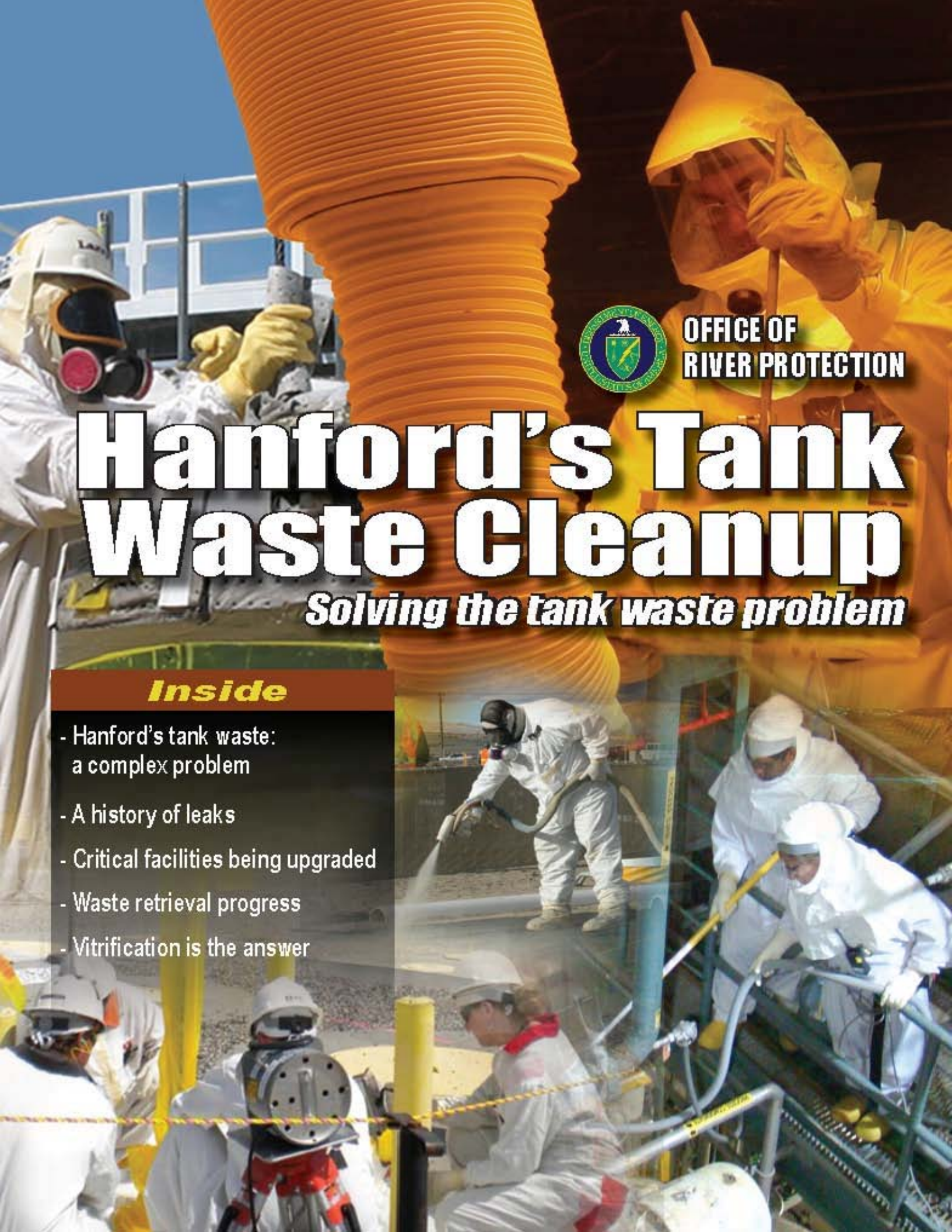


OFFICE OF
RIVER PROTECTION

Hanford's Tank Waste Cleanup

Solving the tank waste problem

Inside

- Hanford's tank waste: a complex problem
- A history of leaks
- Critical facilities being upgraded
- Waste retrieval progress
- Vitrification is the answer

Protecting the Columbia River

The Department of Energy's Hanford Site is located in Washington State's Columbia Basin, a large plateau of arid grassland bisected by the Columbia River. Hanford was established during World War II as part of the top-secret Manhattan Project to build an atomic bomb. The federal government seized control of 586 square miles containing two small towns and scattered farms and ranches.

