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ABSTRACT

Nearly 63 percent of the nation's high-level nuclear waste has accumulated at the U.S. Department of Energy's (DOE) Hanford Site in Washington State. This accumulation is due to defense materials production activities in the various processing facilities over the past 45 yr. The Hanford Waste Vitrification Plant (HWVP) is being developed to process the high-level waste fraction of the Hanford Site tank wastes into canisters of vitrified (borosilicate) glass. Storage of the filled canisters will be provided for eventual shipment to a federal geologic repository. The Westinghouse Hanford Company (Westinghouse Hanford), a prime operating contractor for the DOE, has the lead responsibility for the successful completion and operation of the HWVP. Fluor Daniel, Inc. is the architect engineer with responsibility for facility and equipment specification and design. The general construction contractor is United Engineers and Constructors-Catalytic, Inc., which has the responsibility for all facility construction and equipment procurement. The Pacific Northwest Laboratory (PNL), operated by Battelle Memorial Institute for the DOE, is responsible for glass development technology.

INTRODUCTION

Although the United States has been engaged in defense nuclear activities at the Hanford Site for more than 40 years, there has been no processing of the high-level wastes for final disposal to date. By 1995, however, approximately $1X10^5$ m^3 ($28X10^6$ gal) of nuclear wastes will be stored in underground double-shell tanks at the Hanford Site. The HWVP will immobilize the high-level wastes in borosilicate glass cast into stainless steel canisters, which will be stored at the HWVP until they can be disposed of in a federal geologic repository.

The HWVP design approach is based on adapting existing DOE-developed vitrification technology to meet the unique needs of Hanford Site waste feeds. The vitrification process, plant design, and overall operation of the plant are based on 20 years of vitrification process development and design/construction experience at PNL in Richland, Washington; at the Defense Waste Processing Facility (DWPF) in Savannah River, Aiken, South Carolina; and at the West Valley Demonstration Project (WVDP) in West Valley, New York. Application of the vitrification technology developed in the United States is internationally known; production plants are already in operation in Belgium and France.

The HWVP technology approach is to identify key waste form qualification and design issues, then resolve them through technology exchange with other programs and through an HWVP applied technology development effort. Using DWPF and WVDP as a basis, HWVP applied technology efforts have established a reference Hanford Site pretreated high-level waste feed, vitrification process, and borosilicate glass waste form.

DISCUSSION

The HWVP contains process cells with canyon cranes and ancillary equipment needed to remotely process the high-level nuclear wastes. The cells will house feed preparation, vitrification, canister welding, and canister decontamination operations. A process offgas cell, equipment maintenance cells, and an interim canister storage area will be provided. Figure 1 shows a preliminary design layout. To ensure safe and efficient operation of the plant, support facilities also will be included as part of the HWVP. These include service facilities, a bulk chemical storage area, and exhaust ventilation facilities that will provide filtration and exhaust stacks.

Pretreatment

Before vitrification, the nuclear wastes will be pretreated to minimize the amount of feed to the HWVP. This also reduces the number of canisters requiring final disposal. Waste pretreatment will be conducted at the existing B Plant, which is

