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**VITRIFICATION FACILITY AT THE
WEST VALLEY DEMONSTRATION PROJECT**

Topical Report

By
V. A. DesCamp
C. L. McMahon


July 1996

Work Performed Under Contract No. DE-AC24-81NE44139

Prepared by
West Valley Nuclear Services Co., Inc.
P.O. Box 191
West Valley, NY 14171-0191

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Prepared for
U.S. Department of Energy
Assistant Secretary for Nuclear Energy

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ABSTRACT

This report is a description of the West Valley Demonstration Project's vitrification facilities from the establishment of the West Valley, NY site as a federal and state cooperative project to the completion of all activities necessary to begin solidification of radioactive waste into glass by vitrification. Topics discussed in this report include the Project's background, high-level radioactive waste consolidation, vitrification process and component testing, facilities design and construction, waste/glass recipe development, integrated facility testing, and readiness activities for radioactive waste processing.

1.0 HISTORY

The following is a brief history of the events leading to the Congressional establishment of the West Valley Demonstration Project (WVDP), a description of the guidelines, an introduction of the participants, the selection of the waste solidification method and facility, and the pretreatment activities for high-level waste at the site.

A time line has been developed to reference the sequence of major vitrification events from the inception of the WVDP through readiness for radioactive waste vitrification. Refer to figure 1-1 for the major events for this and subsequent chapters.

1.1 Background

In 1954, the Atomic Energy Commission (AEC) began a program to encourage private reprocessing of irradiated nuclear fuel as part of its program to commercialize the entire nuclear fuel cycle.

Perceiving an opportunity to promote industrial development within the State of New York, a State Council on the Development of Atomic Energy was created in 1956 followed by the formation of the Office of Atomic Development (OAD) in 1959. In 1961, the OAD acquired a 13,537 km² (3,345 acre) site near the hamlet of West Valley in the town of Ashford, Cattaraugus County, about 48 km (29.8 miles) south of Buffalo, NY. The site was judged to be favorable for a nuclear fuel reprocessing plant and its attendant waste facilities due to the site's location with respect to projected nuclear reactor development in the northeastern and mid-Atlantic United States. Additionally, the silty till in the West Valley area was relatively impermeable to water and would, therefore, provide protection against migration of waterborne radioactivity through the ground. Further advantages of the site were a low population density in the area and meteorological conditions favorable for atmospheric dilution of any radioactivity released. The site was named the Western New York Nuclear Service Center (WNYNSC).

In May 1963, the W. R. Grace Company's subsidiary, Nuclear Fuel Services (NFS), was licensed by the AEC to construct the fuel reprocessing plant. At the same time, NFS entered into an agreement with the New York Atomic Research and Development Authority (NYARDA), successor to the OAD, to lease the WNYNSC from New York State, construct facilities for receiving and storing wastes, and manage the storage of high-level radioactive wastes. A Waste Storage Agreement was made part of this lease which basically outlined that NFS was responsible for each radioactive high-level waste (HLW) tank as it was being filled and then would turn over the tank to NYARDA for perpetual care.

Construction of the fuel reprocessing facility began in the fall of 1963. About 1,012 km² (250 acres) of the site were developed for the nuclear reprocessing plant and supporting facilities. Construction was completed in February 1966. This site would become the only commercial nuclear fuel reprocessing facility ever to operate in the United States.

West Valley Demonstration Project Major Vitrification Milestones

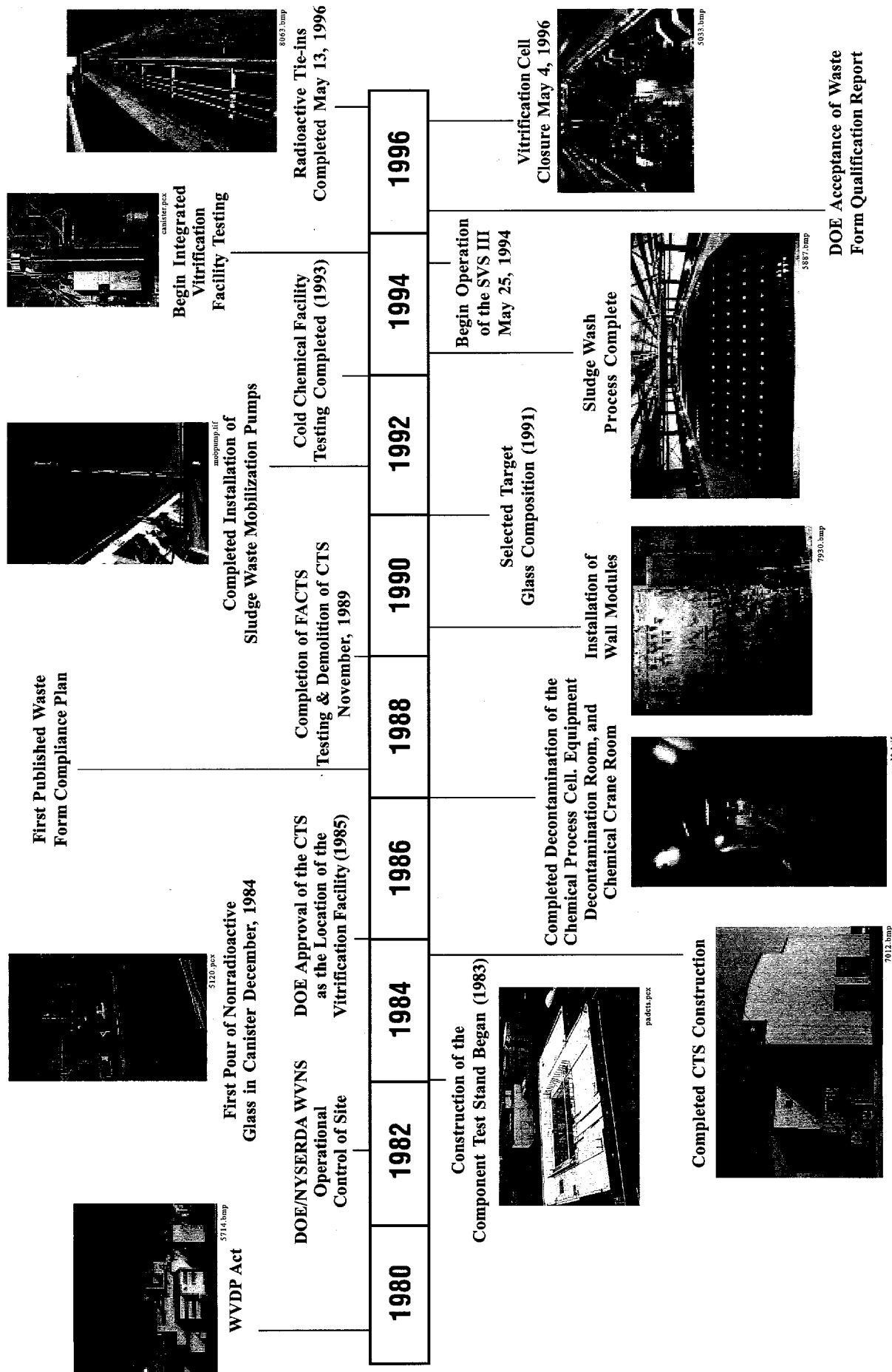


Figure 1-1. Major Vitrification Milestones

When the plant was built, the management of high-level radioactive liquid waste at federal installations employed underground storage in carbon steel tanks. Following this precedent, the WNYNSC was licensed to operate with the expectation that the high-level radioactive liquid wastes generated during fuel reprocessing would be stored underground in steel tanks for an indefinite period.

