HANFORD WASTE VITRIFICATION

AN OVERVIEW

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ABSTRACT

Rockwell Hanford Operations, a prime operating contractor to the U.S. Department of Energy, has the lead responsibility for the development, design, construction, and operation of the Hanford Waste Vitrification Plant (HWVP). The HWVP, which will be built at the Hanford Site, will vitrify existing and future high-level and transuranic wastes produced by defense activities at the site. The Pacific Northwest Laboratory (PNL) of Battelle Memorial Institute has the support responsibility for providing technology for the waste form and the vitrification system to be utilized in the HWVP. This paper describes the vitrification process and the features of the HWVP. At the present time, the HWVP is ready to proceed with conceptual design.

INTRODUCTION

Overview

The United States has been engaged in Defense nuclear activities at Hanford for over 40 years, but to date, none of the high-level and transuranic wastes have been processed for final disposal. The proposed HWVP will be the Nation's third production-scale facility to vitrify high-level and transuranic liquid nuclear waste for disposal. Approximately 28 million gallons ($1x10^5 m^3$) of nuclear wastes, stored as liquids and sludges in underground double-shell tanks, will have accumulated at Hanford by 1995. Some 13 million gallons ($5x10^4 m^3$) of this waste will be pretreated in the existing B Plant on the Hanford site. The purpose of this pretreatment will be to prepare approximately 6 million gallons ($2x10^4 m^3$) of high-level and transuranic waste feed for the vitrification plant. The HWVP will immobilize this high-level and transuranic waste in borosilicate glass cast into stainless steel canisters. The filled canisters will be stored at the Hanford Site until they can be disposed of in a Federal geologic repository.

The Hanford Waste Management Program includes development of the Immobilization Process and design and construction of the HWVP. The Immobilization Process activities will develop those unit processes required for segregating from the Hanford tank wastes those components requiring geologic disposal, vitrifying the high-level and transuranic wastes, and welding and decontaminating canisters containing waste glass. In addition, the Vitrification Process activities will develop the glass formulations for the wastes. The HWVP will be designed for remote operations to receive and concentrate the pretreated feed, add glass formers, vitrify the waste as borosilicate glass, and weld and decontaminate the stainless steel canisters, and will provide support facilities for safe and efficient plant operations.

Conceptual Design

The HWVP contains process cells, served by a canyon crane and ancillary systems needed to remotely process the high-level and transuranic Hanford defense wastes. The process cells within the facility will house the melter feed preparation, vitrification, canister welding, and canister decontamination operations. A process offgas cell also will be included as well as equipment maintenance cells. A temporary canister storage area will be provided. The canisters will be made of 304L stainless steel and will be approximately 2 feet (0.6 m) in diameter and approximately 10 feet (3 m) long. Support facilities also will be included as part of the HWVP for safe and efficient operation of the plant. These include service facilities and a bulk chemical storage area. Exhaust ventilation facilities will include filtration and an exhaust stack. Support facilities such as electrical substations, sanitary and storm sewers, roads and railroads will also be provided.

Design, Construction, and Startup

Conceptual and definitive designs of the HWVP are planned for the late 1980's. Construction is planned for the early 1990's with hot startup planned for the mid 1990's.

IMMOBILIZATION PROCESS

Waste Types

High-level and transuranic wastes that will have accumulated in tanks at Hanford by 1995 will include PUREX first-cycle extraction waste (Neutralized Current Acid Waste - NCAW), Cladding Removal Waste (CRW), Complexed Concentrate (CC), and Plutonium Finishing Plant (PFP) waste. These wastes, prior to vitrification, will be pretreated to minimize the amount of feed to HWVP as well as the number of canisters requiring final disposal. Pretreatment will reduce the quantity of wastes requiring vitrification, as well as provide low-level wastes as feed to the Hanford Grout Facility [1].

Current planning is based on the high-level and transuranic wastes resulting from pretreatment being combined into two HWVP reference feed streams (NCAW and CRW, and those components of remaining streams that require vitrification).

Waste Pretreatment

Waste pretreatment will be conducted in the existing B Plant at the Hanford Site. An example of waste pretreatment is the pretreatment of NCAW and CRW to provide a blended NCAW/CRW HWVP feed stream.

