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The Hanford Site Tank Waste Remediation System: An Update

Prepared for the U.S. Department of Energy
Office of Environmental Restoration
and Waste Management

Westinghouse Hanford Company Richland, Washington

Hanford Operations and Engineering Contractor for the
U.S. Department of Energy under Contract DE-AC06-87RL10930

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Tank Waste Remediation System: An Update

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ABSTRACT

The U.S. Department of Energy's Hanford Site, located in southeastern Washington State, has the most diverse and largest amount of highly radioactive waste in the United States. High-level radioactive waste has been stored in large underground tanks since 1944. Approximately 230,000 m^3 (61 Mgal) of caustic liquids, slurries, saltcakes, and sludges have accumulated in 177 tanks. In addition, significant amounts of ^{90}Sr and ^{137}Cs were removed from the tank waste, converted to salts, doubly encapsulated in metal containers, and stored in water basins.

A Tank Waste Remediation System Program was established by the U.S. Department of Energy in 1991 to safely manage and immobilize these wastes in anticipation of permanent disposal of the high-level waste fraction in a geologic repository. Since 1991, progress has been made resolving waste tank safety issues, upgrading Tank Farm facilities and operations, and developing a new strategy for retrieving, treating, and immobilizing the waste for disposal.

INTRODUCTION

The U.S. Department of Energy's (DOE) Hanford Site, located in southeastern Washington State, has the most diverse and largest amount of highly radioactive waste in the United States. A Tank Waste Remediation System (TWRS) Program was established in 1991 to safely store, treat, and dispose of those wastes. This paper provides an update on the progress of the TWRS program.

BACKGROUND

High-level radioactive waste (HLW) has been stored at the Hanford Site in large underground storage tanks since 1944. Approximately 230,000 m^3 (61 Mgal) of waste have accumulated in 177 tanks. These caustic wastes consist of different chemicals including liquids, slurries, saltcakes, and sludges.

The radioactive waste stored in these tanks came from different sources. These sources include 1) three plutonium and uranium recovery processes from approximately 100,000 Mtu of irradiated fuel, 2) three radionuclide recovery processes from waste, and 3) miscellaneous sources (e.g., laboratories and reactor decontamination solutions). These wastes were then concentrated and mixed in order to minimize the number of storage tanks required. The neutralized wastes include sodium nitrate/nitrite, sodium hydroxide, sodium aluminate, sodium phosphate, the hydrous oxides of iron, chrome, and other transition metals, large amounts of organics, and approximately 250 MCi of radionuclides.