The plant was in operation from 1966 to 1972 and during that time generated approximately 2,270 m³ (600,000 gal.) of high-level radioactive liquid waste and stored the waste in two underground tanks at the site. During 1969, NFS was acquired by the Getty Oil Co. Getty continued operation of the plant under the NFS name.

In 1972, fuel reprocessing operations at the plant were suspended for making modifications to increase capacity and reduce occupational radiation exposure and to reduce radioactive effluents. Upgrades were expected to take about two years. During this shutdown, the AEC decided that these modifications were sufficient to warrant a complete licensing review. By 1976, NFS estimated that if all of the criteria under current consideration were imposed on the modification program, costs would exceed \$600 million.

Changing government regulations and economic considerations led to NFS' decision to close the plant permanently in September 1976. NFS notified the New York State Energy and Research Development Authority (NYSERDA), successor to NYARDA, of their intention to exercise their right under their Waste Storage Agreement to surrender responsibility for all wastes at the WNYNSC. Later that year, NYSERDA advised the Federal Government that ownership of the WNYNSC and responsibility for its contents should be transferred to the Energy Research and Development Administration (predecessor to the Department of Energy).

On October 1, 1980, the President signed into law the "West Valley Demonstration Project Act, (the Act)."¹ The Act directs the Secretary of Energy to carry out a high-level radioactive waste management demonstration project at the WNYNSC in West Valley, NY, for the purpose of demonstrating solidification techniques that can be used for preparing high-level radioactive waste for disposal.

The NYSERDA-owned site was to be managed by the Department of Energy (DOE). The cooperative agreement between DOE and NYSERDA stated that the work outlined by the Act was to be accomplished using the existing facilities at the site to the maximum extent possible. Breakdown of financial responsibility for the site is 90 percent DOE and 10 percent NYSERDA.

In 1981, West Valley Nuclear Services Company, Inc. (WVNS), a wholly owned subsidiary of Westinghouse Electric Corporation, was selected by the DOE to be the management and operating contractor of the site. In 1982, the DOE, WVNS, and their primary subcontractor Dames and Moore, an environmental and site characterization firm, moved into the former NFS offices at the West Valley site.

In 1983, the DOE selected borosilicate glass as the final high-level waste form for the WVDP. This waste-form is produced by mixing the high-level radioactive waste with glass-forming chemicals, and then heating the mixture to a temperature sufficient to convert the constituents into a borosilicate glass.

Ebasco, an architect/engineering firm, was contracted by WVNS to design a seismically qualified foundation and other facilities in which the demonstration of vitrification processes could be performed. Construction of this facility or the Component Test Stand (CTS), as it came to be called, began in 1983. Major component designs for the vitrification process equipment were adapted from designs developed at the DOE's Pacific Northwest National Labs (PNNL). Construction was completed in 1984.

On March 27, 1985, James W. Vaughan, Acting Assistant Secretary for Nuclear Energy, approved the selection of the CTS as the location of the future radioactive Vitrification Facility (VF). In selecting the VF location, the following items were taken under consideration: conversion of the CTS to radioactive operations; comparison of three alternative locations within the existing reprocessing facility; and a letter from NYSERDA supporting the conversion of the CTS.

The decision remained in line with an earlier DOE directive to use the WVDP's facilities to the maximum extent feasible. Other locations required considerable decontamination effort and were a negative impact on cost and schedules.

1.2 High-level Waste Pretreatment and Consolidation

At the time the site was returned from NFS to NYSERDA, HLW from nuclear fuel reprocessing was stored in underground tanks. One tank contained neutralized plutonium uranium extraction process (PUREX) waste. Another tank contained thorium extraction process (THOREX) acidic waste from a special reprocessing run. The other two tanks were spares.

Pretreatment of the HLW began in 1988. In the PUREX HLW tank, the waste had separated into two layers: a clear liquid (supernatant) above a layer of precipitated sludge. Solidification of these separate layers required processing in two stages. The supernatant was transferred through ion-exchange columns containing zeolite that removed greater than 99.9 percent of the radioactive materials. The resultant effluent salt solution was concentrated, blended with cement, and stored as low-level waste in a shielded, above-ground facility on site. Supernatant processing was completed in 1990 producing a total of about 10,000 cement drums.

Mixing pumps were then installed in the PUREX HLW tank to mobilize the sludge for washing. This included the addition of process water to the tank to dissolve additional interstitial sulfates. Salt/sulfate removal was necessary so as to reduce the number of canisters produced during the vitrification campaign. The wash water was then processed similarly to the supernatant; however, titanium-coated zeolite was used as an alternative material in the ion-exchange columns. Two sludge washes were performed and approximately 9,800 cement drums were produced.

During 1994 and 1995, radioactive constituents in all waste tanks were combined into one 2,600 m³ (686,400 gal.) tank. The acidic THOREX HLW and spent zeolite from the ion-exchange process were transferred into the PUREX tank. This combined waste will be the feed for the vitrification process.

2.0 FACTS TESTING/LESSONS LEARNED

Glass recipe development, test equipment performance, and lessons learned from testing are described below:

2.1 FACTS Testing

Full-scale testing of the vitrification process was conducted from 1984 until 1989. This test program was referred to as the Functional and Checkout Testing of Systems, or the FACTS program.

During the FACTS program, new equipment and processes were developed, installed, and implemented. A total of 37 FACTS tests were conducted that produced approximately 150,000 kg (330,750 lbs) of glass using nonradioactive materials to simulate radioactive waste.

The FACTS program demonstrated the effectiveness of equipment and procedures in the vitrification system, and the ability of this facility to produce quality glass at the required production rates. Additionally, the FACTS program provided data to validate the WVDP waste glass qualification method and verify that the product glass would meet federal repository acceptance requirements.²

Much of the test equipment used during the FACTS program was converted for radioactive operations (e.g., civil construction, and the feed mixing and holding vessels.)

The purpose of the FACTS program was to perform vitrification tests of components and systems, and to establish the operating parameters necessary for radioactive operations.³ Some components and systems were installed and tested while others were being designed and built (see figure 2-1). Temporary or substitute components were used for components not yet in place. Melter temperature (1,050° C or 1,922° F) was maintained at molten glass levels throughout the FACTS testing period, including idle times between runs.

The early FACTS runs were characterized by equipment and procedure shakedown. Major vessels were first tested during the period from December 1984 to October 1985. As soon as equipment became available for use, it was included in the FACTS tests. The glass composition in the early tests was based on the one that was developed for the Defense Waste Processing Facility (DWPF) at Savannah River, SC.

In the later FACTS runs, the emphasis shifted to gathering data to demonstrate that the glass product would comply with the waste acceptance requirements for the site. Operating techniques used in earlier runs were refined based on glass qualification objectives. Glass qualification during radioactive operations will be determined primarily by the knowledge of feed composition and process control. The glass product quality will be verified by selected product sampling and analysis. Validation of this approach was one of the major objectives and achievements of the FACTS testing.

The reference feed is nitrate-based. However, the FACTS program was implemented using non-nitrate feed, that is, glass frit or hydroxide-based feed, in the initial runs. Nitrate-based feeds were used following installation of the oxides of nitrogen (NO_x) abatement equipment.