In B Plant, NCAW will be centrifuged to separate solids and supernate. The separated solids will be washed in further centrifuge cycles. The supernate from NCAW will be clarified by inertial filtration and processed through two ion exchange cycles to remove ^{137}Cs. The ^{137}Cs fraction can then be combined with the washed solids slurry to form one component of the NCAW/CRW HWVP feed stream. Alternately, the ^{137}Cs fraction can be processed into by-product ^{137}Cs capsules.

The CRW will be pretreated in B Plant by a rare earth strike to precipitate high TRU-solids followed by solids separation. The solids slurry from the CRW will form the other component of the NCAW/CRW HWVP feed stream. The CRW supernate will constitute one feed to the Hanford Grout Facility[1].

Feed Preparation

Provisions for HWVP feed receipt, concentration, and melter feed preparation will be similar to unit processes utilized by the Defense Waste Processing Facility (DWPF), now under construction at the Savannah River Plant. Feed will be initially concentrated and redox adjustments made in a Slurry Reciept and Adjustment Tank (SRAT). Glass formers will be added and feed concentration completed in a slurry mix evaporator.

Feed will then be transferred to the melter feed tank. In current planning, feed to the melter will be controlled by a cantilevered centrifugal pump circulating slurry through a feed loop, from which a small portion of the slurry is diverted as melter feed.

Vitrification

The waste glass former slurry will be vitrified at approximately 1150° C (1423 K) in a joule-heated ceramic-lined melter. Development of this melter concept was initiated by PNL beginning in 1973[2,3]. Borosilicate glass production is well developed. The liquid fed ceramic melter (LFCM) concept is being utilized by the DWPF, the West Valley Demonstration Project (WVDP), and a developmental Radioactive Liquid Fed Ceramic Melter (RLFCM) now in operation at PNL.

In LFCM operation; a slurry of waste chemicals in solution, waste solids, and glass formers tailored to the waste composition are continuously metered into the melter. The elevated temperature of the molten pool in the melter vaporizes the water in the slurry, causing the formation of a "cold cap" of oxides and other chemicals over the pool. The effluent stream, containing gaseous and particulate contaminants, is treated in the LFCM offgas train which is discussed later in this paper. At the LFCM operating temperatures, the majority of the solids in the cold cap convert to oxides, which then dissolve in the molten glass. Operating temperature in the HWVP melter is maintained by joule-heating from an electrical current passed through the molten inventory. The vitrified product is withdrawn by overflow through a riser, supplemented as necessary by air lifting the product to the overflow level. Air lifting permits continuous feeding of the melter and maximizes the production of waste glass.

The features of the HWVP melter/turntable have been described by Brouns and Hansen [3] and by Siemens [4]. The current design basis for the HWVP LFCM requires 0.15 m^3/hr (150 l/hr) of slurry feed at a concentration of 300 kg/m^3 (300 gm/l) of oxide formers, resulting in the production of 45 kg/hr of waste glass.

The vitrified product from the melter will be cast and sealed in stainless steel canisters of the same outer dimensions as the DWPF canister.

Canister Welding

Filled canisters will be sealed by a remotized solid state welding process prior to canister decontamination. The solid state welding processes that have been utilized in development programs include upset welding and inertia welding.

HANFORD WASTE VITRIFICATION PLANT

Process

A diagram for waste vitrification in the HWVP is provided as Fig. 1. The dotted line delinates waste pretreatment activities which will occur in B Plant, which are not part of the HWVP.

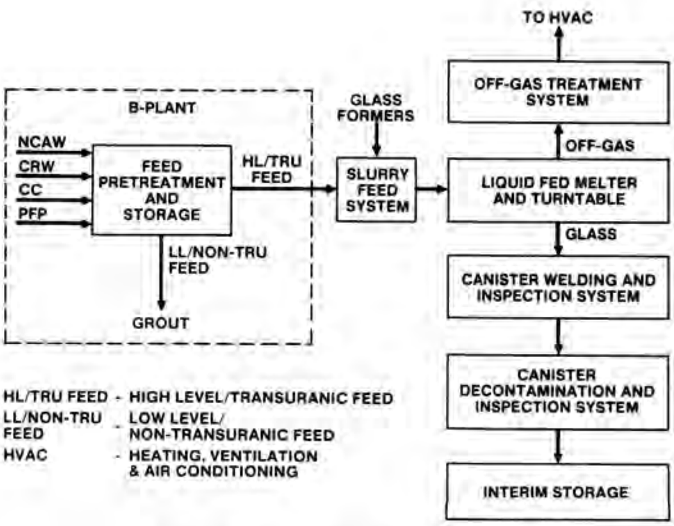

Fig. 1. Process Flow Diagram.

