DESIGN ASPECTS

OF THE

HANFORD WASTE VITRIFICATION PLANT

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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 for the Department of Energy (DOE) at the Hanford Site, will vitrify existing and future liquid 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 design aspects of the HWVP. At the present time, the HWVP is proceeding with Reference Conceptual Design. Definitive design for the HWVP is planned to start in FY 1988. Procurement and construction are planned to start in FY 1989 with hot startup planned for FY 1995/1996.

INTRODUCTION

Overview

The United States has been engaged in defense related nuclear activities at Hanford for over 40 years. To date, none of the high-level wastes have been processed for final disposal. The proposed HWVP will be among the Nation's first production-scale facilities to immobilize high-level nuclear waste for disposal. Disposal activities will be qualified, of course, through the National Environmental Policy Act (NEPA) Process. Approximately 28 million gallons ($1x10^5m^3$) of high-level waste, stored as liquids and sludges in underground double-shell tanks, will have accumulated at Hanford by 1995. The HWVP (Fig. 1) will immobilize the high-activity fraction of the waste in borosilicate glass cast into stainless steel canisters. Filled canisters will be stored at the Hanford Site until a Federal Geologic Repository is available for final disposal.

The Hanford Waste Vitrification Program includes development of the Immobilization Process and Design and Construction of the HWVP. The Immobilization Process activities will define the specific glass formulations for the Hanford wastes and evaluate melter performance with those glass formulations. The HWVP design activities will design the facility for remote operations to receive and concentrate the pretreated waste streams and glass formers, vitrify the waste as borosilicate glass, decontaminate and weld the stainless steel canisters, store the canisters, and will provide support facilities for safe, environmentally sound, and efficient plant operations.

Tanks at the Hanford Site contain PUREX Plant first-cycle extraction waste (Neutralized Current Acid Waste [NCAW], Complexant Concentrate (CC), and Plutonium Finishing Plant (PFP) waste. These wastes, prior to vitrification, will be pretreated for removal of inert chemical components. This step will minimize the feed to the HWVP and thus the number of canisters

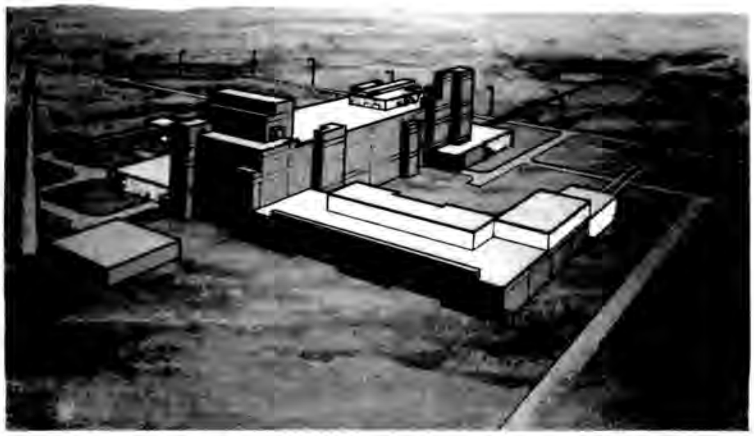

Fig. 1. Hanford Waste Vitrification Plant (HWVP).

requiring geologic disposal. Pretreatment will segregate inerts and low-level waste as feed to the Hanford Grout Facility. Radiocesium (^{137}Cs) will be removed from NCAW supernate and sent to the HWVP. Pretreatment operations will occur in the existing B-Plant located on the Hanford Site. Current planning assumes the high activity fractions will be in two HWVP streams ("NCAW" and a "CC/PFP" stream). Low-level/nontransuranic effluents from the HWVP will be sent to the Tank Farms for subsequent disposal through the Hanford Grout Facility.

HANFORD WASTE VITRIFICATION PLANT DESIGN

Process

A diagram for waste vitrification in the HWVP is provided as Fig. 2. The dotted line delineates waste pretreatment activities in the B-Plant, which are not part of the HWVP Project.

