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DESCRIPTION OF A MULTIPURPOSE PROCESSING AND STORAGE COMPLEX FOR THE HANFORD SITE'S RADIOACTIVE MATERIAL

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ABSTRACT

The mission of the U.S. Department of Energy's (DOE) Hanford Site has changed from defense nuclear materials production to that of waste management/disposal and environmental restoration. The Multipurpose Processing and Storage Complex (MPSC) is being designed to process discarded waste tank internal hardware contaminated with mixed wastes, failed melters from the vitrification plant, and other Hanford Site high-level solid waste. The MPSC also will provide interim storage of other radioactive materials (irradiated fuel, canisters of vitrified high-level waste [HLW], special nuclear material [SNM], and other designated radioactive materials).

INTRODUCTION

The mission of DOE's Hanford Site has recently changed from defense nuclear material production to that of waste management/disposal and environmental restoration. To satisfy this mission, the DOE has established the Tank Waste Remediation System (TWRS) Program in the Office of Environmental Restoration and Waste Management to manage and immobilize for eventual disposal the waste in 177 underground storage tanks at the Hanford Site. The TWRS Program includes all activities for receiving, safely storing, maintaining, treating, and packaging for disposal all radioactive tank waste. This tank waste includes the contents of 149 single-shell tanks, 28 double-shell tanks, and any new waste added to these facilities, as well as all cesium/strontium capsules currently stored onsite and those cesium/strontium capsules from offsite users. Other radioactive materials, such as irradiated fuels, also will be safety processed and interim stored.

The MPSC is structured to process discarded waste tank internal hardware (e.g., risers, pumps, thermocouple wells, etc.) contaminated with mixed wastes in preparation for final disposal. In addition, the MPSC will process failed melters from the Hanford Waste Vitrification Plant (HWVP) to segregate the high-level solid waste portion (residual glass, ceramic brick, etc.) from the balance of the melter. Other Hanford Site high-level solid waste also will be processed in preparation for final disposal. The MPSC will provide stabilization and interim storage of the Site's irradiated fuel, cesium/strontium capsules, SNM, canisters of vitrified HLW glass, and other designated radioactive materials.

DISCUSSION

The capability to process the Site's high-level solid waste and discarded tank internal hardware contaminated with mixed waste in preparation for final disposal is one of the critical operations required for cleanup of the Hanford Site.

Permitted interim storage is required to proceed with tank waste retrieval. Several of the Site's former production facilities are being used to store radioactive material (cesium/strontium capsules, irradiated fuel, and SNM). Storage of these radioactive materials in a modern facility that meets today's environmental and regulatory requirements will allow the former production facilities being used for storage to be put into a mode preparatory for ultimate decontamination and decommissioning. This will result in the savings of plant operating funds that can be turned into cleanup dollars. Current technology, both domestic and foreign, will be adapted with the expectation that no new technology will be required.

PROCESSING

A major feature within the MPSC is the Processing Storage Preparation and Shipping (PSPS) facility. The PSPS consists of a number of hot cells that will be used to decontaminate discarded tank internal hardware, segregate the HLW portion of failed HWVP melters from the balance of the melter, and stabilize failed N Reactor fuel (and sludge) in preparation for dry storage. The facility will have volume (size) reduction capability and a temporary lag storage pool for receipt of damaged and intact N Reactor fuel. Also included will be a capability for shipping material stored in the MPSC to final disposal or subsequent processing prior to final disposal.

Tank Internal Hardware

The U.S. Environmental Protection Agency promulgated a final rule for the treatment of hazardous (dangerous and/or mixed waste) debris, including discarded equipment contaminated with listed solvents. This rule, known as the Debris Rule,[1] became effective on November 19, 1992. The Debris Rule requires that any waste tank internal hardware that is to be discarded must be cleaned (externally and internally). The standards require treatment to a relatively "clean" metal surface. No visible waste (e.g., salt cake) can be left on any metal surface in quantities greater than 5 percent per square inch. This must be verified for all internal and external surfaces.