Hanford Waste Vitrification Plant feed is forwarded to the HWVP through available lines in the underground tank farm system. The wastes (NCAW, CRW, CC, and PFP) are pretreated in B Plant to prepare a low-level/non transuranic feed stream for the Hanford Grout Facility and a high-level and transuranic feed stream for the HWVP.

The HWVP is divided into six major process systems: Slurry Feed, Melter/Turntable, Canister Welding and Inspection, Process Offgas, Canister Decontamination and Inspection, and Interim Storage. A detailed review and evaluation was conducted of the DWPF, WVDP, and PNL vitrification technologies with respect to HWVP requirements for each of the six process systems. A preferred design concept was established for the HWVP.

Slurry Feed System

The slurry feed system receives the high-level and transuranic feed stream from feed storage tanks and prepares a melter feed (see Fig. 2).

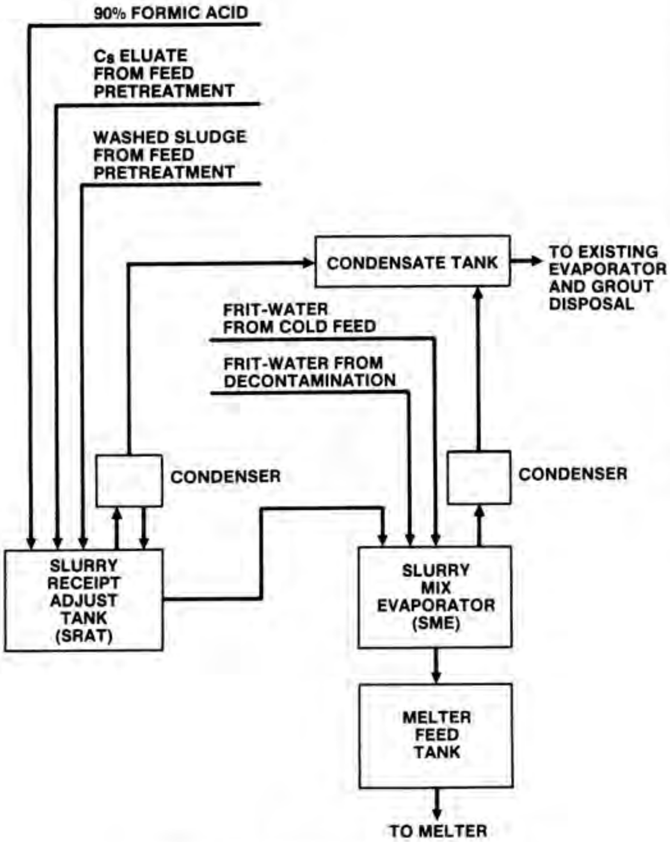

Fig. 2. Slurry Feed System.

The high-level and transuranic feed stream is treated with formic acid in the Slurry Receipt and Adjustment Tank (SRAT). The formic acid addition helps keep the slurry solids in suspension and free flowing. The materials are added and blended with glass formers (frit or chemicals) in the Slurry Mix Evaporator (SME). Material in the SME is concentrated by evaporation to approximately 30 percent total solids. The concentrated material is pumped, after cooling, sampling, and quality verification (i.e., quality control and assurance) to the Melter Feed Tank (MFT). Material in the MFT is circulated by pump through a feed loop from which a small portion of the slurry is diverted as melter feed. The slurry feed system also provides agitation to keep the slurry homogeneous in composition, particle distribution, and temperature.