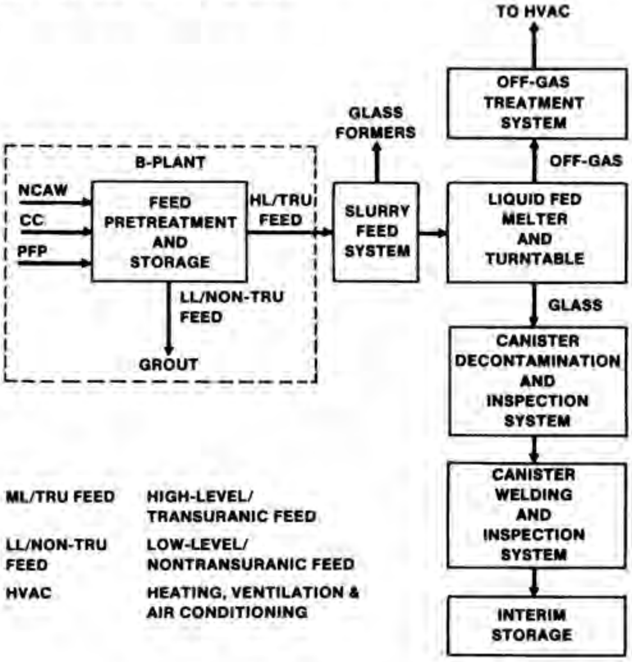

Fig. 2. Process Flow Diagram.

HWVP feed is transferred to the HWVP through available lines in the underground Tank Farms system. Wastes (NCAW, CC/PFP) are pretreated in B-Plant to prepare a low-level/nontransuranic feed stream for the Hanford Grout Facility and a high-level and transuranic feed stream for the HWVP.

The HWVP is divided into major process systems: Feed Receipt and Storage/Slurry Feed, Melter/Turntable, Canister Decontamination and Inspection, Process Off-Gas, Canister Welding and Inspection, and Interim Storage. A detailed review and evaluation was conducted of the Defense Waste Processing Facility (DWPF), West Valley Demonstration Project (WVDP), and PNL vitrification technologies with respect to HWVP requirements for each of the process systems. A preferred design concept was established for the HWVP.

Feed Receipt and Storage

The feed receipt and storage system will receive and store feed from the Tank Farms. The system will have the capability for feed sampling and feed transfer, in batches, to the feed preparation systems.

HWVP feed (NCAW or PFP/CC) will be pumped from double-shell storage tanks in the Tank Farms to the Receipt and Lag Storage Tank (RLST). In the tank, the feed will be cooled and agitated. Feed will be batch transferred, as required, to the Slurry Receipt and Adjustment Tank (SRAT) for processing.

Slurry Feed System

The slurry feed system receives the high-level and transuranic feed stream from the RLST and prepares a melter feed (see Fig. 3).

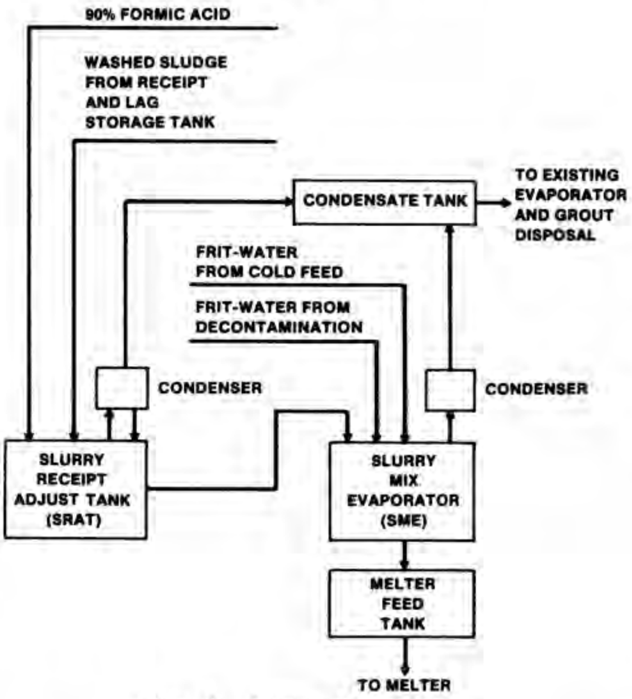

Fig. 3. Slurry Feed System.