Figure 2-1. Vitrification Equipment During FACTS Testing

The waste glass tested was as close as practical in composition to the glass that will be processed in the radioactive system. Nonradioactive isotopes were used in place of radioactive elements in the high-level waste. Elements having no nonradioactive isotopes were simulated using other nonradioactive species with similar behavior.

2.1.1 Summary of Early Runs

Preliminary glass frit runs were used to define melter, turntable, and canister parameters. Runs #1 through #3 used hydroxide slurry to define the vitrification system parameters. Nitrate-based slurry, which was required for the reference glass, was used in slurry-fed (SF) run #4 when the NO_x abatement equipment was placed on-line. The main objective of runs #4 through #6 was to establish reliable processing equipment, instrumentation, and control systems. These runs also identified the problem of foaming in the melter.

Runs #7 and #8 were preliminary operational tests performed to ensure a reasonable understanding of the facility and process, with emphasis on glass oxidation (redox) control and film cooler operational requirements. Run #10 was actually a series of runs that permitted extended steady-state operation. These runs were used to assure process equipment integration, sampling, analytical techniques, and cold chemical preparation methods. These runs also provided the data required to demonstrate that the WVDP waste form would meet federal waste acceptance criteria.

In runs #11 and #12, the VF was operated under conditions that simulated radioactive waste processing using nonradioactive species to simulate a radioactive species. These runs were conducted using prototypical remote technology to the extent the existing facility would permit.

The FACTS program successfully demonstrated the ability of the WVDP VF to produce high quality glass on a production schedule. It also demonstrated the WVDP waste glass qualification approach, which consisted of remote determination and control of product glass quality through knowledge and control of input feed and system processes. In the final FACTS runs, nonradioactive species were used to simulate radioactive species in the HLW.

Thirty-seven FACTS tests were performed over a five-year period. Approximately 150,000 kg (330,750 lbs) of glass were produced. Process components and subsystems were sequentially added. Subsystems tested in the order of addition were the: melter (producing glass from a hydroxide-based frit feed) and canister turntable; melter off-gas cleanup and ventilation system (excluding NO_x abatement components); NO_x abatement components of the off-gas system and melter feed hold tank; and slurry feed preparation system.

Following the final run, the VF was disassembled for examination of test components and subsequent conversion to radioactive service. Based on the success of the FACTS program and lessons learned, much of the test facility (i.e., civil structural, and feed mixing and holding vessels), was reassembled and reused. Melter replacement was necessary because the FACTS melter exceeded its recommended design life.

2.2 Lessons Learned During FACTS Testing

As expected for a test program of this nature, some components and procedures did not perform to their desired standards during initial implementation in FACTS. Upon completion of FACTS testing, numerous items were noted that required modification prior to installation and operation of components in the VF. Major modifications to equipment or the vitrification process are described below:

2.2.1 Slurry-fed Ceramic Melter

As the primary component of FACTS and the vitrification process, efficient ceramic melter performance was critical to the production of a quality waste form. The following items highlight the changes prescribed by FACTS testing:

2.2.1.1 Melter Lid and Nozzles

Severe corrosion problems were noted with the melter nozzles due to sulfidation corrosion. In addition, the nozzles deflected from vertical when the melter was heated to operating temperature due to temperature differentials, thus preventing the remote installation or removal of jumpers. Refractory spalling also was noted in the melter lid.

A single composite uni-flange design was used to replace individual nozzle flanges, making the configuration stronger due to its composite construction and providing a more thermally stable base for jumper connections. Inconel 690 liners were added to each nozzle to eliminate corrosion problems. Air cooling of the liners was also implemented to maintain nozzle temperatures outside the range in which corrosion occurs. An additional nozzle was added to provide access for a bubbler system. Several other nozzles were deleted upon evaluation. Ceramic castable refractory hangers were increased in length to provide greater refractory support in the lid. C-clip supports for these hangers were increased in thickness and sprayed with a protective coating of Inconel 72 to mitigate corrosion.

2.2.1.2 Cooling Water Jacket

FACTS testing prompted redesign of the melter's cooling water jacket. Lower design pressure (15 psig) created several operational and system interfacing problems. Uneven flows and thermal profiles were evident at low flow. Additionally, isolation of the side and bottom water jackets was not maintained due to a fabrication process that used "skip" welds that allowed leakage under the baffles. Redesign to accommodate the closed-loop cooling water system pressure of 35 psig included increasing the water jacket plate thickness from 6.35 mm (1/4 in.) to 9.53 mm (3/8 in.) and replacing the multiple jacket arrangement with a continuous weld with a single jacket plate with 9.53 mm (3/8 in.) plug welds. Baffle plate width was reduced by 3.18 mm (1/8 in.) to account for the increased jacket plate thickness. The baffle plate configuration also was changed to provide an adequate base for seismic support and maintain isolation between the side and bottom water jackets. Hydrostatic testing of the jackets at 44 psig confirmed the redesign and isolation between the two water jackets.

2.2.1.3 Discharge Lid Redesign

The discharge lid on the melter was designed to be a remotely replaceable component on the melter. Several issues arose during testing that prompted redesign. Interferences between the discharge heater bars, thermowells, and the discharge cavity refractory resulted in broken heater bars. The physical layout of the PUREX electrical connectors on the discharge lid was designed prior to completion of the wall module design. This caused the lid arrangement to impede the ability to interchange the east and west discharge lid due to limited clearances. Air in-leakage from the canister turntable was allowed to travel through the cavity before being drawn into the off-gas system. This prompted concerns that excessive air in-leakage would hinder the cal-rod heater's ability to maintain operating temperatures in the discharge cavity and would disrupt the glass pouring

operation. The discharge lid design was a welded enclosure that hindered the replacement of the heater bars. The internal electrical connections were damaged by the high-temperature environment resulting from the discharge lid refractory design.

To eliminate these problems, the discharge heaters and thermowells were repositioned and the shape of the discharge cavity was modified. The PUREX electrical connectors were repositioned closer to the discharge lid to allow sufficient clearances for the electrical jumpers. To resolve the air in-leakage problem, the discharge lid was redesigned to allow the installation of a vent pipe. One nozzle was converted from an angled viewing port to a vertical vent nozzle that accommodated the installation of a vent pipe. The welded discharge lid design was changed to a flanged lid to facilitate heater bar replacement. The discharge lid refractory design was also modified to mitigate exposure of the electrical components to high temperatures.

2.2.1.4 Electrodes

The cooling channels for the three melter electrodes were created by milling slots in the electrode body with a welded cover plate. This fabrication method caused minor warping of the electrodes. To eliminate this warpage, the cooling channels were drilled instead of milled and covered. For drilling, the east and west electrodes retained square ends versus the originally specified 25° taper.

2.2.1.5 Seismic Restraint Addition

Although the FACTS melter was not designed with a restraint system, seismic requirements were needed for radioactive vitrification operations. These modifications included the addition of a restraint system to the outside of the melter box that was attached to the cell walls. The melter base was also widened to accommodate the restraint design and provide adequate allowance for thermal growth.

2.2.2 Distributed Control System (DCS) and Instrumentation

The DCS that was used to control and monitor the vitrification process did not have adequate processing capability due to both hardware and software limitations. Separate controllers were originally used for control and for monitoring. Later in the testing evolution, the addition of new vitrification and Waste Tank Farm (WTF) process equipment filled all inputs on the DCS making it impossible to add additional controls or alarms.

After five years, it was necessary to upgrade the DCS hardware and software due the lack of availability of parts and the advancements in computer technologies.