Hanford plutonium was used in the first atomic bomb test on July 16, 1945, at Alamogordo, New Mexico. A few weeks later, a bomb made with Hanford plutonium leveled Nagasaki, Japan, ending World War II. For the next 45 years Hanford's nine nuclear reactors and five chemical processing plants produced plutonium for the nation's nuclear arsenal.

The West's largest river, the mighty Columbia, flows through the Department of Energy's Hanford site on its way to the Pacific Ocean. This 50-mile free-flowing stretch of the river, known as the Hanford Reach, was ironically spared from development by Cold War plutonium production. More than 2 million salmon return from the ocean to spawn in the Columbia River system each year; a large number spawning in the Hanford Reach, the largest natural Chinook salmon hatchery in the nation, outside of Alaska. Today, this natural wonder is a National Monument.

Downstream from Hanford, the Columbia River forms a 300-mile border between Washington and Oregon. More than 1.2 million people live on the banks of the Columbia downstream from Hanford in over 15 cities and towns.

The largest city is Portland, Oregon, about 200 miles downstream from Hanford. Portland is the largest grain-exporting port in the U.S., handling nearly 40 percent of the nation's grain exports. Most of this wheat travels down the Columbia by barge from wheat-growing areas in eastern Washington and is loaded on ships bound for Asian markets.

Now irrigated and developed, southeastern Washington is some of the most fertile land in North America, but 70 years ago it was considered a barren wasteland.

Agriculture is the mainstay of the economies of Washington and Oregon. Washington agriculture employs 300,000 people with an annual payroll in excess of $3 billion. Oregon agriculture employs an additional 215,000 workers with an annual payroll in excess of $2 billion. More than $13 billion in food and agriculture products were exported through Washington and Oregon ports in 2010.

The Columbia River is literally the lifeblood of the Pacific Northwest. Protecting the river from hazardous Hanford tank waste is the critical mission of Washington River Protection Solutions, the Tank Operations Contractor.

The Tri-Party Agreement and Hanford's tank waste

Hanford's 177 underground tanks contain 56 million gallons of radioactive and chemical wastes. Most of Hanford's waste tanks – 149 of them – are an old single-shell design built between 1944 and 1964. More than 60 of these tanks have leaked in the past, putting an estimated 1 million gallons of waste into the soil, threatening the nearby Columbia River. There are another 28 newer double-shell tanks, built from 1968 to 1986, that provide greater protection for the environment.

In 1989, the U.S. Department of Energy, the U.S. Environmental Protection Agency and the Washington State Department of Ecology signed a landmark agreement that required Hanford to comply with federal and state environmental standards. Known as the Tri-Party Agreement, the document set cleanup milestones that will bring the site into compliance with federal and state environment laws.

In 2010, a consent decree was signed that sets new deadlines for retrieving single-shell tank

waste, and constructing, commissioning and operating the Waste Treatment Plant. The consent decree calls for completing construction of the Waste Treatment Plant by 2019, achieving initial WTP operations by 2022, completing retrieving the waste from all 149 single-shell tanks before 2041 and closing the tanks in early 2043, treating all of Hanford's tank waste by 2047 and closing all 28 double-shell waste tanks in 2052.