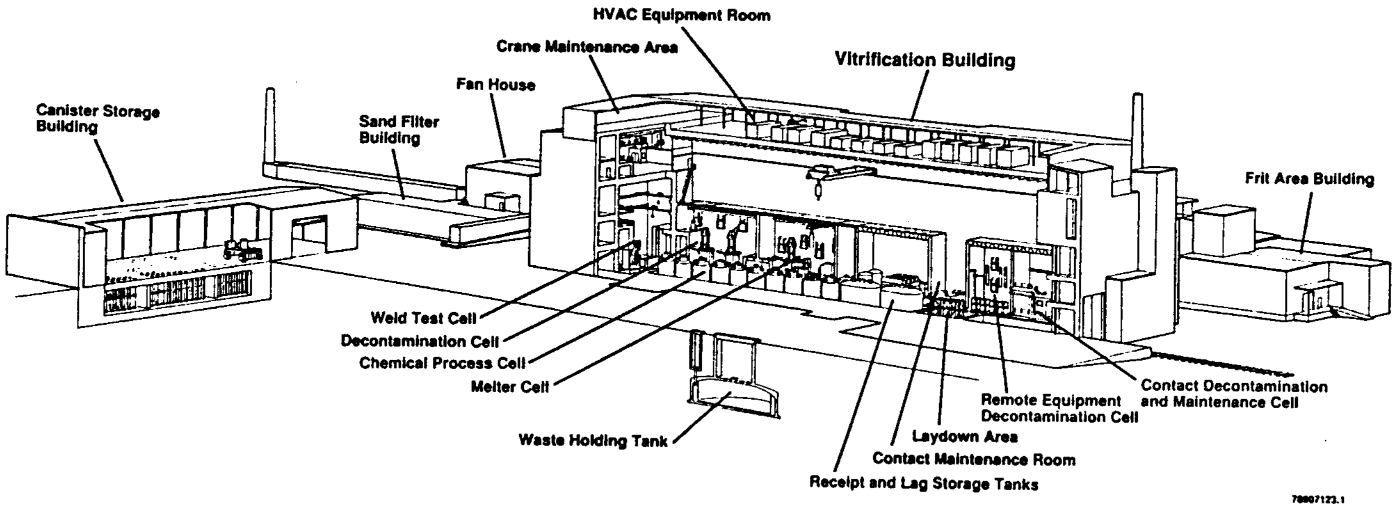


Figure 1. Hanford Waste Vitrification Plant.

located near the HWVP site. Several waste types are scheduled for vitrification at the HWVP: neutralized current acid waste (NCAW), complexant concentrate waste, Plutonium Finishing Plant waste, neutralized cladding removal waste (NCRW), transuranic-contaminated cladding waste, and possibly waste pretreated from single-shell tanks. The NCAW is scheduled to be processed first among these various waste forms.

Pretreatment will separate the nuclear waste into two fractions. Approximately $2X10^4$ m^3 ($6X10^6$ gal) of high-level waste from double-shell tanks will be prepared as feed for vitrification. The remaining waste fraction will be processed in the nearby Grout Treatment Facility, with ultimate disposal in near-surface disposal vaults located on the Hanford Site.

Feed Preparation and Vitrification

The HWVP feed preparation and handling equipment consists of receipt and lag storage tanks and feed preparation/transfer equipment. The feed will be initially concentrated and valence adjustments made. Formic acid is added to improve slurry rheology and to control the redox state of the glass in the melter and the vitrified product. Glass formers will be added and the feed concentration completed in a slurry mix evaporator. The feed will then be transferred to the melter feed tank.

The vitrification system equipment, located in the melter cell, consists of a refractory-lined melter vessel with stainless steel cooling water jacket, heating electrodes, water-cooled feed nozzles, closed-circuit television, instrumentation, offgas vents, and a stainless steel turntable and canister-to-melter spout bellows seal system. In operation, the feed is continuously metered into the melter producing waste glass at 100 kg/h (220 lb/h). A preliminary design concept for the Melter/Turntable System is shown in Figure 2.

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 above the pool. The effluent stream, containing gaseous and particulate contaminants, is treated in the offgas train. At the melter operating temperatures, the majority of the solids in the cold cap convert to oxides, which then dissolve in the molten glass. The glass is poured from the melter by establishing a vacuum in the canister and pour spout relative to the melter vapor space. The vacuum causes glass to rise to the top of the pour spout and fall into the canister.

During the pouring operation, the canisters are sealed to the melter pour spout by means of a bellows assembly. The filled canisters remain sealed to the pour spout for a short time after filling to ensure complete venting of all volatiles to the offgas system before closing of the canisters. (Figure 3 provides additional information on the canister.) The filled canister is then cooled in the turntable.