HWVP Melters

It is expected that the HWVP melter operating life is about 3 years. The high-level solid waste portion of the failed melters needs to be segregated from the balance of the melter. A failed melter probably will contain about 2,300 kg (5,000 lb) of vitrified HLW. The PSPS includes remotely operated and maintained dismantling equipment and segregation/decontamination capability. Also included will be the function of packaging the low-level waste rubble for shipment to a low-level waste-handling facility, and preparation of the high-level portion for inclusion in the glass/grout pretreatment operation or for interim storage in the MPSC.

N Reactor Fuel

Uranium and zirconium metals are chemically reactive in water and air. Their reactivity is increased by greater metal surface area and higher temperatures, as well as other factors. Small pieces of the metals are more reactive than large pieces, and powders are pyrophoric. Precautions are required to avoid fires when handling or processing uranium or zirconium metal.

The N Reactor fuel inventory in the current water storage basins contains many elements whose cladding was breached during reactor discharge, subsequent handling, or storage. The cladding failures range from cracks to severed fuel elements. The exact number of damaged elements is unknown at this time. Fuel-handling operations and fuel oxidation resulted in irradiated fuel accumulating on the water storage basin floors. Zirconium oxide, iron oxide, concrete grit, and other materials also have accumulated and mixed with the fuel to form a sludge on the basin floors. The sludge and failed fuel elements require stabilization before dry storage. This consists of a remotely operated and maintained oxidation and packaging process in an inert atmosphere.

The PSPS also will have a temporary lag storage pool for receipt of N Reactor fuel (and sludge). Included will be a capability for packaging the fuel and stabilized sludge/failed elements for interim dry storage and monitoring in the MPSC.

STORAGE

The MPSC will provide interim storage of the Site's cesium/strontium capsules, vitrified HLW glass canisters, irradiated fuel, unirradiated uranium, SNM, and other designated radioactive materials.

Several dry storage systems have been developed worldwide for irradiated fuel.[2,3,4,5,6,7] These include metal casks, concrete casks, horizontal concrete modules, dual-purpose casks, and modular concrete vaults. It is expected that one or more of these concepts will be used for storage of the cesium/strontium capsules, glass canisters, and irradiated fuel. The SNM will be stored with the appropriate safeguards/security requirements being fully implemented.

Cesium/Strontium Capsules

It is anticipated that about 1,300 cesium capsules and 600 strontium capsules will be stored in the MPSC.

The cesium capsules contain cesium chloride and consist of stainless steel inner and outer containers. The outer capsule dimensions are 52.8 cm (20.8 in.) long and 6.6 cm (2.6 in.) in diameter. The average radioactivity in each cesium capsule is 42 kCi. The peak radioactivity in a cesium capsule is about 59 kCi. The average power per capsule is about 200 W. The peak power is about 280 W.

The strontium capsules contain strontium fluoride and consist of hastelloy* inner, and stainless steel outer, containers. The outer capsule dimensions are 51.1 cm (20.1 in.) long and 6.6 cm (2.6 in.) in diameter. The average radioactivity in each strontium capsule is 39 kCi. The peak radioactivity in one capsule is about 102 kCi. The average power per capsule is about 280 W. The peak power is about 691 W.

HLW Glass Canisters

The HWVP will produce canisters of vitrified HLW in a borosilicate glass form. Each canister is 60 cm (2 ft) in diameter, 3 m (10 ft) tall, and weighs about 454.5 kg (1,000 lb) empty. Each canister normally will be 85 percent filled with glass, and at that time will weigh about 2,104.5 kg (4,630 lb).

The HWVP as currently designed will produce about 2,000 canisters of glass from the Hanford Site double-shell tanks. The number of glass canisters from single-shell tank wastes is dependent upon the pretreatment process selected.

*Hastelloy is a trademark of Stoody Deloro Stellite, Incorporated.

Irradiated Fuel

Table 1 lists the quantity of the various types of irradiated fuel currently stored at the Site.