Comparing Hanford's high-level radioactive waste to other DOE sites

Hanford	**177 tanks**	**56 million gallons**
Savannah River	**49 tanks**	**37 million gallons**
Idaho Falls	**11 tanks**	**1 million gallons**

Hanford's Cold War legacy

Eliminating the tank waste risk

Hanford produced plutonium for nuclear weapons for 45 years, leaving a legacy of 56 million gallons of deadly radioactive waste stored in 177 underground tanks. The oldest of these tanks went into service during World War II; the newest tanks were built during the Reagan Administration. Many of the tanks have leaked and, if the waste is not removed, eventually all 177 tanks will leak.

Hanford's high-level radioactive waste contains many radioactive isotopes that are soluble in water, such as cesium, strontium, technetium 99 and tritium. Once this material is in the groundwater, it can get to the Columbia River and send radioactive contamination downstream.

The Department of Energy and its Tank Operations Contractor, Washington River Protection Solutions, put extraordinary effort into safely managing the tank waste. Hundreds of millions of dollars every year go into monitoring the tanks for leaks, adding chemicals to control corrosion of the steel tank walls, assessing the integrity of the tanks, characterizing the radioactive and chemical composition of the waste and developing tools to retrieve the waste from the tanks.

The waste in the most vulnerable tanks – the old single-shell tanks – was "stabilized" by pumping most of the water from the waste. The waste wasn't removed; it was thickened so it couldn't flow out of a breached tank as easily.

All of these efforts are focused on reducing the risk posed by the tank waste; not eliminating the risk. The only way to eliminate the risk is by immobilizing the tank waste in the Waste Treatment Plant. Using a process known as vitrification, the waste is turned into a sturdy glass that keeps it isolated from the environment for thousands of years while its radioactivity slowly decays.

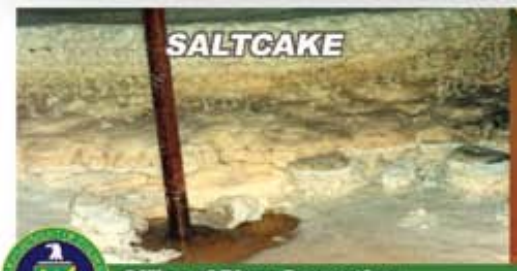
Types of waste

Hanford's 56 million gallons of tank waste contains a stew of radioactive materials and hazardous chemicals. It is highly radioactive, highly caustic, and requires remote handling and shielding. The chemistry of Hanford's tank waste continues to change, driven by the tank's chemical environment, radiation, and heat from the decay of radioactivity.

Multiple fuel processing methods were used at Hanford and waste was transferred between tanks and between tank farms. With the huge volume of waste produced, tank space was very limited. Past waste processing campaigns, conducted to remove uranium, strontium and cesium, added additional chemicals to the tanks.

During processing, uranium metal fuel, irradiated in Hanford's reactors, was dissolved in nitric acid. The solution was processed to remove plutonium for weapons and uranium for recycling into new reactor fuel. Hanford's tanks are made of carbon steel, rather than acid-resistant stainless steel, so the acid waste had to be neutralized with sodium hydroxide. Hundreds of tons of lye was added to the tanks, making Hanford's waste is both chemically and physically complex.

The waste in Hanford's tanks has separated into layers and the composition varies from tank to tank. In general, the waste is in the form of liquid, sludge, saltcake, slurry and hard, compacted waste at the bottom of some tanks. Chemical vapors are also present in the tanks.

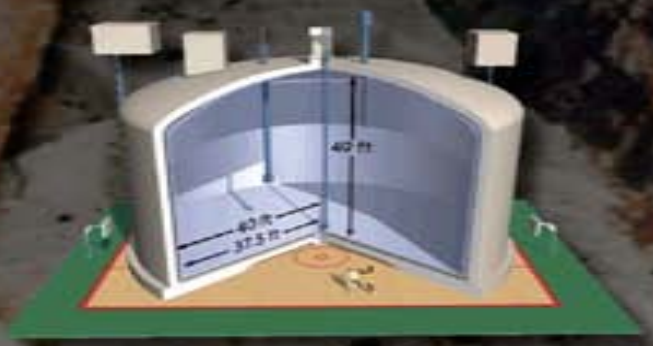


Anatomy of a waste tank

Hanford's tanks have an inner carbon-steel shell(s) surrounded by steel-reinforced concrete. They are covered with about 10 feet of soil and gravel. The only visual evidence of the tanks are pipes, called risers, that protrude from the ground. The risers vary in size from a few inches to 42 inches in diameter and are the only access to the tank's contents.