The slurry feed system (feed adjustment, concentration, and delivery subsystems) will prepare and provide feed to the melter. Formic acid and other chemicals will be added for feed rheology and feed redox adjustment. Glass forming frit will be added. The material will be delivered by dual slurry pumping and metering loops that will control the rate of feed to the melter.

Feed will be batch transferred from the RLST to the SRAT as a slurry containing approximately 19 grams of oxides per liter. After receipt of the slurry in the SRAT, it will be sampled and analyzed to determine the amounts of additives required. At $90^{\circ}C$ to $95^{\circ}C$ (363 K to 368K), formic acid at 90 wt% will be added at a controlled rate to react with the carbonates, nitrates, some metal hydroxides, and other compounds to form metal formates and to adjust the pH. After formic acid has been added, the slurry will be refluxed to complete the conversion to metal formates, and the slurry will be concentrated.

Formic acid-treated and partially concentrated waste for melter feed makeup will be batch transferred from the SRAT to the Slurry Mix Evaporator (SME). Frit slurry and water that were used for canister decontamination will be transferred in an appropriate slurry batch size from the Spent Frit Hold Tank (SFHT) to the SME. Additional frit needed for melter feed makeup will be added as a nonradioactive slurry. Diluted formic acid will be used in preparing frit slurry to prevent reactions between the frit and water. After the frit additions, the slurry will be heated again for subsequent concentration.

Made-up melter feed will be batch transferred from the SME to the Melter Feed Tank (MFT). The feed to the melter will be drawn off as a side stream from each of two pump recirculation loops on the MFT.

Melter and Turntable System

The melter receives the melter feed slurry 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 Decontamination and Inspection System. The design concept for the HWVP Melter and Turntable System is shown in Fig. 4. Design information for the design is provided in Table I.

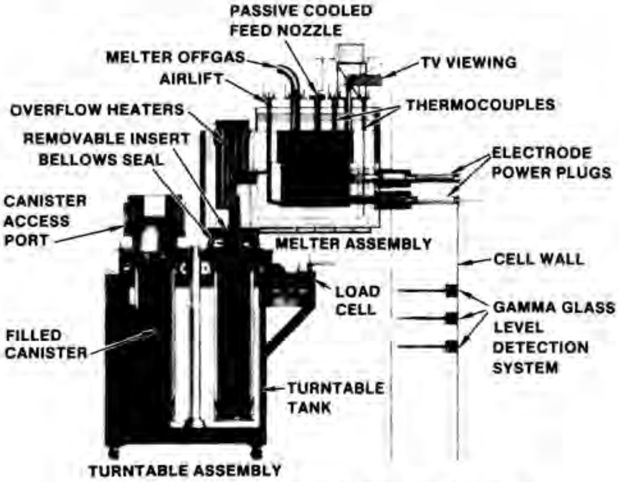

Fig. 4. Preliminary Conceptual Design for Melter and Turntable.

TABLE I
HWVP MELTER AND TURNTABLE SYSTEM DESIGN INFORMATION

ITEM	DESIGN INFORMATION
Nominal Melter Feed Rate	113 m^3 hr^{-1}
Nominal Melter Throughput	45 kg hr^{-1}
Nominal Annual Production	145 Canisters
Waste Oxide in Glass	25 wt. %
Startup	Heater Insertion
Canister	0.6 M diameter x 3 M L 304 L SS
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, dual overflow drains, feed ports, and 4 electrodes (2 pairs). The melter refractory consists of Alfrax 66, Alfrax 57, fiberboard, Monofrax H, Monofrax K-3, Monofrax E and Zirmul. Power dissipation of the electrodes maintains the glass temperature at approximately 1,150°C (1,423 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 carrousel.

An empty canister will be loaded into the four position turntable through the canister access port. During this operation, a vacuum will be maintained on the other positions in the turntable, by a secondary lid. The empty canister will be rotated to the fill position. After the canisters are filled they will be rotated through the two cooling positions to solidify the glass at a controlled rate. When the canisters are moved back to the starting position they will be removed from the turntable and checked for acceptable surface temperatures.