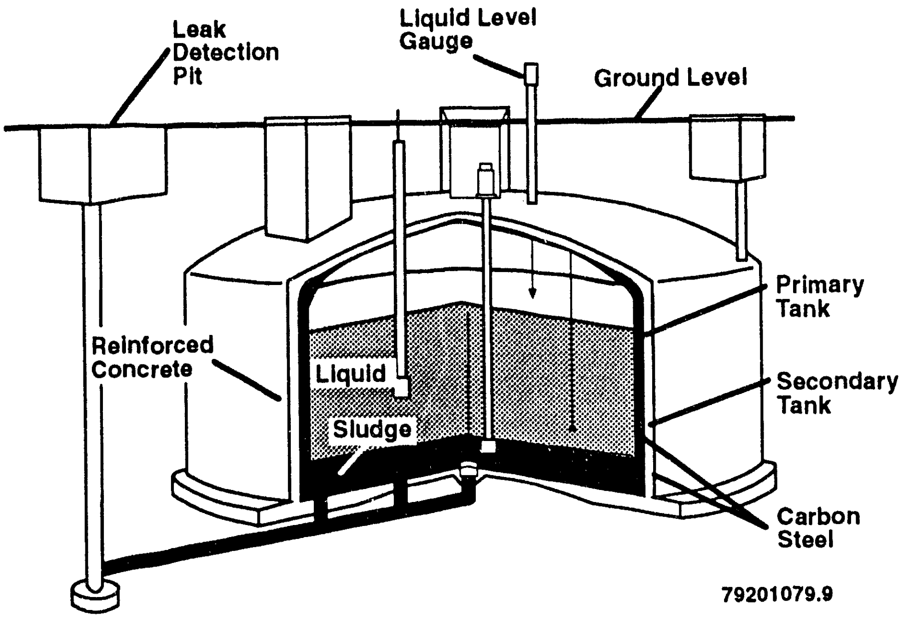
The wastes are stored in 149 single-shell tanks (SSTs) and 28 double-shell tanks (DSTs). The SSTs are made of reinforced concrete with a carbon-steel liner and can hold 208 m^3 (55,000 gal) to 3,800 m^3 (1 Mgal) of radioactive waste. The DSTs are a carbon-steel tank within a steel-lined concrete tank. The DSTs have a nominal capacity of 3,800 m^3 (1 Mgal), as shown in Figure 1. Of the older SSTs, 67 have leaked or are suspected to have leaked approximately 3,800 m^3 (1 Mgal). No waste has been added to the SSTs since 1980. The pumpable liquids are being removed from the SSTs so that the remaining waste is mostly sludge and saltcake. There is no evidence to suspect that any of the newer DSTs, which were placed in service in 1971, have leaked.

In addition to the waste stored in the tanks, significant amounts of ^{90}Sr and ^{137}Cs were removed from the tank waste, converted to salts, doubly encapsulated in metal containers, and stored in water basins. There are approximately 1,900, 6.7 cm (2.6 in.) dia x 52 cm (20.5 in.) long capsules containing approximately 160 MCi.

TWRS PROGRAM DESCRIPTION AND STATUS

The purpose of the Tank Waste Remediation System is "to store, treat, and immobilize highly radioactive Hanford Site waste in an environmentally sound, safe, and cost-effective manner." During the past two years, an

Figure 1. Double-Shell Tank.



extensive reevaluation of the waste treatment and disposal plan established from 1987 to 1989 (DOE 1987, 1988; Ecology 1989) was conducted. This reevaluation was needed because a number of major changes occurred, including the following:

- Identification of several tank waste safety issues that need to be resolved.
- Rejection of an existing facility (B Plant) for conversion to a waste pre-treatment facility.
- A decision by the DOE to retrieve waste from all the single-shell tanks, which caused a four-fold increase in the volume of waste to be treated.
- Concerns about the long-term adequacy of grout as the waste form for disposing of low-level waste.