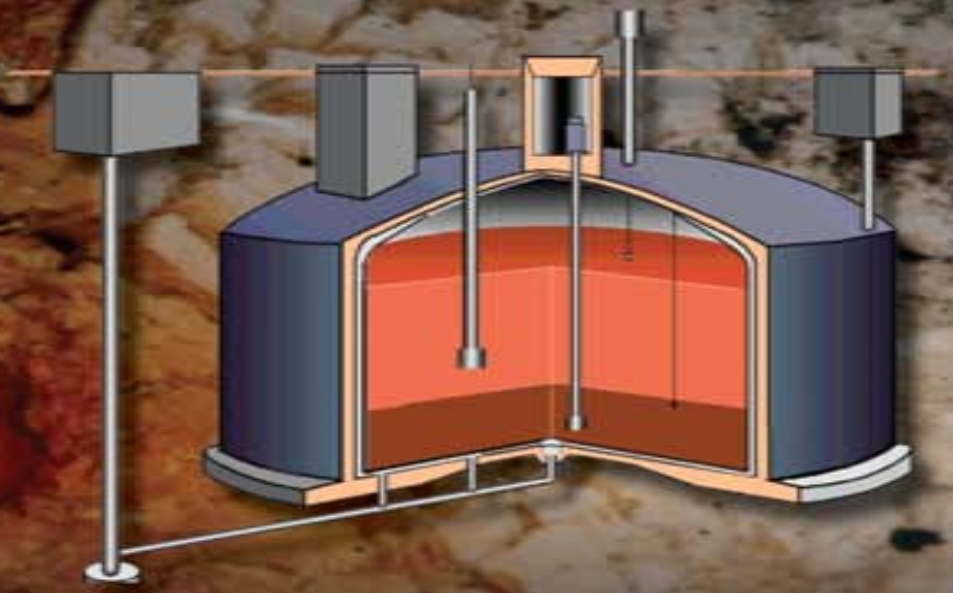
Tanks are grouped into 18 "tank farms" spread over two areas in central Hanford. The 200-East and 200-West areas are separated by about seven miles. Of the 177 tanks, 149 are single-shell design with a single steel liner and 28 are double-shell tanks with two steel liners separated by an air space.

TYPICAL SINGLE-SHELL TANK



Single-shell tanks were built from World War II until the mid-1960s. They vary in capacity from 55,000 gallons to 1 million gallons. The largest tanks are about 45 feet deep and 75 feet across -- slightly less than the length of a basketball court. About 60 of the single-shell tanks are suspected of leaking sometime in the past.

TYPICAL DOUBLE-SHELL TANK



Double-shell tanks were built from 1968 to 1986 in two capacities: 1 million gallons and 1.16 million gallons. With their double steel liners, the double-shell tanks are considered safer than the older single-shell tanks.

A history of leaks

Vadose Zone Project

The Vadose Zone Project was established to understand the radioactive and chemical contamination in the soil beneath Hanford's waste tanks as the result of past tank leaks and discharges from past plutonium-production operations. The vadose zone is the area of soil between the ground surface and the water table 200-to-300 feet below.

The Vadose Zone Project tracks and monitors contamination in the soil. Technologies are being developed and deployed to detect and monitor contaminants. Because surface water percolating into the soil can drive contaminants towards the water table, an important part of the project is controlling rain and snow runoff and directing it away from the single-shell tank farms.