2.2.3 Electrical Power Supply

Operation of the melter and DCS during FACTS testing was not powered by an uninterruptible power supply (UPS), but by power provided by the local utility to the site. A UPS was purchased at the same time as the DCS to ensure the accurate operation of system instrumentation. It was determined that the UPS was needed primarily to provide uninterruptible power to the system in case of a utility power outage and to cleanup power spikes and noise (surging power) from operation of the melter.

Joule heating of the melter that alternates electric current between the melter's electrodes required a rapid on and off of electric power, causing voltage spikes and interference to the DCS. Additionally, this method of current use for heating was capable of disrupting current flow to the connecting systems. Since computers (mainly the DCS) were particularly susceptible to damage or loss of data due to power spikes, a UPS was required.

2.2.4 Turntable

The original test turntable had substantial problems. Turntable rotation was driven from a center post with wheels out on the diameter of the turntable. It was found that the wheels would not rotate past very small debris (0.25 mm or 0.010 in.) that may be present on the track. The load cells used were sensitive to thermal expansion and as the glass load increased, and hence the temperature, the indicated value from the load cells actually decreased.

The turntable had a closed metal barrel that enclosed the canisters and was to have a radioactive cobalt source to detect the level of glass in the canister. This method was determined to be insufficiently accurate and could not be tested until the facility was completely finished since it required a radioactive source in the cell. An infrared camera was developed to detect the glass level. This required an open structure around the canister.

Many of the components on the test turntable could not be maintained in a remote environment. This and the aforementioned problems required a full redesign of the turntable.

2.2.5 Submerged Bed Scrubber

An off-gas system consisting of; a submerged bed scrubber (SBS), a condenser, high-efficiency mist eliminators (HEMEs), and high-efficiency particulate air (HEPA) filters; is used to trap the by-products from melter off-gases and direct them back into the process.

Several design deficiencies were noted after evaluating the testing data. The design of the inner tank promoted concerns about corrosion. Numerous welds on the cooling coil exhibited cracking. In the radioactive feed there are trace amounts of mercury that prompted a change in materials from stainless steel to Hastelloy C-22 to prevent corrosion. The sludge transfer and sparge rings appeared to be ineffective and the tank's design made removal of accumulated solids difficult. These solids had settled into a heavy layer of sludge. If the tank were to be reused and placed into radioactive operations, these deficiencies had to be resolved. The accumulation of solids would eventually close off flow from the melter and would create a problem during later decontamination and decommissioning. Re-engineering the scrubber design was required to confine and remove accumulated solids.

The Westinghouse Scientific and Ecology Group (WSEG) and the Westinghouse Science and Technology Center (WSTC) were consulted. Full-scale testing of a new scrubber unit was performed at the WSTC to develop a method of removing solids from the bottom of the vessels.

The first tests conducted were to characterize the sludge that accumulated in the old scrubber tank. After determining the characteristics of the material, further testing was performed using a full-scale mockup. The tank's flat-bottom design for both the scrubber and the receiver vessels was changed to a dished-bottom, four nozzles were added to the inner tank to circulate the settling solids to the bottom of the tank, and a vacuum-type rake was added to the tank to remove the solids. Nozzles and a vacuum rake were also added to the receiver tank.

2.2.6 NO_x Abatement

A wet scrubber system adapted from the original nuclear fuel reprocessing plant was used during FACTS testing. This system had been designed for mercury removal and potentially iodine removal and not the removal of oxides of nitrogen (NO_x). During testing, it was found that NO_x removal efficiencies of only 65-75 percent did not meet the New York State regulatory requirements.

Alternative technologies were researched, a catalytic system was purchased, and a pilot plant was set up to sample a side stream of the melter off-gases. The pilot plant ran for approximately two years with good results.

The new system heats the off-gas to 340° C (650° F), ammonia is injected upstream of the catalytic convertor, and the resultant reaction converts the oxides of nitrogen to nitrogen and water vapor. This became a usable process with NO_x removal efficiencies of over 90 percent.

2.2.7 Melter Feed Delivery System

At the start of FACTS testing, the original configuration of the process tanks included two concentrator tanks and one feed tank upstream of the melter. The feed tank had a double air-lift system to transfer the feed into the melter. The air-lift required continued circulation of the feed. Extra agitation of the feed produced foaming that caused the feed to segregate and be unevenly delivered to the melter.

Additional testing at PNNL was performed before changing the configuration of the tanks. Testing determined that the separate feed tank should be removed from the configuration and that one concentrator tank should be reused as a hold tank. The original concentrator tank was modified to become this hold tank.

Feed to the melter is now delivered by a single air displacement slurry (ADS) pump. This type of pump did not recirculate feed and, therefore, avoided the production of foam.

2.2.8 Temporary Cold Chemical System

Early PNNL testing of the chemical makeup for melter feed concluded that the addition of chemicals had to be performed in a proper sequence to avoid plugging and the production of gel in the delivery system.

During FACTS, a gravity-dump system was employed for adding chemicals into the temporary plastic chemical feed makeup tanks.

About mid-point of the FACTS testing (at SF-11), a vacuuming system (Vac-U-Max™) was added to ease the process of chemical addition. Clogging of this vacuum system also occurred if the chemicals were not added in the proper sequence. This resulted in hygroscopic chemicals being added first, then the abrasives to act as a type of scouring agent (silica).

2.2.9 Sampling

A sample station was employed to sample nonradioactive fluids in the vitrification process. Inconsistencies were found by the Analytical Lab in approximately 17 percent of the samples. These inconsistencies were characterized by: slurry leakage from the sample station unit; underfilled sample bottles, improper rinses, feed-covered sample bottles, and plugging of the sample transfer jumper.

The sample module on the same station became inoperative when the sample needle mechanism bent to a point where it would not accept a sample bottle. The sample station proved to be too complex and delicate for remote maintainability. Redesign of the sample station was required to improve the remote aspects in obtaining a sample.

3.0 FACILITIES DESCRIPTION

The facilities to be used for solidification of radioactive waste are: the Vitrification Cell, which houses all major radioactive process equipment; operating aisles and working areas, which primarily support operations; and auxiliary facilities, which are either new facilities or existing facilities reused to perform specific vitrification support functions.

The Vitrification Cell is constructed of concrete walls, cast-in-place concrete columns, a floor pad, a mat, the roof structure, access hatches, shield doors, shield windows, various penetrations, and the primary process components.

Areas surrounding the Vitrification Cell are used to support Cell operations and are generally constructed of structural steel, exterior metal siding, floor slabs, access hatches, wall partitions, stairways, doors, and platforms. Activities in these areas are protected by the Facility weather enclosure. Operating aisles provide areas for manually controlling activities in the Vitrification Cell and utility service delivery to in-cell components. The Vitrification Main Control Room also supports Cell operations in these areas.

Auxiliary facilities provide specific support functions, house large support systems, and are generally separated from the Vitrification Building. These include the Cold Chemical Building, Load-in Facility, Waste Tank Farm (WTF), NO_x Abatement Facility, and Main Plant support buildings.

3.1 Vitrification Cell

The Vitrification Cell is located immediately north of the Main Plant Building and occupies the same space as the former CTS facility. The CTS structure and equipment were used to the optimum extent in the design and construction of the VF.