Canister Decontamination and Inspection System

The Canister Decontamination and Inspection System will receive the canister from the melter cell. In the melter cell, a temporary closure plug will be inserted into the canister neck by the Inner Canister Closure System (ICCS), and a preliminary or initial, low-pressure, water spray canister decontamination step completed.

In the canister decontamination cell, the canister will be slurry-frit blasted (decontaminated), inspected, and sent to the Canister Welding Cell for permanent closure. The final canister decontamination system will be designed to reduce surface smearable contamination levels to less than <220 dpm/100 cm^2 (<370 Bq m^{-2}) alpha and to <2,200 dpm/100 cm^2 (<3,700 Bq m^{-2}) beta-gamma.

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 canister decontamination step will be performed. This reduces the amount of radionuclide contamination carried to the Canister Decontamination Cell (CDC).

The canister is placed in the preliminary decontamination chamber with the cell crane. The canister will be rotated and moved up and down while the decontamination spray is directed at the canister surface through an array of nozzles. Before removal from the spray chamber, the canister will be air dried by blowing air through the spray nozzles or by allowing heat to evaporate surface water. After preliminary decontamination, the canister will be transferred to a final decontaminational chambers in the CDC.

Final canister decontamination will be done by air-injected wet blasting with a frit slurry (230-320 Kg/canister). After frit blasting, the canister will be rinsed and air dried. When the canister is dry, it will be removed from the decontamination chamber and smear tested. A canister failing the smear test will be returned to a second decontamination chamber for rework. The slurry and rinse water used for canister decontamination will be transferred to the SFHT (part of the Slurry Feed System). Canisters passing the smear test will be transferred to the Canister Welding and Inspection Area (Weld Test Cell [WTC]).

Off-Gas Treatment System

The off-gas treatment system removes particulates, chemically reactive gases, and radionuclides such that the HWVP exhaust gas meets the environmental release criteria. The system begins with the exhaust port of the melter and ends with the discharge stack (Fig. 5).

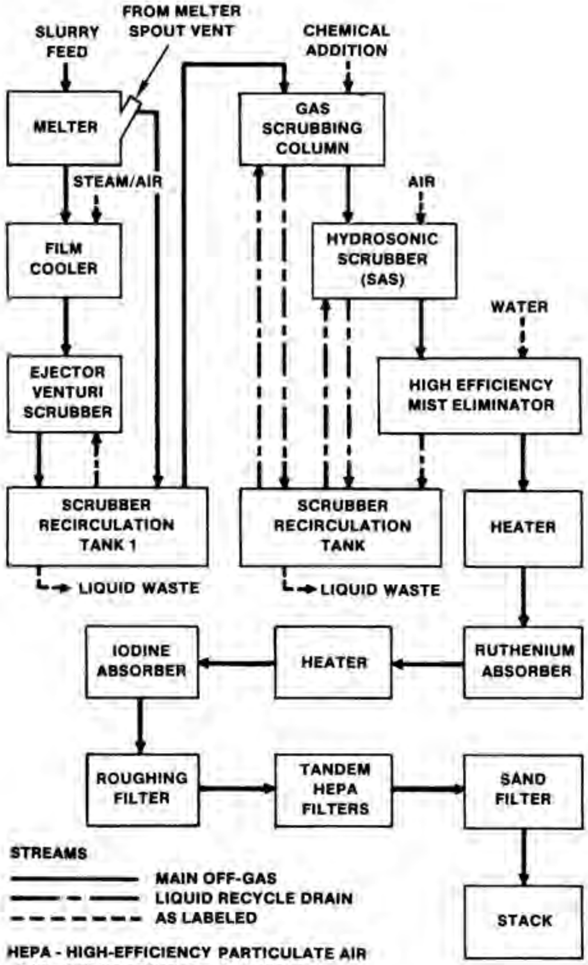

Fig. 5. Preliminary Design Concept for Off-Gas System.

The HWVP off-gas consists of noncondensables, particulates, and condensables. Up to one percent of the melter feed components and frit may be entrained in the melter off-gas. 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^- gases in the melter, thus requiring NO_x abatement.

The melter off-gas system will have several particulate removal operations, and two absorption stages to remove particulate and gaseous radioactive material. The system will maintain a negative pressure on the melter at all times. The system will have a duplicate backup to ensure that environmental release criteria can be met at all times.