Starting in the late 1950s, waste leaks from dozens of Hanford's single-shell tanks have been detected or suspected. Estimates of the amount of waste that has leaked vary from more than one-half million gallons to more than 1 million gallons. Most of the waste is in the soil around the tanks, but some of this waste is thought to have reached groundwater.

Hanford's single-shell tanks are decades past their 20-year design life and waste that leaks from these tanks enters the soil and eventually the groundwater. Beginning in 1998, a project was initiated to remove all the pumpable liquids from the single-shell tanks and transfer it to the newer and safer double-shell tanks.

The Interim Stabilization Project resulted in a major reduction in the risk to the environment by transferring more than 3 million gallons of liquid waste to the double-shell tanks. This left relatively immobile saltcake and sludges in the single-shell tanks. In 2004, the waste in the last of the 149 single-shell tanks was stabilized, greatly reducing the potential for additional leaks.

Interim surface barriers

Washington River Protection Solutions is constructing surface barriers over several of Hanford's single-shell tank farms as environmental protection until the contamination beneath the tanks can be cleaned up. The temporary barriers prevent rain and snow from soaking into the ground and spreading contamination. So far, barriers have been constructed over two tank farms.

The 60,000-square-foot barrier over T Farm covers the site of the largest tank waste leak in Hanford's history – some 115,000 gallons in the early 1970s. An impermeable barrier was applied over the farm. The barrier is sloped to drain moisture and collect it outside the tank farm.

The other barrier is over TY Farm. It is constructed of asphalt and drains moisture to a nearby evaporation basin.

Upgrading infrastructure

Hanford's tank farms are among the largest and most complex environmental projects in the nation. With 177 tanks ranging in age from 25 years old to nearly 70 years old, Hanford's facilities and infrastructure are in serious need of upgrading to support the long-term cleanup mission. This includes upgrades and installation of systems needed to reliably feed the Waste Treatment Plant a steady and consistent diet of high-level radioactive waste.

In addition to the tank farms, the Tank Operations contractor also operates the only nuclear facilities left at Hanford. The two facilities, the 222-S Laboratory and the 242-A Evaporator, are critical to safely storing and retrieving the tank waste and will be key to the operation of the Waste Treatment Plant.

222-S Laboratory

The 222-S Laboratory has operated since the early 1950s and has undergone several upgrades, expansions and changes in its mission. In 1994, 11 hot cells were added to the 70,000-square-foot laboratory to allow remote handling and analysis of highly radioactive waste samples. These hot cells are critical for analyzing tank waste bound for processing in the Waste Treatment Plant.

A number of upgrades have been made to the 222-S Laboratory since the Tank Operations Contract was awarded in late 2008. New analytical equipment was procured and installed. The obsolete DOS-based computer network at the lab was replaced with a modern system. A new energy-efficient office building was constructed, along with a climate-controlled warehouse, and a new heating system was installed at the laboratory.

242-A Evaporator

The 242-A Evaporator is critical to the safe and efficient management of Hanford's tank waste. Since it began operating in 1977, it has been used to control the volume of waste in the double-shell tanks, which have limited storage space. And the evaporator is a key component in the system that is used to transfer waste from aging single-shell tanks and will be critical to transferring waste to the Waste Treatment Plant.

The evaporator takes liquid waste from the double-shell tanks and processes it to remove excess water. The water is evaporated in a sealed vessel where it is heated under vacuum. The evaporated water is captured, condensed, filtered and sampled before being sent to a nearby effluent treatment plant.

Crews at the 242-A Evaporator decontaminated the operating heart of the facility, procured critical spare parts, and replaced valves and filters in the facility's raw water system. High-efficiency particulate air (HEPA) filters to eliminate contamination were replaced and new air compressors were installed.

Tank farm upgrades

Upgrades to the tank farms include removing old, contaminated equipment, bringing the electrical systems up to national codes, replacing old valves and filters and removing and replacing transfer lines for moving waste from tank to tank.