The Vitrification Cell is a reinforced concrete structure with interior dimensions of 10.36 m (34 ft) by 19.2 m (63 ft) and approximately 14.02 m (46 ft) above grade. The north, east, and west walls are 1.22 m (4 ft) thick between elev. 100.00' and elev. 120', 10 in., 860 mm (2 ft, 10 in.) thick between elev. 120', 10 in., and elev. 127.00', and 660 mm (2 ft, 2 in.) thick above elev. 127.00'. The south wall at column line 5, including east and west shear wall extensions are nominally 1.22 m (4 ft) thick, but vary in thickness as a function of shielding and structural considerations. The roof of the Vitrification Cell is 840 mm (2 ft, 9 in.) thick with the top at elev. 146.25'. Stay-in-place forms consisting of steel beams and metal Q-decking are used for roof construction. The walls and roof thicknesses are governed by WVNS shielding, seismic, and structural considerations. The east and west walls (columns B & D) support a bridge crane at elev. 132.00'.

The Vitrification Cell acts as a confinement barrier for the radioactive vitrification process. The walls are *seismically qualified to perform confinement during and after a seismic event*. The wall structure of the Vitrification Cell consists of prefabricated wall modules placed between previously cast-in-place concrete columns. The modules consist of a structural framework to support internal piping and various penetrations for windows and utilities. A 9.5 mm (3/8 in.) thick stainless steel plate faces the radioactive or "hot" Cell interior and becomes the liner for the Cell. The nonradioactive or "cold" side of the 1.22 m (4 ft) thick module was formed after the modules were installed by filling each module with concrete. A total of seven modules were installed and welded together.⁴ Refer to figure 3-1 for a plan view/general arrangement of the VF/Cell.

The Vitrification Cell liner, in areas other than the wall modules, is stainless steel nominal 10-gauge plating on the Cell floor and up the walls to elev. 123-0'. All areas above the stainless steel liner are painted with an epoxy coating that is resistant to radiation and chemicals, and suitable for decontamination.

The roof hatch in the Vitrification Cell has three removable hatch blocks that are constructed of precast, reinforced concrete with a steel frame. They are designed to be welded to the steel hatch enclosure embedment structure.

Design floor loadings for the Cell are 1,466 kg per m² (300 lbs/sq ft) live load. In addition, the floor is designed for the 48,678 kg (107,000 lbs) melter load.

Six shield windows filled with mineral oil and 16 closed-circuit television (CCTV) cameras permit viewing into the Cell. The Cell is lit by 48, 400-watt high-pressure sodium lamps.

3.1.1 Vitrification Cell Shielding

Shielding thicknesses for the Cell are based on the waste containing the greatest radionuclide inventory and emitting the highest energy radiation. Penetrations through shielding walls for windows, manipulators, instrumentation, piping, ventilation ducts, etc. have been designed to provide shielding equivalent to the walls.

3.1.2 Major Cell Components

All the vessels and components required for the vitrification process are installed in the Vitrification Cell. These include: the primary process tanks, a concentrator feed makeup tank (CFMT) and a Melter Feed Hold Tank (MFHT); a ceramic-lined melter; the SBS; the canister turntable; a canister storage rack; the canister lid welding station; the canister decontamination station; and the melter off-gas system.

The CFMT, MFHT, melter/turntable, and SBS are located in a pit on the north end of the Vitrification Cell. The bottom of the pit is at elev. 86', grade level is at elev. 100'.

[illegible]

FIGURE 3-1

3.1.2.1 Concentrator Feed Makeup Tank (CFMT)

The CFMT holds, mixes, and boils feed for delivery to the MFHT. The CFMT is a large, cylindrical vessel, approximately 3.96 m (13 ft) in height and made of Hastelloy C-22 to resist corrosion (see figure 3-2). Design volume of the tank is nominally 22,600 l (6,000 gal.). The exterior is partially covered by two half-pipe coil heating/water jackets. The coils are dimensionally 89 mm (3-1/2 in.) schedule 10 pipe, covered with 25 mm (1 in.) of fiberglass blanket and 14-gauge 304L stainless steel sheet. An agitation system is installed in the tank to maintain homogeneity of the slurry. The vessel is supported on a 3.07 m (10 ft, 3/4 in.) skirt from the bottom head to a 25 mm (1 in.) thick base plate. The base plate is bolted to a support plate positioned at the bottom of the process pit.

3.1.2.2 Melter Feed Hold Tank (MFHT)

The MFHT holds and mixes slurry feed for delivery to the ceramic melter. The MFHT is a large, cylindrical vessel approximately 3.05 m (10 ft) in height and made of 304L stainless steel (see figure 3-3). Design volume of the tank is nominally 18,900 l (5,000 gal.). The MFHT's exterior is partially covered by a cooling jacket. The jacket has internal baffles that cause the water flow to spiral within a rectangular channel. An agitation system is installed in the tank to maintain homogeneity of the slurry. The MFHT is supported by four trunnions, each 102 mm (4 in.) in diameter.