The melter off-gas will first pass through an annular device at the melter outlet (the Film Cooler [FC]), where a radially injected air-stream flow will inhibit solids buildup and will dilute and cool the off-gas. The off-gas will next go through a quencher (ejector venturi scrubber) for further cooling, steam condensation, and particulate removal. Cooled solution from the Off-Gas Condensate Tank (OGCT) will be pumped through the quencher as a scrubbing and quenching agent. The off-gas will enter the quencher at approximately 200°C (473 K) and exit at approximately 40°C (313 K). It will then pass through the OGCT into a gas scrubbing column.

Scrub solution will be pumped to the scrubbing column to absorb soluble gases such as NO_x. The scrubbing column will also remove particulates. The off-gas will then pass through the Steam-Atomizing Scrubber (SAS).

From the scrubber the off-gas will pass through a condenser followed by a High-Efficiency Mist Eliminator (HEME). A small flush water stream to the HEME will be used to reduce accumulation of solids.

After exiting the HEME, the off-gas will be heated to about 90°C (363 K) and passed through a silica gel bed that absorbs ruthenium. The ruthenium adsorber off-gas will be heated to about 150°C (423 K) and passed through a silver zeolite bed for iodine removal. From the iodine adsorber, the off-gas will be passed through a cooler to reduce the gas temperature to 90°C (363 K) for filter compatibility.

The off-gas will finally be passed through one stage of roughing filtration and two stages of High Efficiency Particulate Air (HEPA) filtration for particulate removal prior to passing through the variable speed blower into a sand filter. From the sand filter, the off-gas is routed to the discharge stack.

Current estimates of the Off-Gas Treatment System Decontamination Factors are detailed in Table II.

TABLE II

Off-Gas 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
Sand Filter	1	Gas
	800	Aerosols

Canister Welding and Inspection System

The canister welding and inspection system will provide a welded closure on the canister fill opening that will meet storage, transportation, and disposal requirements. Requirements will include prevention of leakage into or out of the canister, survival from various accident situations, and effectiveness as a long-term barrier.

The HWVP canister closure system will be a multistep process including an Inner Canister Closure (ICC) plug to permit canister decontamination prior to welding. Canister closure operations are described as follows:

Melter Cell

The empty canister will be placed in the melter turntable and a throat protector inserted in the neck. The canister will then be rotated into the filling position. After filling it will be rotated through two cooling positions then rotated to the removal position. The throat protector will be removed, and the canister will be transferred to the ICCS.

At the ICCS a temporary closure will be installed in the canister. To do this, the canister neck will be heated between 150 and 200^{o}C (423 K and 473 K) and the ICC plug will be inserted with a master-slave manipulator. The canister neck will cool and shrink to form a watertight seal. The ICC plug will be helium leak tested by pressurizing a container installed around the canister neck and monitoring the pressure. Canisters passing the leak test will be transferred to the temperature survey station.

Weld Test Cell

After final decontamination operations in the CDC, the canister will be moved to the WTC.

The WTC will be a shielded process cell containing equipment for welding the canister plug, space for a future oversize repair welder, and the final smear test station. Equipment in the WTC will be remotely operated but direct contact maintained.

The plug welder system will perform two basic functions: (1) the ICC will be pressed further down in the neck of the canister so that it will not interfere with the insertion and welding of the weld plug; and (2) the weld plug will be welded into the neck of the canister by means of an upset welder. The plug welder system will consist of a canister insertion position, hydraulic press station, and an Upset welder station.

A hydraulic ram will be used to press the ICC down into the canister neck. A master-slave manipulator will be used to place the weld plug into the canister neck. A pneumatically operated upper ram will be used to press down on the weld plug. Resistance of the circuit will be measured to ensure adequate continuity. With the ram force maintained, a weld current of 240,000 A for 1.5 seconds will be applied. As the metal at the plug/canister interface heats, plastic deformation will occur and the plug will be forced about 1.3 cm into the canister neck, forming a solid state weld. The WTC crane will be used to transfer the canister to the WTC smear test station for final inspection and surface contamination checks.