Melter and Turntable System

The melter receives the melter feed stock producing a homogeneous glass product. This vitreous waste product is transferred to a canister. The canister is cooled in a turntable and forwarded to the Canister Welding and Inspection System. A preliminary design concept for the HWVP Melter and Turntable System is shown in Fig. 3. Design information for the system is provided in Table I.

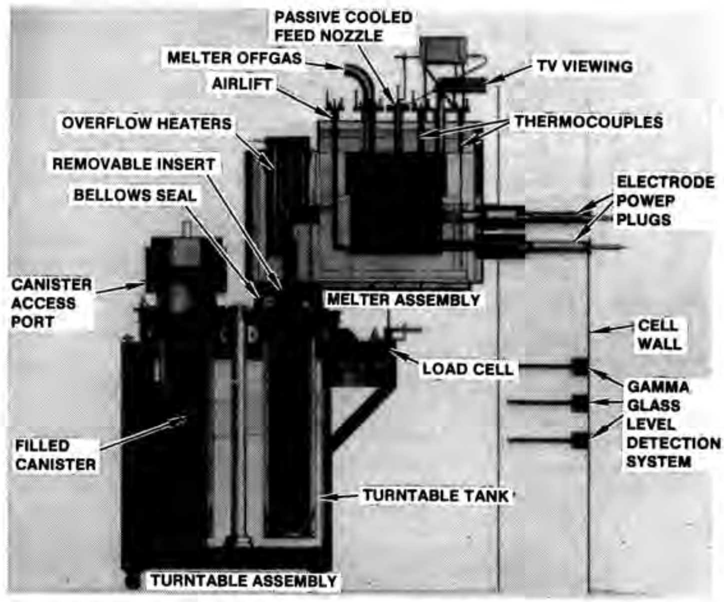

Fig. 3. Preliminary Design Concept for Melter and Turntable.

TABLE I

HWVP Melter and Turntable System Design Information

ITEM	DESIGN INFORMATION
Nominal Melter Throughput	45 kg/hr
Nominal Annual Production	145 Canisters
Startup	Heater Insertion
Canister Fill	Air Lift-Spare System Provided With Replaceable Heaters
Final Draining	Evacuated Canister
Turntable	One (four canisters): sealed to the melter

The HWVP melter is water cooled along the walls and floor, has an Inconel 690 shell, has dual overflow drains, and a single feed port. The melter refractory uses Alfrax 66, Alfrax B1-57, fiberboard, Monofrax H, Monofrax K-3, and Vision. Power dissipation of the electrodes maintains the glass temperature at approximately 1150° C (1423 K). Adjustments of the power ratio between electrode pairs controls the temperature profile and convection currents. The melter is positioned above the turntable. The canister turntable accommodates the melter dual-discharge design. It isolates the canisters from the cell and permits water cooling. The turntable is a sealed vessel connected to the melter overflow sections and vented to the melting chamber. It houses four canisters mounted in a reversing carousel.

Canister Welding and Inspection System

The Canister Closure System provides a closure weld for the canister, performs weld inspection, and transfers the canister to the decontamination cell. The HWVP will utilize solid state welding (either Upset or Inertia welding) remotized for hot cell use.

A canister lid is placed on a canister and welded. The canister closure must be leak tight to prevent leakage of glass fines from the canister or the leakage of, for example - water, into the canister during transportation and/or storage. Nondestructive testing of the closure weld will be thoroughly investigated to ensure meeting interim storage, transportation, and repository requirements.

Upset Welding

Upset welding will be utilized by the DWPF. A cap is welded in place by application of force while current is passed between the cap and the canister for a period of seconds. A larger repair weld cap utilizing additional pressure and amperage can be used to recover from any unacceptable primary weld.

Inertia Welding

A cap is welded in place by application of flywheel speed and axial force for a period of seconds. A larger repair weld cap utilizing essentially the same flywheel speed and additional axial force can be used to recover from any unacceptable primary weld.

Resolution of the final choice of the HWVP Canister Welding and Inspection System (i.e., Upset or Inertia welding and nondestructive testing techniques) will be made during the HWVP design.

Offgas Treatment System

The offgas treatment system removes particulates, chemically reactive gases, and radionuclides such that the HWVP exhaust gas meets the guidelines for emission. The system begins with the exhaust port of the melter and ends with the building exhaust duct (Fig. 4).