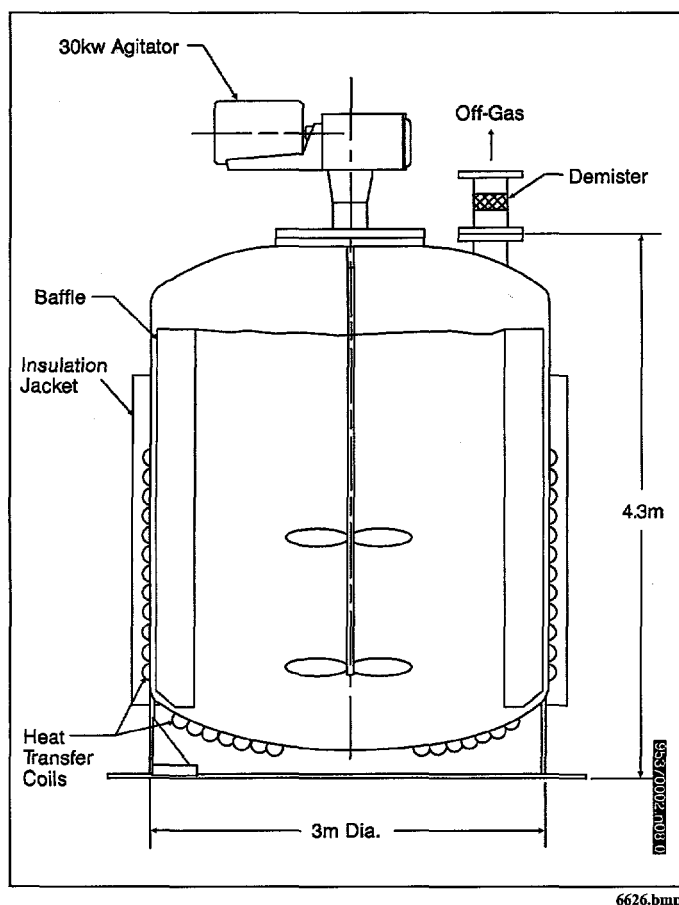


Figure 3-2. Cutaway View of the Concentrator Feed Makeup Tank

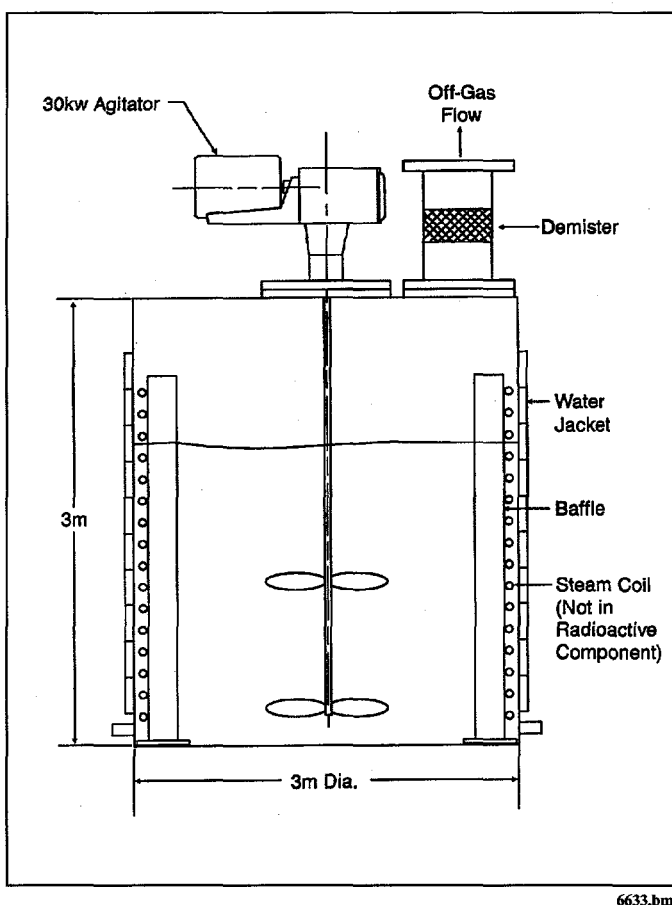
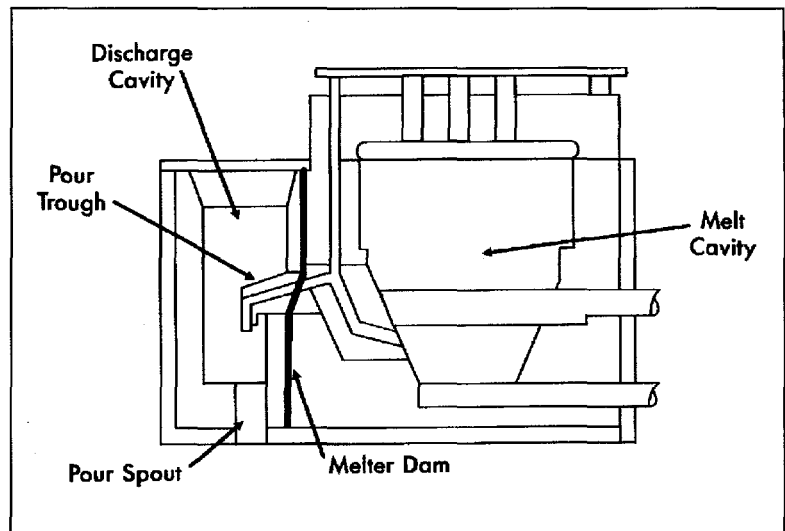


Figure 3-3. Cutaway View of the Melter Feed Hold Tank

3.1.2.3 Melter

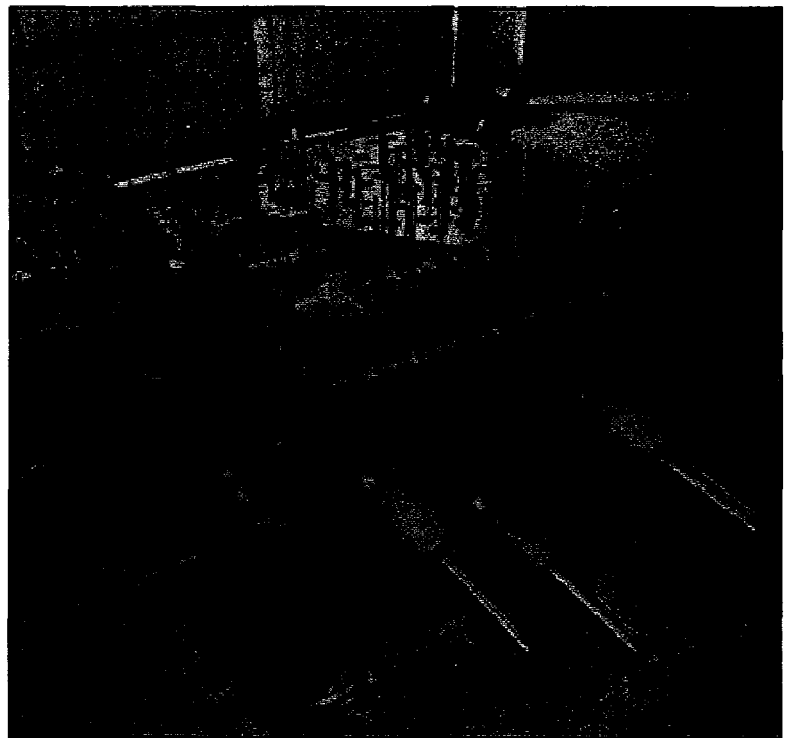
The joule-heated melter heats the batch feed mixture to a sufficient temperature for vitrification and delivers the feed into canisters for solidification. The melter is a stainless steel, water-jacketed box complete with a corrosion-resistant interior and separate chambers for glass melting and glass pouring. Dimensions of the melter are approximately 3.05 m (10 ft) wide by 3.05 m (10 ft) high by 3.05 m (10 ft) in depth. Thermal-resistant refractory bricks line the melter interior. Interior surfaces of the melter box are fabricated from Inconel 690. The exterior water jacket is 304 stainless steel. The basic shape of the melter vessel is an inverted truncated rectangular pyramid. The walls of the vessel slope inward toward the bottom. The melter is heated by three electrode plates. Two of the three electrodes are located in the sides of the vessel. The third electrode is located on the floor of the vessel. Electricity is conducted through the molten glass between alternating pairs of electrodes. Melter electrode extensions penetrate the concrete shield wall. Additionally, the melter is equipped with a dam cooling air supply, closed loop cooling water system, and seismic restraint system.

The discharge section of the melter has two pour chambers and pour spouts; one the primary pour spout, the other a backup. The weight of the melter is approximately 48.1 Mg (53 tons). Figures 3-4 and 3-5 provide different melter views. The melter is supported by a carbon steel structure that is bolted to the process pit floor, along with seismic restraints fastened to the walls of the Cell.



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Figure 3-4. Melter - Section View