N Reactor Fuel

The N Reactor fuel elements consist of two concentric tubes made of uranium metal coextruded into Zircaloy-2 cladding. There are two basic types of fuel elements differentiated by their uranium enrichment. Mark IV fuel elements have a preirradiation enrichment of 0.947 percent ^{235}U in both tubes and an average uranium weight of 22.7 kg (50 lb). These elements have an outside diameter of 6.15 cm (2.42 in.) and a length of 44.2, 9.1, 62.5, or 66.3 cm (17.4, 23.2, 24.6, or 26.1 in.). Mark IA fuel elements have a preirradiation enrichment of 1.25 percent ^{235}U in the outer tube and 0.947 percent ^{235}U in the inner tube. These elements have an average uranium weight of 16.4 kg (36 lb). Mark IA fuel elements have an outside diameter of 6.1 cm (2.40 in.) and a length of 37.8, 49.8, or 53.1 cm (14.9, 19.6, or 20.9 in.). There is also a small amount of Mark IV fuel with 0.71 percent ^{235}U enrichment.

Single-Pass Reactor (SPR) Fuel

The SPR fuel consists of a machine's uranium core that is sealed within, and metallurgically bonded to, an aluminum can. There are three basic designs for SPR fuel elements: solid core cylinders, hollow core cylinders, and tubes. The SPR fuel is made primarily in two ^{235}U concentrations, natural (0.71 percent) and 0.94 percent; although other enriched fuel, including 1.25, 1.7, and 2.1 percent ^{235}U, and depleted fuel, including 0.114 and 0.22 percent ^{235}U, also were made. The lengths of the fuel elements range from approximately 11.9 to 22.9 cm (4.7 to 9.0 in.), with specific lengths generally associated with specific ranges of

Table 1. Irradiated Fuel Inventory.

Fuel type	Quantity
N Reactor	2,096.3 MTU
Single-pass reactors	3.4 MTU
Shippingport Core II	15.7 MTU
Fast Flux Test Facility	12.9 MTHM*
Miscellaneous	2.6 MTHM

*Includes 1.9 MTHM of unirradiated fuel as of November 1992.

MTHM = Metric tons of heavy metal (uranium plus plutonium)
MTU = Metric tons of uranium

enrichment. The diameters of most of the fuel elements vary from 3.45 to 3.63 cm (1.36 to 1.43 in.) for compatibility with slight differences in the process tubes of the different production reactors.

Shippingport Core II Fuel

Seventy-two Shippingport Core II standard blanket assemblies (natural uranium) are stored at the Site. The assemblies are 361.4 cm (142.3 in.) long and have a 19.1-cm (7.5-in.) square cross-section. The assemblies contain three basic sections which are bolted together: an extended fuel cluster and top and bottom extension brackets. The fuel cluster is clad with Zircaloy-4. The extension brackets are made of 304 stainless steel. Each assembly weighs approximately 536.4 kg (1,180 lb). The fuel cluster consists of two identical oxide fuel plate subassemblies welded together to form a square structure and two Zircaloy-4 cluster extensions welded to the ends of the subassemblies. Each subassembly consists of 30 compartmented fuel plates and two Zircaloy-4 end plates welded together to form parallel coolant channels. The fuel plate design includes many small fuel wafers surrounded by a Zircaloy-4 grid to provide adequate structural strength. The wafers have a pyrolytic carbon coating that prevents the zirconium from reacting chemically with the uranium oxide.

Fast Flux Test Facility (FFTF) Fuel

The FFTF driver fuel assembly consists of a 217-pin bundle enclosed in a hexagonal duct fabricated from 0.3-cm (0.12-in.) thick 316 stainless steel. The assembly is 3.66 cm (12 ft) long and 11.6 cm (4.575 in.) across the flats, with an overall cross-sectional width of 13.1 cm (5.16 in.). Assembly features include a shield orifice assembly, an inlet nozzle, load pads, and a grapple socket at the top. The fuel pins are 0.58 cm (0.23 in.) in diameter and approximately 237.5 cm (93.5 in.) long, with a 91.4-cm (36-in.) long fuel-bearing region centered 166.6 cm (65.6 in.) from the bottom end of the fuel assembly. Preirradiation fuel enrichment for standard fuel is enveloped by the following numbers: 0.714 or 0.200 percent ^{235}U, 88 percent ^{239}Pu and ^{241}Pu, and 22 to 29 percent plutonium/(uranium + plutonium).