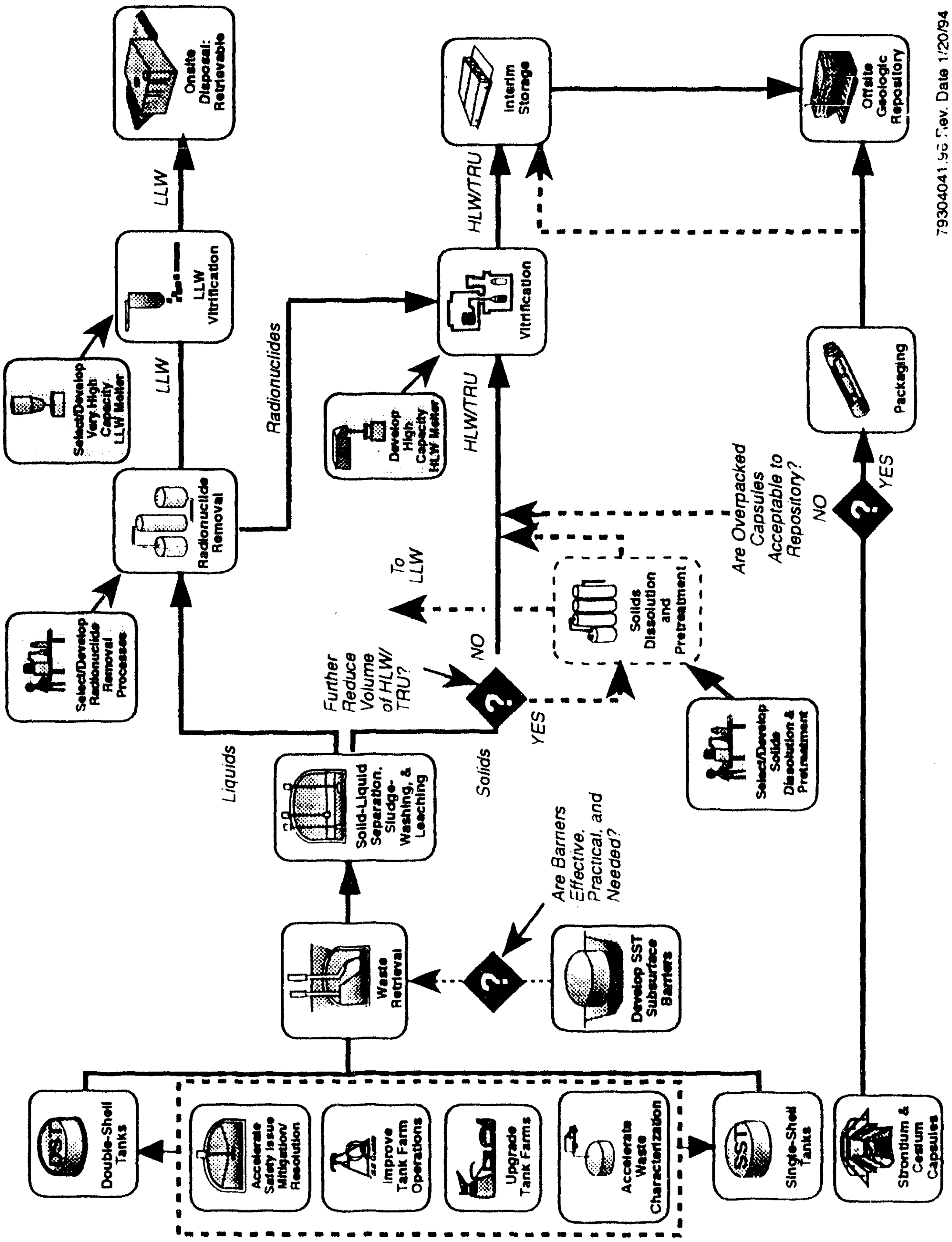
Systems Engineering is being applied to the TWRS to establish functions and requirements, and to identify all the relationships to other programs, as well as evaluating alternatives to accomplish this TWRS mission. This systematic, disciplined, and documented approach is an effective way to manage this large, complex waste management program that will require many years to complete at the Hanford Site.

The strategy developed as a result of this reevaluation has received extensive review and comment by the regulators and the public. Changes were made in an amendment to the *Hanford Federal Facility Agreement and Consent Order* (Ecology 1989) establishing milestones for conducting the TWRS strategy. This amendment was approved by the U.S. Environmental Protection Agency, the Washington State Department of Ecology, and the U.S. Department of Energy on January 25, 1994. The TWRS technical strategy is shown in Figure 2, and is described in the following paragraphs.

TANK FARM OPERATIONS

Newly generated wastes continue to be received in the double-shell waste tanks, and approximately four million gallons of liquid waste are yet to be pumped from the older single shell-tanks to the DSTs to reduce the risks of leaks. During 1993, liquid was pumped from three assumed leaking tanks: 241-T-101, 241-BX-110, and 241-BX-111. The 242-A waste evaporator has been refurbished and is ready to resume operation. This will reduce the volume of waste stored in DSTs by several million gallons and will concentrate dilute wastes received from facility cleanup in the future. Hundreds of tank waste samples need to be taken and analyzed before resolving safety issues and designing waste treatment processes. Continuous surveillance and monitoring of the 177 underground tanks is necessary to assure the waste is safely stored.