The WTC smear station will also record the surface temperatures of the canister at three different elevations and will be equipped with an optical device that will measure surface defects on the canister. Following final inspection, the canister will be sent to the interim storage facility.

Interim Storage

The canister storage area facility will provide: (1) onsite storage of filled canisters; (2) capability for final inspection of the canister; and (3) equipment for loading the canisters into casks for transport to a federal repository.

The canister storage area will have two functionally discrete areas: the canister storage area, and the cask loadout and shipping area. Storage will be provided for 750 canisters. The facility will be arranged to allow the addition of a second storage facility that will double the storage capacity. The canister storage area will be partitioned into four sections to accommodate four heat-load canister groups.

Cooling air will be provided for each canister. Access to an individual canister in the ventilation plenum will be gained by removing a shielding cover plug in the top of the ventilation plenum shielding. A remotely operated bridge crane will transfer canisters within the facility.

The cask loadout and shipping area will have a transfer port, handling and closure equipment, provisions for final inspection of the canisters, and a transfer tunnel connection with the truck/rail loading area. A separate bridge crane will be provided for cask handling and loading.

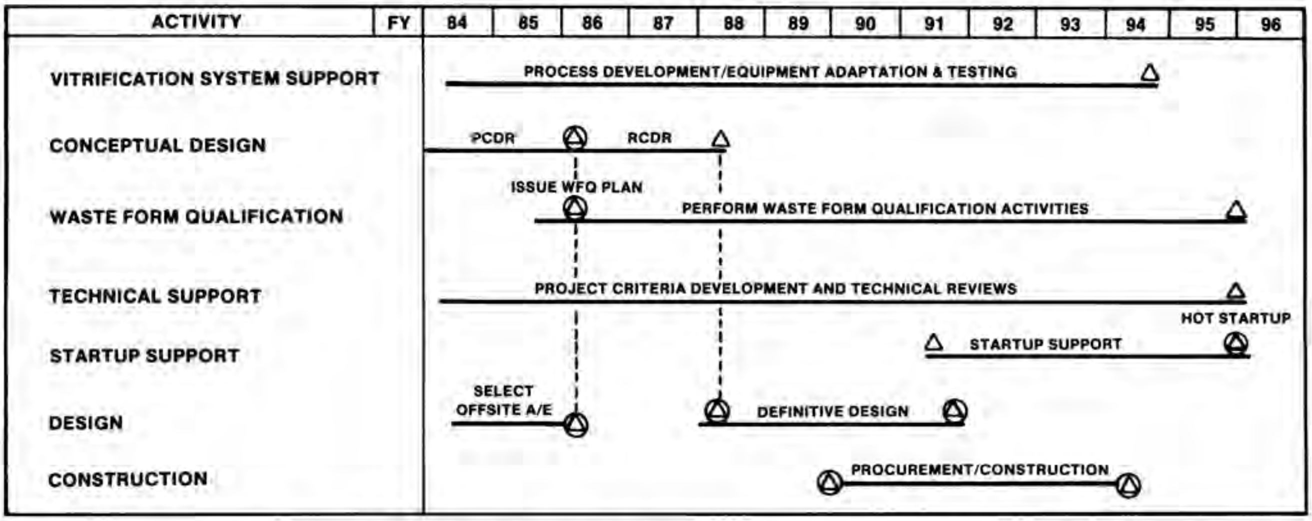

Fig. 6. Summary Hanford Waste Vitrification Plant Master Schedule.

HWVP SCHEDULE AND COST BASIS

HWVP Schedule

A Summary HWVP Project Master Schedule is provided as Fig. 6.

Reference Conceptual Design of the HWVP is planned for FY 1986. The Reference Conceptual Design will be followed by Definitive Design. Contract negotiations are underway to secure the services of an Architect/Engineer for the Reference Conceptual Design. Procurement and Construction will begin in FY 1989 with hot startup scheduled for FY 1995/1996.

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 Reference Conceptual Design of the plant. During the Reference Conceptual Design effort, an 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.

The HWVP is proceeding with Reference Conceptual Design activities. This project will provide the public with a crucial demonstration that the Hanford liquid high-level and transuranic wastes can be safely and permanently immobilized.