1795.pcx

Figure 3-5. The WVDP Melter

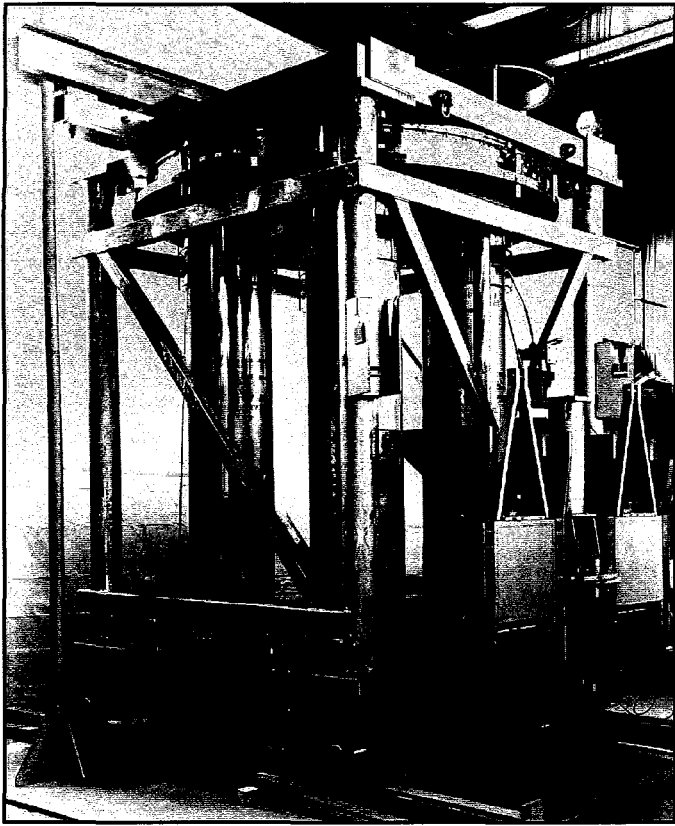


Figure 3-6. Canister Turntable

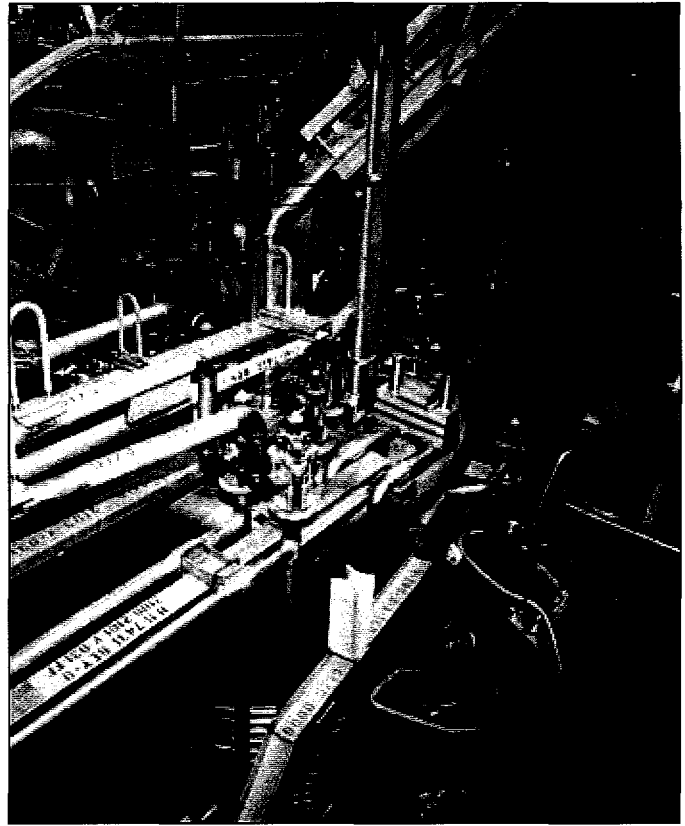


Figure 3-7. Submerged Bed Scrubber

3.1.2.4 Canister Turntable

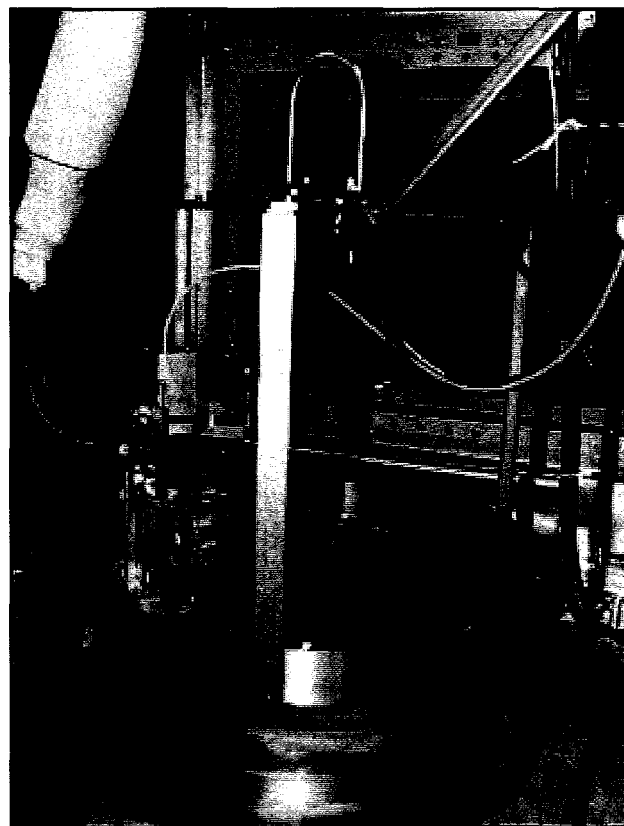
The canister turntable holds and rotates canisters under the melter pour spout for filling. The canister turntable is a geared, open support structure fabricated from 304L stainless steel and consists of a stationary frame and a rotating frame. The rotating frame has positions for four canisters to move in a carousel-like fashion on a 1.69 m (5 ft, 1/2 in.) diameter circle. The stationary frame dimensions are approximately 2.64 m (8 ft, 8 in.) wide by 2.44 m (8 ft) deep by 2.95 m (9 ft, 8 in.) high. The upper region of the turntable is sealed to the melter discharge section. The turntable rotates to place empty canisters into one of two positions beneath the melter pour spout and moves filled canisters to the two cooling positions (see figure 3-6). Viewing the glass pour level of the canister while the canister is in the turntable is performed by an infrared level detection system (ILDS).

3.1.2.5 In-Cell Off-Gas System

The SBS is the first component in the in-cell off-gas system train and is located in the process pit immediately west and downstream of the melter. The scrubber consists of two concentric right cylindrical vessels made from Hastelloy C-22 (see figure 3-7). The inner vessel contains the scrubbing bed which is 1.2 m (3 ft, 11 in.) tall by 910 mm (3 ft) in diameter and contains ceramic spheres. The outer vessel is 1.64 m (5 ft, 4 in.) tall by 1.83 m (7 ft) in diameter with a capacity of 3.3 m³ (880 gal.). The vessel's solid bottom is dished-shaped to facilitate evacuation by jet transfer. Cooling coils are in the scrubber vessel and on the outside of the receiver vessel. The rest of the in-cell off-gas system consists of preheaters, HEPA filters, and mist eliminators that are located above the pit area at elev. 100'. This system removes the bulk of the radioactive particulate from the off-gas stream and is located downstream of the SBS adjacent to a stub wall for utility service connections. Component housings in this system are made of Type 304L stainless steel.

3.1.2.6 Canister Lid Welding Station

The canister lid welding station remotely welds stainless steel covers to canister flanges. The canister lid welding station is located on the east wall of the Vitrification Cell between column lines 3 and 3Z. The station consists of a stainless steel work bench, weld head, hoist, flange conditioning tool, lid magazine, vacuum lid lifter, cover gas supply, and glass shard sampling equipment. The work bench structure measures approximately 3.96 m (13 ft) long by 1.22 m (4 ft) wide by 3.66 m (12 ft) high. It has two canister-holding compartments; one for welding, the other for backup canister storage. Primary lids are held in a lid magazine capable of holding 15 lids. A secondary lid can also be welded onto a canister if the primary weld is unacceptable. The remote weld head assembly consists of a guide track and support ring about 686 mm (27 in.) in diameter, a carriage drive unit, a torch, and a cable assembly (see figure 3-8). All weld head controls are managed through a welder control console located outside the Cell.