Figure 2. Hanford Tank Waste Remediation System Strategy.



Two Tank Farm Conduct of Operations incidents and a higher than expected worker injury rate caused an administrative hold to be placed on tank farm operations in August 1993 until improvements were made. These improvements included organizational restructuring, focused work teams, training, revised procedures, and equipment repairs. Tank farm activities were restarted sequentially as the work teams have become ready. Today, most of the tank farm activities have restarted, and worker injury rates, as measured by first-aid cases, OSHA recordables, and lost work days, are one-third what they were in the first eight months of 1993.

The plan is to continue improving tank farm operations to increase productivity and keep the workplace safe.

TANK FARM UPGRADES

Many of the Hanford Site facilities and equipment at the tank farms are 40 to 50 years old and have not been well maintained. Upgrading the tank farms is a high priority. Upgrades include new safety analyses; replacing old instrumentation, equipment, and ventilation systems; constructing new waste transfer lines; constructing additional DSTs (six are currently being designed); and removing old contaminated equipment and soil. A typical alarm panel upgrade with before and after photographs, is shown in Figure 3. The tank farms need to be upgraded, because they will continue to provide interim waste storage for many years until the waste can be disposed.

SAFETY ISSUES RESOLUTION

The highest TWRS program priority is resolution of waste tank safety issues. The status on resolving these safety issues was recently reported (Reep 1993). The safety issues of primary importance are summarized below.

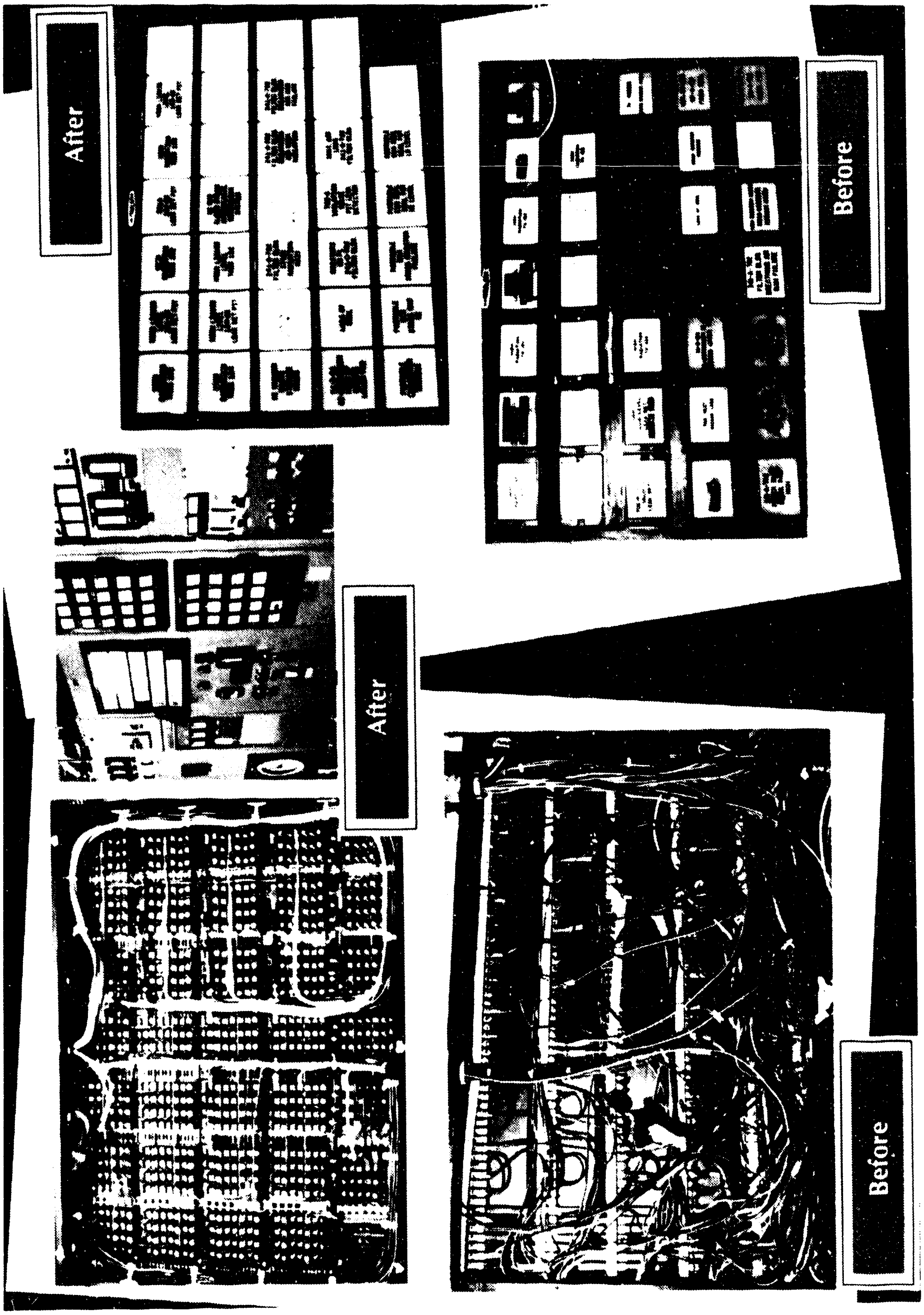
- Flammable gas concentrations in 25 SSTs and DSTs