Canister Handling and Storage

After the canister is cooled, it is transferred to the Inner Canister Closure

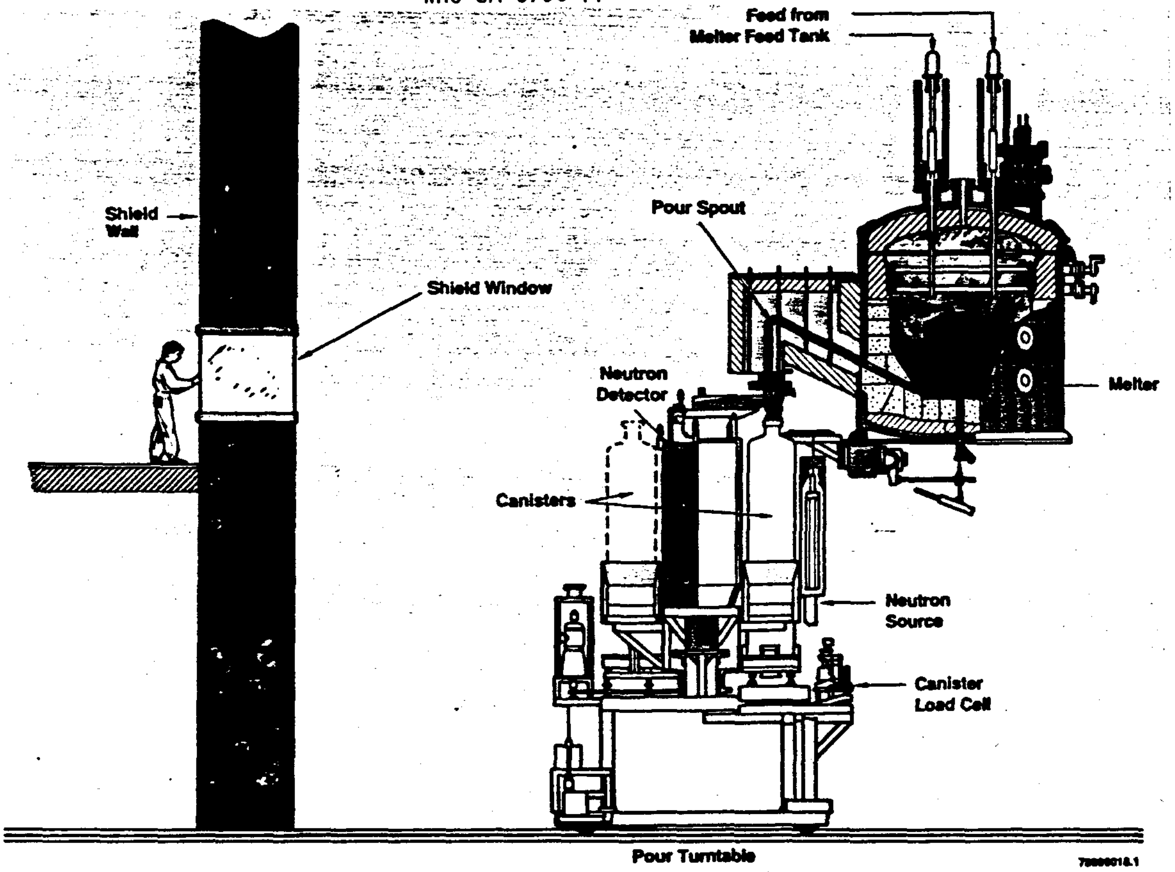
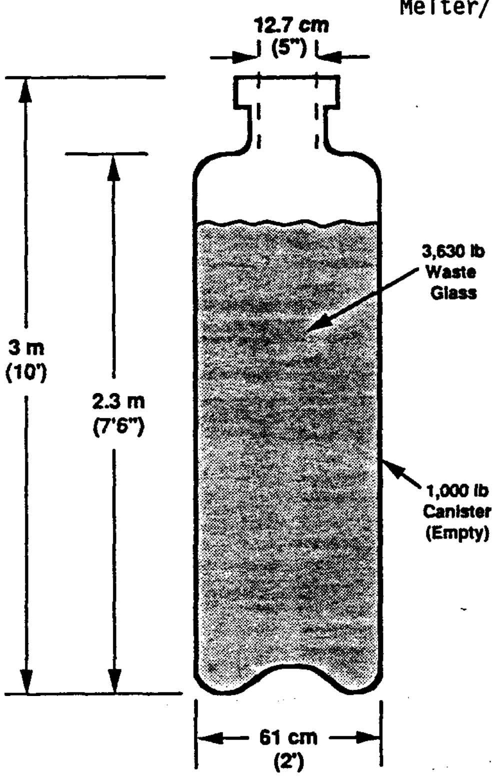


Figure 2. Hanford Waste Vitrification Plant Melter/Turntable.



Canister

Material:	Type 304L stainless steel (Schedule 20 pipe)
Surface Area:	6.5 m^2 (70 ft^2)
Heat Load:	750 - 1400 Watts
Surface Temperature:	82° C (~179° F)
Lid Temperature:	57° C (~135° F)
Glass Density:	2.64 g/cm^3 (164.8 lb/ft^3)
Glass Volume:	625 L (22 ¢ ft^3)
Waste Loading:	25% oxide
Activity:	~4 x 10^5 Ci
Exposure Rate:	~2 x 10^4 rad/h

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Figure 3. Hanford Waste Vitrification Plant Canister.

System (ICCS). The ICCS consists of a canister flange heater and a leak test system. An ICC plug will be inserted into the heated canister opening. The canister neck will be allowed to cool in order to create a leak-tight, shrink-fit seal. After cooling, the ICC plug seal will be helium leak-tested. Canisters will then be decontaminated before installation of the final canister closure plug.

Preliminary decontamination will be performed to remove loosely adhered contaminants by lowering the canister through a low-pressure spray of hot water. Canisters are then transferred to the Final Canister Closure Station (FCCS), which has two functions: (1) the ICC plug will be pressed down in the neck of the canister a sufficient distance so that it will not interface with the insertion and welding of the FCC plug and (2) the FCC plug will be welded into the neck of the canister.

Final decontamination will then be performed using an air-injected, frit-slurry blasting technique. Upon completion, the canister will be tested to verify that smearable radioactive-surface-contamination levels are acceptable.

A shielded canister transporter transfers the decontaminated canisters to the canister storage building for interim storage, pending shipment to a federal geologic repository.