These upgrades make the tank farms a safer place to work and will allow the Tank Operations contractor to transition from a waste management role to an operations company responsible for feeding the Waste Treatment Plant.

Improvements have been made in the systems that monitor the integrity of the waste tanks and in tank ventilation and exhauster systems. Worker exposure to asbestos and other contaminants has been reduced. Working conditions have improved with new office facilities, change rooms and monitoring equipment.

Another tank farm upgrade will protect the environment. Interim moisture barriers built over the top of the T and TY Farms act as a protective shield, preventing rainwater from seeping into the soil and pushing leaked radioactive and chemical waste deeper into the ground. Precipitation collected on the TY barrier will be directed to a nearby evaporation basin lined with material to prevent it from leaking. The basin is covered with soil and grass to help soak up the moisture.

Retrieval challenges

Removing waste from Hanford's single-shell tanks is an incredible challenge. The high-level radioactive waste is complex and takes many forms, from hard saltcake, soft sludges and, in some tanks, a bottom layer of hard, insoluble material. Access to the tanks is limited to small pipes, called risers, that extend from the inside of the tanks to above ground and the tanks themselves are covered with 10 feet of soil. All work conducted inside the tanks must be done remotely.

To remove the waste from the tanks, several tools and techniques have been developed to break up the waste and mix it into a slurry that can be pumped. Liquid is sprayed into tanks to dissolve the saltcake and mobilize the sludges. High-pressure jets of liquid are used to break up the hardened waste at bottom of tanks. Chemicals are added to dissolve some types of waste .

The Tri-Party Agreement requires that 99 percent of the waste inside the tanks be removed.

Cold Test Facility

Testing of retrieval technologies and training of tank farm operators takes place at Hanford's Cold Test Facility. A nearly full-scale mock-up of a single-shell tank, it is 75 feet in diameter and 27 feet tall. Steel superstructures above the mock tank simulate ground level above different types of tanks and contain vertical risers like those found in Hanford's tanks.

The Cold Test Facility is a clean non-radioactive environment where simulated tank waste is used to test retrieval tools. Tools and retrieval methods are put through their paces without compromising the safety of workers.

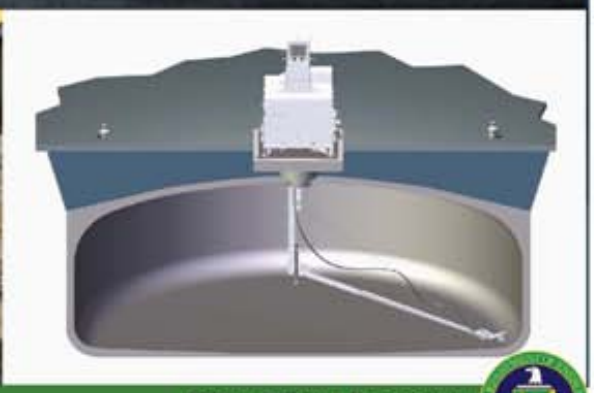
Mobile Arm Retrieval System

Washington River Protection Solutions has developed a new generation of robotic arm to speed waste retrieval from Hanford's single-shell tanks. Known as the Mobile Arm Retrieval System or MARS, it is capable of rotating 360 degrees, moving up and down and telescoping to reach all parts of the inside of a tank. The arm has high-and low-pressure water nozzles on its end to clean the sides of a tank and break up waste solids.

The arm extends from a central mast that hangs from the top of the tank. A pump moves the waste up the mast and outside the tank. The MARS is controlled remotely by an operator using joysticks, switches and push-button controls. In-tank video cameras guide the operators.

Unlike earlier retrieval systems that were lowered into tanks through the existing risers, the MARS is mounted on a concrete platform placed on top of the tank. This requires excavating the soil covering the tank and cutting a 55-inch hole in the steel-reinforced concrete tank dome.