  The most serious concentration is in tank 241-SY-101. In this tank, hydrogen has been generated and released periodically at high enough levels so that the lower flammability limit was exceeded in the tank head space for several minutes until the hydrogen is removed by the ventilation system. A 60-foot-long experimental mixer pump was installed in July 1993, and is being tested to determine if it will mix the solids so that the gas will be released continuously and, therefore, will not build up to unsafe concentrations. Test results to date are favorable. It is estimated that most of the gas generated since the last venting in June 1993 was released with periodic operation of the pump. Closure of the flammable gas unreviewed safety question is scheduled for March 1995.

- Potentially explosive mixtures of sodium nickel ferrocyanide and sodium nitrate and nitrite in 20 tanks.

  In certain concentrations, these chemicals are known to react exothermally at high temperatures. Extensive testing of waste samples and simulants, along with temperature measurements and

Figure 3. A Typical Tank Farm Alarm Panel Upgrade.



modelling, suggests that these wastes are safe and can continue to be safely stored for many years. The understanding and evaluation of this safety issue has progressed to the point that the unreviewed safety question will be closed in early 1994.

- The potential for exothermic nitrate-nitrite organic chemical reactions in nine SSTs.

  These tanks contain organic materials that, in certain concentrations, may react with nitrate and nitrite at high temperatures. Evaluation work on those tanks has begun. The tank of greatest concern, because of potential for a liquid fuel burn, tank 241-C-103, has a thin floating organic layer on top of the waste. In December 1993, samples were taken of the vapor space, the organic layer, and the aqueous waste of this tank. These wastes are now being analyzed. Preliminary results indicate that this organic waste is predominately tributyl phosphate with a small amount of natural paraffin hydrocarbons. The tank temperature conditions are well below the flashpoint of such a mixture. Closure of the tank 241-C-103 unreviewed safety question is expected in March 1994.

- Mitigation of worker safety concerns resulting from the random release of fugitive noxious vapors from passively ventilated SSTs.

  These vapors have a strong odor and, on occasion, have made some workers ill. Workers are now protected with breathing apparatus, but the goal is to eliminate the source of the vapors. Investigative work is in progress to determine the causes of the vapors, and corrective actions are being developed. Eight tank farms have been released from respiratory protection requirements to date and restrictions have been reduced in other tank farms.