Waste Form Qualification

The DOE has established a waste acceptance process to outline the documentation and activities required to ensure that waste forms, other than spent fuel, will be acceptable at a geologic repository. The DOE has assumed that the waste form will play a role in satisfying 10 CFR 60[1] and 40 CFR 191[2]. Consequently, these regulatory requirements have resulted in derivative requirements for the waste forms to demonstrate compliance. Waste acceptance is considered to be intimately and inseparably related to repository licensing.

Significant quantities of waste forms are likely to be produced prior to licensing of a repository, and yet waste form performance requirements cannot be considered final until the U.S. Nuclear Regulatory Commission issues a license to a repository. This licensing is not expected to occur until after production of the waste form is complete. Therefore, the waste acceptance process calls for the waste form producer to contribute to a licensing data base that will be used for licensing the repository.

To address imminent and ultimate repository requirements, the HWVP first must not only be in compliance with existing requirements, but it must also furnish process measurements comprehensive enough to allow final acceptance specifications to be addressed.

The waste acceptance preliminary specifications for the HWVP likely will differ little from the DWPF and the WVDP, with exceptions such as the specified maximum heat generation rate. Assuming HWVP specifications will be similar to those for the DWPF, requirements can be used immediately to guide and evaluate design of the HWVP.

Qualities such as radiation field, external contamination, and, prior to processing, the canister material and the conformance to fabrication specifications can be assessed without altering the product. Regions such as the interior of the glass and the interface between the canister and glass cannot be characterized directly without altering the product; they must be assessed by non-destructive methods. The properties that characterize the glass generally include its composition and structure and the homogeneity of a canister. The structure comprises macroscopic qualities, e.g., the occurrence of voids and cracks, and microscopic qualities, e.g., the occurrence of crystallization and dispersed bubbles. The product structure can be related to processing conditions, primarily melter temperature, glass composition, and cooling rate.

The requirements imply either or both of two actions: documentation of the product, and/or control of the product. For example, the chemical specification requires that the chemical composition be documented, but it does not require that the composition be controlled. Conversely, the "durability" specification requires that the chemical durability be documented and controlled. In some respects, the product can be controlled only by controlling the HWVP equipment. Therefore, both documentation of the product and process control must be addressed as part of a waste form qualification strategy.

The requirements for documenting and controlling the HWVP product have been preliminarily grouped into four categories, as follows:

- Canister/Waste Form Qualification: The design or characteristics of the canister or the waste form (glass) are qualified in order to meet or partially meet a specification. For example, the durability of the glass must be correlated with the composition of the glass.

- Canister Vendor: Characteristics of the canister are documented and controlled at the vendor, prior to shipment, in order to meet or partially meet a specification. For example, the material of construction of a canister is controlled and documented at the canister vendor.

- Process Qualification: The response of the process to control variables is characterized in terms of the ability to produce an acceptable product. For example, the glass cooling rate in a canister must be characterized for crystal formation and glass durability.

- Process Instrumentation: The characteristics of the product are inferred from, and controlled, based on sampling analysis and process measurements. For example, the composition of the glass may be inferred in part from analysis of samples from the slurry mix evaporator (SME) and the melter feed tank, and the composition will be controlled in part based on measurements in the SME, slurry receipt and adjustment tank, and the recycle collection tank.

The last two categories, process qualification and process instrumentation, will be further interpreted in terms of functional design requirements for HWVP equipment. The strategy and details of compliance for WFQ are still being addressed for the HWVP.

SUMMARY

At present, the HWVP is nearing completion of the preliminary design phase. Construction is scheduled to start in mid-1991 with completion in 1999. Construction of the DWPF has been completed. Thus, the construction and operation of the HWVP is substantially behind that of the DWPF. Consequently, experience gained at the DWPF is being incorporated into the design of the HWVP. Further, to the maximum degree feasible, the design of the HWVP incorporates the special processes and equipment developed for the DWPF and will replicate those items for use in the HWVP. By utilizing these designs and incorporating the DWPF experience, the HWVP Project has/will realize substantial savings.

Although the similarities have been maximized, differences exist between the facilities. There are variations in the waste streams that provide the feed stock for the vitrification process. There are also differences due to the local regulatory and permitting requirements, and in the site characteristics, including geology, hydrology, weather, etc. Differences between the designs will be inevitable, but the DWPF experience will be essential to the success of the HWVP.

The technology and engineering have been and are being demonstrated for the immobile borosilicate glass. The HWVP will accomplish this conversion for Hanford Site wastes in a facility that is safe to operate and maintain and that has minimal environmental impacts.

REFERENCES

1. U.S. NUCLEAR REGULATORY COMMISSION, *Code of Federal Regulations*, Title 10, Part 60, "Disposal of High-Level Radioactive Wastes in Geologic Repositories," Washington, D.C.

2. U.S. ENVIRONMENTAL PROTECTION AGENCY, *Code of Federal Regulations*, Title 40, Part 191, "Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes," Washington, D.C.