The HWVP offgas consists of noncondensables, particulates, and condensables. Up to one percent of the melter feed components and frit may be entrained in the melter offgas. The melter will treat waste feed with substantial levels of NO_3^- which, upon decomposition, causes oxidizing conditions in the melter Plenum. These conditions favor the formation of I_2 (^{129}I) and volatile forms of ruthenium (either RuO_4 or *ruthenium* - nitroso compounds). Additionally, HWVP feeds may contain levels of NO_3^- which convert to NO_x gases in the melter, thus requiring NO_x abatement.

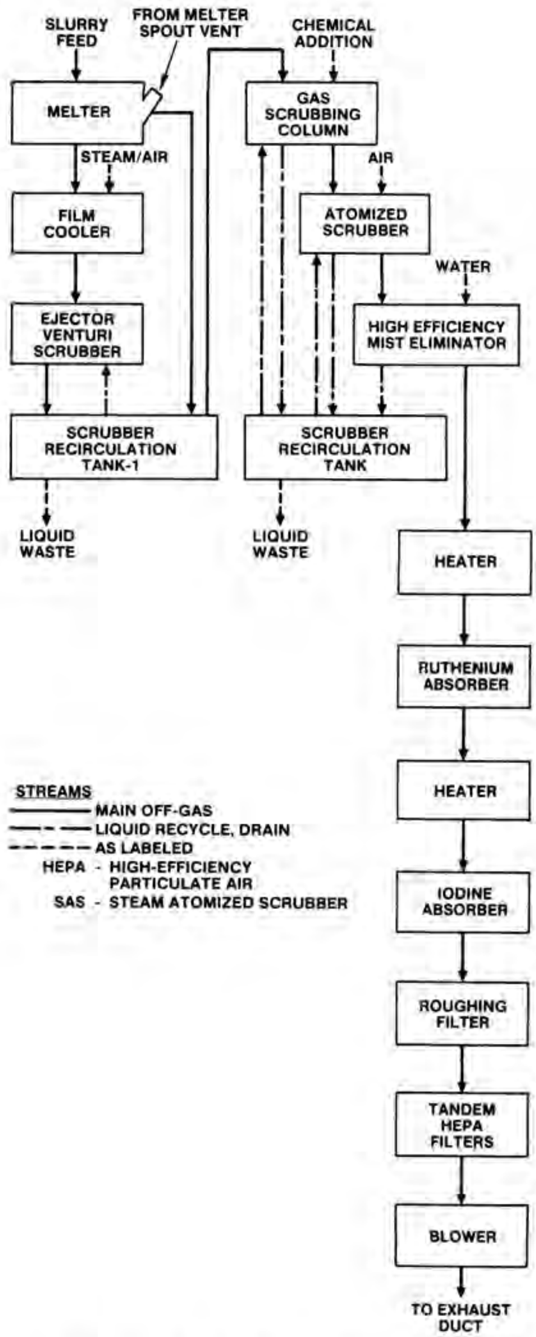

Fig. 4. Preliminary Design Concept for Offgas System.

Offgas from the melter will be drawn into the Ejector Venturi Scrubber which condenses steam and other condensables, cools the noncondensables, and removes some particulates. From the scrubber, the motive material will pass through two stages of scrubbing for aerosol removal (e.g., NO_x and acid halide gases) and then to a high efficiency mist eliminator (HEME). The offgas from the HEME flows through a silica gel ruthenium absorber, through a silver-doped zeolite iodine absorber, a roughing filter, and Tandem High Efficiency Particulate Air (HEPA) filters. Current estimates of the Offgas Treatment System Decontamination Factors are detailed in Table II.