- High-heat load in SST 241-C-106 requiring periodic addition of water to provide evaporative cooling.

  Because many of the SSTs have leaked, attempts are underway to remove as much liquid as possible from the tanks. Currently, the liquid cannot be removed from tank 241-C-106 because the tank would overheat and might potentially damage its structural integrity. Therefore, plans are underway to remove the waste from this tank, and a project has begun to provide the facilities and equipment to start sluicing the waste from this tank in 1997.

WASTE CHARACTERIZATION

It is necessary that waste characterization data meet the needs of safety, waste treatment, and disposal program elements. The waste core sampling equipment is improving and additional systems have been placed in service. Additional analytical laboratory hot cells are under construction; faster more accurate analytical methods and instruments are being developed, and the laboratory data management system is being upgraded. In response to a Defense Nuclear Facility Safety Board Recommendation (93-5), waste sampling and characterization for safety issue identification and resolution will be accelerated. This includes screening all single-shell tanks over the next three years to determine if any other tanks have safety concerns that may require resolution.

WASTE RETRIEVAL

Waste will be retrieved from the tanks for treatment, immobilization, and disposal. The waste in some safety issue tanks may also have to be removed to resolve the safety issues. Hydraulic sluicing has been the method used to retrieve waste from underground radioactive waste tanks at the Hanford Site and elsewhere. While sluicing is the preferred method of waste retrieval, it may not be acceptable in single shell tanks that leak (or it may not remove some of the hard sludges). A robotic long reach arm with an assortment of tools is being developed to solve these problems. Subsurface containment barriers that could be installed around and beneath the leaking tanks are also being considered. Design of the first SST sluicing system (for tank 241-C-106) is in progress.

WASTE PRETREATMENT

The waste retrieved from the tanks will be separated into two fractions so that most of the radionuclides, and only a small part of the waste volume, are in the HLW fraction. The HLW will be vitrified and shipped offsite for disposal in a geologic repository. The bulk of the chemicals, and only a small amount of radionuclides, would be in the low-level waste stream which will be vitrified and disposed near the surface onsite. The strategy is to use proven separations technology, to the fullest extent possible. More advanced separations technologies will be developed but only implemented if needed to achieve the required level of radionuclide removal or an acceptably small enough volume of HLW. The pretreatment processes will include the following:

- Solid-liquid separation, and sludge washing and leaching, with the soluble liquid fraction destined to be the low-level waste stream. A sludge settling test in tank 241-AZ-101 was initiated.

- Radionuclide removal from the soluble liquid fraction to 1) assure it is categorized as low-level waste, and 2) to enable it to be vitrified in a lightly shielded waste vitrification facility. Ion exchange processes are planned to remove ^{137}cesium and possibly ^{90}strontium, which will be routed to the HLW stream. Removal processes for long-lived mobile radionuclides (e.g., ^{99}technetium) will be developed as a contingency.

- Enhanced sludge washing, leaching, and blending will be used to minimize the amount of high-level waste.

- Technology development for selective sludge dissolution and advanced radionuclides separation processes will continue as a contingency. These technologies may be needed if the amount of vitrified HLW to be produced is not acceptable to the repository or if there is an economic reason to reduce the amount of glass.

- Organic destruction process development will also continue as a contingency for resolution of waste tank safety issues or, if needed, to achieve radionuclide separation.

LOW-LEVEL WASTE IMMOBILIZATION

The low-level waste will be vitrified and disposed near surface, onsite in a retrievable form. The existing grout immobilization and the disposal system will be maintained as a contingency for freeing up tank space until new DSTs are available. The low-level waste vitrification facility capacity will be approximately 100 tons per day of glass. Standard glass industry melter technology may be adapted for this application and the radiation level of the waste stream should be low enough to allow minimal shielding. Neither the final vitrified waste form (large monoliths or small pieces) nor the disposal container have been selected. Some melter tests have been conducted and an aggressive program of waste form development and vendor melter tests must be carried out to meet the schedule.