The MARS was extensively tested on a demonstration platform and then installed in tank C-107. Development work is continuing on retrieval tools that can be attached to the end of the arm.



The Waste Treatment Plant

The Department of Energy is building one integrated system to solve the tank waste problem. Hanford's tank waste must be retrieved, transferred, pretreated to separate the high-level waste and the low-activity waste and processed to immobilize it using a technology known as vitrification.

Vitrification takes the toxic tank waste and blends it with glass-forming materials, heats in a melter to extreamly high temperatures to create molten glass. The waste-glass mixture is placed in stainless-steel canisters to cool. Borosilicate glass is an extremely sturdy and durable waste form. It is stable and impervious to the environment while its radioactivity decays over thousands of years.

The Waste Treatment Plant will vitrify a large portion of Hanford's 56 million gallons of radioactive tank waste. The cornerstone of Hanford cleanup, the $12.26 billion plant will be commissioned in 2019 and be in full operation in 2022. Bechtel National, Inc. is designing, constructing and initially commissioning the first-of-a-kind plant.

The Hanford Tank Operations Contractor, Washington River Protection Solutions, is responsible for managing the tank farms, upgrading the infrastructure to support continued operations while the waste is being retrieved and processed, and supporting startup of the Waste Treatment Plant, safely and reliably feeding waste to the plant, and accepting and storing the waste from the Waste Treatment Plant.

The Waste Treatment Plant consists of four nuclear facilities and scores of support facilities and utilities:

The Pretreatment facility separates the low-activity waste from the high-level waste. Low-activity waste is the liquid portion of the tank waste. It contains a relatively small amount of radioactivity in a large volume of material. High-level waste is primarily in the solids of the tank waste. It contains most of the radioactivity in a relatively small volume of material. During pretreatment, the solid waste is removed by filters and an ion-exchange process removes soluble high-level waste from the remaining liquid. The Pretreatment facility is the largest of the Waste Treatment Plant facilities with a footprint 1.5 football fields in length, more than one football field wide and the height of a 12-story office building.

The Analytical Laboratory's key function is to ensure that the glass waste product produced by the vitrification facilities meets all regulatory requirements and standards. About 10,000 waste samples a year will be analyzed to confirm the correct "recipe" is used to produce a consistent glass waste form.

The High-Level Waste Vitrification facility receives the high-level waste from the Pretreatment facility and mixes it with glass-forming materials in electric melters. The mixture is heated to 2,100 degrees F. The high-level waste canisters, each about 14 feet long and weighing about four tons, will be temporarily stored at Hanford in a specially designed shielded facility.

The Low-Activity Waste Vitrification facility uses the same melter technology to treat the low-activity waste. It is estimated that about 90 percent of volume of the Hanford tank waste is low-activity waste and 10 percent is high-level waste. The low-activity waste containers are four feet in diameter and seven feet tall, each weighing about seven tons. The containers will be stored at Hanford in a permitted landfill.

Supporting WTP operations

In addition to upgrading the tank farm infrastructure to support Waste Treatment Plant operations, several new facilities and systems need to be designed and constructed before the plant goes into full operation in 2022. These new facilities are necessary to feed waste to the vitrification plant, to treat secondary waste created by the Waste Treatment Plant and to store vitrified waste produced by the plant.

Waste Tank Feed System

Consistently feeding the Waste Treatment Plant high-level tank waste that meets strict regulatory and operating requirements is one of the toughest challenges faced by Washington River Protection Solutions.

Waste sludge is made up of liquids containing solids in various particle sizes. The waste must be mixed to break up the sludge and distribute the solid particles throughout the mixture. The waste must then be reliably delivered to the plant's Pretreatment facility in consistent 150,000 gallon batches.

WRPS will be required to meet the Waste Treatment Plant's requirements for waste feed, but many of those requirements are still being precisely defined. The current baseline plan is to use two 300-horsepower mixing pumps in the double-shell feed tanks to mix the waste prior to delivery to the Pretreatment facility. However, tests may show that a more robust feed system is required.