Miscellaneous Fuel

The miscellaneous fuel consists of seven full or nearly full assemblies and disassembled fuel pin pieces from pressurized water reactors and boiling water reactors. In addition, there are small fuel fragments and pellets from the FFTF reactor; the K Reactors; the Experimental Breeder Reactor II at the Idaho National Engineering Laboratory in Idaho Falls; the Training Reactor; Isotopics, General Atomics at Oregon State University;

General Electric Test Critical Facility and Southwest Experimental Fast Oxide Reactor at Vallecitos Nuclear Center in Pleasanton, California; and experimental light-water reactors.

Unirradiated Uranium

There are approximately 2,500 MTU of unirradiated, low-enriched uranium to be interim stored in the MPSC. The current inventory consists of uranium metal billets, finished and unfinished N Reactor fuel elements, and uranium oxide powder and pellets.

SNM

The SNM is located in secured storage on the Hanford Site. Some of the materials also contain uranium in varying enrichments as well as plutonium. These materials exist in many different chemical forms with various degrees of purity. The nine categories of SNM are as follows:

- Ash
- Polycubes
- Sludge
- Oxide
- Sand, slag, and crucible
- Filters
- Metal
- Unirradiated FFTF fuel
- Miscellaneous liquids.

Most of the material is either an oxide or a solution. Solutions may be converted to a solid before they are dry stored in the MPSC.

Other Radioactive Materials

The MPSC is also designated to provide interim storage for other radioactive materials. This includes, but is not limited to, spent cesium ion-exchange columns, material separated from past reprocessing operations (e.g., ^{238}Pu and neptunium), and remote-handled transuranic wastes with a dose rate greater than 100 rem/h.

MONITORING AND CONTROL

The PSPS will house a central control room, which shall have the capability to monitor and coordinate the various systems that provide displays and reporting for the MPSC and minimize the number of personnel required for intrusion control and maintenance of the MPSC safeguards and security system. Following is a partial list of these systems:

- Accounting control--Receiving of the different materials (ensuring the material is still in container), entering accountability information (imaging and other means), remote handling and placement of the material, verification before shipping, etc.

- Material control--Retrieval (remote handling), comparison to original (values, quantities, image, etc.), monitoring of sensors (storage vessel, vault, stacks, etc.), special inventories, etc.

- Intrusion detection--Graphic display of sensor alarms, video display of alarmed area, sensor self-test, operator selection of area video (camera pan/tilt/zoom), remote physical test of sensors, redundancy of components, etc.

- Access control--Access control cards, biometric checks, personal identification numbers, operator assistance via intercom and video display, two-person rule, door cameras, emergency preparedness area accountability, redundancy of components, etc.

- Reports--Operator-selected alarm time slices, authorized access lists, rally point lists, zones on access, selected inventories of material, inoperative sensors, inoperative cameras, etc.

SHIPPING

Shipping of the material stored in the MPSC to final disposal, or subsequent processing prior to final disposal, shall include the following:

- Glass canister load-out system (crane, transfer cask, cask inspection, overpack/repack, etc.) for shipment to a federal repository for final disposal

- Fuel assembly container load-out system (crane, transfer cask, cask inspection, overpack/repack, etc.) for shipment to a federal repository for final disposal or subsequent processing; may be the same system used for glass canisters

- Cesium/strontium capsule load-out system for shipment to a federal repository for final disposal, to HWVP for vitrification, or to pretreatment before vitrification

- SNM load-out system for transfer of material to other DOE sites

- Load-out system for shipment of other radioactive materials for subsequent processing in preparation for final disposal.

STATUS

The MPSC is a proposed fiscal year 1997 major system acquisition within the Hanford Site TWRS Program. The Justification for Mission Need has been submitted to the DOE. A preconceptual design of the complex will be performed by Kaiser Engineers Hanford. Preliminary (Title I) and Detailed (Title II) Design are to be conducted by an offsite Architect-Engineer beginning in 1997. Construction of the complex will be in sequential modules with the initial module expected to be in operation in the 1999 time frame. The PSPS is to be in operation in the 2005 time frame.

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