HIGH-LEVEL WASTE VITRIFICATION

Vitrification as borosilicate glass is generally accepted as the method to immobilize high-level waste. The TWRS strategy is to provide a high-level vitrification capacity that will be able to vitrify all of the high-level waste in 20 years. This will require a melter capacity of approximately 15 tons per day. A high capacity melter development program is being conducted. A stirred melter and a high temperature melter are being acquired for test. The number and size of melters that will be installed in the HLW vitrification facility will depend upon the results of the development program.

The waste container capacity and configuration will be optimized considering such factors as the vitrification plant, interim storage, and the geologic repository. This may include a larger HLW "package" (e.g., $10m^3$ container) to reduce the cost of disposal at the repository.

INTERIM HLW STORAGE

HLW containers will require onsite storage for many years until a geologic repository is ready to accept them.

SCHEDULE

The schedule for carrying out the TWRS program includes 1) completing retrieval of all SST waste by 2018, 2) closing all SST farms by 2024, and 3) completing all waste vitrification by 2028. The major milestones embodied in a recently approved amendment to the Tri-Party Agreement (Ecology 1989) are listed in Table 1.

Table 1. TWS Major Milestones.

Milestone	Date
• Mitigate/Resolve Tank Safety Issues	9/2001
• Complete Single-Shell Tank (SST) Interim Stabilization	9/2000
• Provide Additional Double-Shell Waste Tanks • Double-Shell Tank Space Evaluation	12/1998 9/1994 (annually thereafter)
• Complete Tank Farm Upgrades	6/2005
• Tank Waste Characterization - Issue Tank Characterization Reports for all SSTs and DSTs (177)	9/1999
• Complete Closure of All Single-Shell Tank Farms - Develop SST Waste Retrieval Technology - Complete Evaluation and Testing of Subsurface Barriers - Initiate Full Scale Demonstration of Waste Retrieval - Initiate Tank Waste Retrieval from One SST - Complete Waste Retrieval from All SSTs	9/2024 9/1994 9/1997 10/1997 12/2003 9/2018
• Complete Pretreatment Processing of Hanford Waste - Start Construction of LLW Pretreatment Facility - Start Hot Operations of LLW Pretreatment Facility - Start Hot Operation of HLW Pretreatment Facility	12/2028 11/1998 12/2004 6/2008
• Complete Vitrification of Hanford High-Level Waste - Initiate Construction of HLW Vitrification Facility - Initiate Hot Operations of HLW Vitrification Facility	12/2028 6/2002 12/2009
• Complete Vitrification of Hanford Low-Level Tank Waste - Select Reference Melter - Initiate Construction of LLW Vitrification Facility - Initiate Hot Operations of LLW Vitrification Facility	12/2028 6/1996 12/1997 6/2005

NOTE: See Part 1, Amendment 4 of the Tri-Party Agreement (Ecology 1989) for a description of these milestones and the many additional sub-tier milestones.

CONCLUSION

The Hanford Site TWRS Program is a large, complex program that will require many years to complete. Acquiring the commitment and funding to conduct this program will require a national consensus that this work is necessary and is being done in a cost-effective manner. Therefore, it is imperative to work safely, protect the public, seek the best technology, and use national expertise in planning and conducting this TWRS Program.

The DOE is committed to an open, responsive policy and encourages public participation in the Hanford Site cleanup discussions. Ten public meetings on the TWRS Program were held in 1993 in the Pacific Northwest, and citizens advisory groups have been established. The Hanford Site has also been selected as a place to test the Clinton administration's thrust to "reinvent government." This is particularly appropriate because cleaning up the Hanford Site is estimated to cost tens of billions of dollars.

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