Secondary Liquid Waste Treatment facility

The existing Effluent Treatment Facility in the 200-East Area has treated liquid waste from Hanford cleanup activities for nearly two decades. Contaminated liquid is stored, treated to remove the contaminants and the clean water is disposed of in a landfill.

The Waste Treatment Plant will generate a large volume of liquid waste that is secondary to the plant's primary mission of vitrifying Hanford's tank waste. The Effluent Treatment Plant will be upgraded and expanded with a new facility designed to treat the liquid waste from the Waste Treatment Plant.

Integrated Disposal Facility

The Integrated Disposal Facility is a low-level waste disposal trench located in the 200 East Area. It consists of an expandable lined landfill divided into two disposal cells. One cell is permitted for mixed chemical and low-level radioactive waste. The other cell will be used to dispose of containers of vitrified low-activity radioactive waste produced by the Waste Treatment Plant.

The low-activity waste containers are four feet in diameter and about seven feet tall. When filled with vitrified waste, each container weighs about seven tons. More than 100,000 containers of low-activity waste are expected to be produced by the Waste Treatment Plant.

Interim Hanford Storage facility

The Interim Hanford Storage facility is a major project that is critical to the operation of the Waste Treatment Plant. The facility will store the first 4,000 canisters of immobilized high-level radioactive waste glass produced by the plant -- enough to support about 10 years of operation.

In the High-Level Waste Vitrification Facility, tank waste will be mixed with silica and other glass forming materials and heated to 2,100 degrees F in an electric melter. The molten waste/glass mixture will be poured into stainless-steel canisters that are 14 feet long and two feet in diameter, each weighing about four tons. Without an interim storage facility, the plant could run only for a short period of time before exhausting its limited on-site storage capacity.

The conceptual design for the facility is scheduled to be completed by mid-2012 and the facility is scheduled to be operational in August 2018.

Artist concept - Interim Hanford Storage Facility

Investigating supplemental treatment

The Waste Treatment Plant, as currently being built, will not have the capacity to vitrify all the low-activity waste in Hanford's tanks. A second Low-Activity Waste Vitrification facility is planned adjacent to the Waste Treatment Plant. However, the consent decree between DOE and Washington state requires DOE to evaluate bulk vitrification and other alternatives for treating up to half of the low-activity tank waste.

Technologies are being evaluated on their ability to create a waste form as good as, or better than, vitrified glass; the ability to contain mobile radioactive contaminants; technical maturity; cost effectiveness and life-cycle costs, ability to scale up to treat up to half the low-activity tank waste and ease of operation and maintainability within the defined schedule.

Supplemental treatment options

- Steam reforming, which uses superheated steam and a reactant to convert low-activity waste into a dry mineral product.
- Bulk vitrification, which places the waste and glass formers within a large open box and uses electrodes inserted into the mixture to heat and glassify the waste.
- Cast stone, in which the low-activity waste is mixed with cement and fly ash to produce a hard stone-like waste product.

All of the supplemental treatment options require an in-tank pretreatment system to separate low-activity waste from the high-level radioactive tank waste. Pretreatment options that are being considered are ion-exchange technology to remove soluble radioactive cesium from liquid low-activity waste by binding it to a specially designed resin, and rotary microfiltration to remove suspended solid high-level waste.

One of the toughest challenges facing the Tank Operations Contractor is consistently and reliably feeding the Waste Treatment Plant 150,000-gallon batches of high-level tank waste that meet strict regulatory and operating requirements. Waste must be retrieved from underground tanks and transferred to 15 double-shell tanks that will be used to feed waste to the Pretreatment facility.

A demonstration project is under way to test the effectiveness of the baseline plan to use two 300-horsepower mixing pumps in the feed tanks to break up the waste sludge, suspend the solid particles and keep the waste mixed while it is transferred to the Waste Treatment Plant.

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