TABLE II

Offgas Treatment System Decontamination Factors

EQUIPMENT	DECONTAMINATION FACTOR	FORM OF AIRBORNE RADIONUCLIDES
Melter	1	Gas (iodine)
	4	Gas, semivolatile (ruthenium)
	40	Semivolatiles
	200	Aerosols
Ejector Scrubbing	2	Semivolatiles
	10	Aerosols and ruthenium
Gas-Scrubbing Column	1	Aerosols
	20	Gas (iodine)
	100	Gas (ruthenium)
Atomized Scrubbing	1	Gas
	10	Aerosols
High-Efficiency Mist Eliminator	1	Gas
	100	Aerosols
Ruthenium Absorber	1	Aerosols
	1000	Gas (ruthenium)
Iodine Absorber	1	Aerosols
	500	Gas (iodine)
Tandem High-Efficiency Particulate Air (HEPA) Filters	1	Gas
	2000	Aerosols
Heating Ventilation, and Air Conditioning HEPA Filters	1	Gas
	1000	Aeorsols

As there will be some residual, gaseous ^{106}Ru remaining after the ruthenium absorber, the melter offgas will be blended with air from the Heating, Ventilation and Air Conditioning (HVAC) system.

A redundant Offgas Treatment System will be provided for the HWVP. This mitigates potential accident conditions and helps maintain a high, Time Operating Efficiency (TOE) for the melter/turntable/offgas systems. The degree of redundancy (complete or key components, etc.) will be established during the HWVP design.

Canister Decontamination and Inspection System

The Canister Decontamination and Inspection System will receive the canister from the melter cell. In the melter cell, a cap is welded in place, and a preliminary or initial canister decontamination step (water rinse) is completed. In the canister decontamination cell, the canister will be slurry-frit blasted (decontaminated), inspected, and sent to interim storage.

The specific activity of the waste glass at the Hanford Site, coupled with the characteristics of the melter/turntable, provide a source of contamination for the canister. Thus a preliminary or initial canister decontamination step (utilizing water) will be performed in the melter cell. This reduces the amount of radionuclide contamination carried to the decontamination cell.

In a decontamination chamber in the decontamination cell, the waste glass canister will be wet blasted with an air injected, abrasive slurry of dilute formic acid and glass frit (230 - 320 kg/canister). The canister is water rinsed, air dried, and then moved to the smear-test station.

The decontamination process must be capable of removing smearable radioactive contamination to <220 dpm/100 cm^2 (<370 Bq/m^2) for alpha contaminants and < 2,200 dpm/100 cm^2 (<3,700 Bq/m^2) for beta-gamma contaminants. Canisters failing the smear test are returned to a secondary or spot decontamination chamber for additional frit blasting of only those areas of the canister surface determined to be contaminated.

The used formic acid and glass frit decontamination slurry is recycled to the SME in the Slurry Feed System for use in melter feed preparation.

Interim Storage

The canisters will be stored in an interim Storage Facility (pending shipment to a repository). The interim Storage Facility will utilize natural air convection (forced air backup) for canister heat removal. The facility will maintain the canister centerline temperature to <500° C (773 K) (needed to prevent glass degradation) and the storage area temperatures to <65° C (338 K) (needed to prevent long-term degradation of the concrete structure). The Interim Storage Facility will be an integral part of the Vitrification Facility. Canister transfer will be accomplished by a remotely operated, overhead crane.

The size of the HWVP Interim Storage Facility (i.e., number of canisters) will be determined during the HWVP design.

HWVP COST BASIS

Feed pretreatment development, process development, and engineering studies supporting the HWVP are in progress. The results of these studies will be incorporated in the conceptual design of the plant. During the conceptual design effort, a HWVP cost basis will be developed.

CONCLUSIONS

The technology and engineering have been and are being demonstrated for the conversion of nuclear wastes, at Hanford (PNL), Savannah River (DWPF), and West Valley (WVDP), to an immobile borosilicate glass. The HWVP will accomplish this conversion for Hanford wastes in a facility that is safe to operate and maintain, and that has minimal environmental impacts. The preferred HWVP design was established utilizing existing DOE technology (Table III).

TABLE III

HWVP Preferred Preliminary Design Basis

SYSTEM	BASIS
SLURRY FEED	DWPF
MELTER/TURNTABLE	PNL/WVDP
CANISTER WELDING	DWPF/PNL
OFFGAS TREATMENT	DWPF
CANISTER DECON-TAMINATION	DWPF
INTERIM STORAGE	DWPF

The HWVP is ready to proceed with conceptual design. This project will provide the public with a crucial demonstration that the Hanford high-level and transuranic wastes can be safely and permanently immobilized.

ACKNOWLEDGEMENT

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