7925.bmp

Figure 3-8. Canister Lid Welder

3.1.2.7 Decontamination Station

The decontamination station is used to submerge each filled and capped canister in a nitric acid-cerium (+4) solution to etch off a thin (5 micron) layer of the canister's exterior that may contain submicron particles of fixed contaminants in the oxidized layer. The decontamination station is located on the east wall of the Cell, south of the weld station. The station consists of an in-cell decontamination station and an out-of-cell mixing station with two tanks; one to hold the decontamination solution and the other to hold a neutralizing solution. The decontamination tank is made of titanium and is approximately 760 mm (30 in.) in diameter with a capacity of 1,550 l (410 gal.). The tank equipment includes a nozzle for the addition of decontamination solution, a sparge ring for agitation of the solution, a level probe, a thermowell to support temperature control, heating and cooling coils, and a spray ring for removal of solution residue from the decontaminated canister. The neutralizer tank is also made of titanium, is 760 mm (30 in.) in diameter, and has a capacity of 1,460 l (385 gal.). This tank includes a nozzle for the transfer of waste solution, a vent to the vent header, a sample nozzle, a level probe, and a sparge ring. Transfer jets and service jumpers control addition and removal of process fluids (see figure 3-9).



3661.bmp

Figure 3-9. Canister Decontamination Station

3.1.3 Vitrification Cell Remote Handling

All operations within the Vitrification Cell are conducted remotely. Cranes are used for routine operations, such as canister handling and sampling; for maintenance, such as jumper removal and replacement; and other high-capacity lifts, as required. The crane system includes a 4.09 Mg (4.5 ton) crane, a 22.7 Mg (25 ton) backup crane, a powered hook rotator, an impact wrench, a bridge trolley and rails, and special handling equipment.

In-cell piping, valves, instrumentation, and electrical components are incorporated into crane-removable jumpers. All components in the Vitrification Cell are remotely removable using only crane-mounted equipment. Additional remote handling requirements within the Cell are performed by manipulators. Operations requiring manipulator use are primarily high-dexterity jobs such as sampling and sample packaging.

A remote robot is used for off-normal operations and for final decommissioning. The robot is transported into the Cell by the overhead crane and can be fixed at any location to perform maintenance tasks. The robot has two hydraulic arms that are remotely controlled (see figure 3-10).

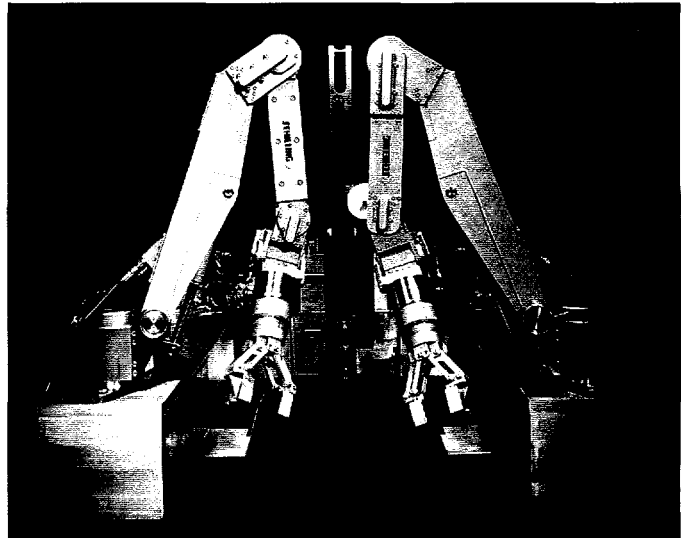


Figure 3-10. Remote Robot

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3.1.4 Vitrification Cell Penetrations

Numerous piping and electrical penetrations into the Vitrification Cell supply fluids, gases, and power/control to the Vitrification Cell components. The Cell has 35% spare penetrations and numerous spare utility sleeve penetrations. Penetrations have valved piping, with the valves located on the outside of the cell for isolation.⁵

Types of penetrations into the Vitrification Cell are described below:

3.1.4.1 Windows

Shield windows provide viewing into the Vitrification Cell. Window penetrations are large plate weldments that allow for cold-side installation of oil-filled, leaded glass, radiation-shielding windows. These penetrations are stepped similar to utility penetrations to provide adequate shielding. On the side of the windows facing into the Cell, a hot-side cover glass provides a seal that allows maintenance of the oil-filled window without breaching the Cell seal. The window penetrations also include seismic mounting (see figure 3-11).⁶



5164.pcx

Figure 3-11. Shield Window and Manipulator

3.1.4.2 Cell Hatch

The Cell hatch provides access for eventual equipment removal. The hatch is located above the Cell with opening dimensions of 3.96 m (13 ft) by 3.96 m (13 ft). The hatch is comprised of three stepped hatch blocks, each made of reinforced concrete with steel casing around the perimeter. The hatch blocks are 3.96 m (13 ft) long by 1.22 m (4 ft) wide by 838 mm (2 ft, 9 in.) thick and weigh approximately 6.9 Mg (15,000 lbs) each. They are welded onto the hatch by 102 mm (4 in.) metal clips to preserve the seismic integrity of the Cell.

3.1.4.3 Utility Sleeves

Utility penetrations or sleeves are cylindrical, straight-through penetrations machined from pipe and cast into the Cell concrete walls. They allow future installation of new services such as air, steam, or electrical power without having to core-drill through a concrete wall. The inside diameter of the penetration is machined with a concentric step so that a stepped plug may be installed to provide adequate shielding. Utility penetrations sizes are 178 mm (7 in.), 229 mm (9 in.), and 406 mm (16 in.). The penetrations include mounting provisions to seismically support the shield plug.

Unused utility penetrations are plugged with a 1.22 m (4 ft) thick shield plug constructed from pipe and filled with normal concrete.

3.1.4.4 Manipulator Ports

Manipulator penetrations are 254 mm (10 in. interior dimension) tubes that are used to mount Type-F manipulators. Shielding is provided by close-fit lead assemblies provided with the manipulator. They also include a seismic mount for the manipulator or plugs.

3.1.4.5 Pipe/Conduit

Pipe/conduit penetrations are used for the delivery of fluids and electrical/instrumentation connections. All of the penetrations are constructed from stainless steel.

The 76 mm (3 in.) and 51 mm (2 in.) penetrations are "S" shaped welded pipe fabrications with two pipe bends to provide a shielding offset. The back sides of both bends are shielded with steel bar stock. These penetrations are used for remote fluid connections in the Vitrification Cell.

Fifty-one millimeter (2 in.) electrical connections are "S" shaped pipe fabrications with two bends to provide a shielding offset. The back sides of both bends are shielded with an extra piece of steel bar stock. These penetrations are used for remote electrical/instrumentation connections in the Vitrification Cell.

The 51 mm (2 in.) three-way pipe penetrations are bent pipe penetrations with two bends to provide a shielding offset. The back side of the bottom bend is shielded with an extra piece of round steel bar stock. These penetrations include three 13 mm (1/2 in.) nominal pipes and are used for remote fluid connections in the Vitrification Cell.

3.1.4.6 Other Penetrations

Frit Addition:

The frit addition penetration is located at elev. 120' in the north wall adjacent to the melter viewing window and is used to feed frit to the melter on initial start-up. It is a straight-through penetration at a 45° angle to the Cell wall that is 76 mm (3 in.) in diameter and made of Schedule 40 stainless steel pipe. The penetration has a steel screw cap with a shield plug insert.

Melter Viewing:

The melter viewing penetration is used to house an optical periscope that is used to view the inside of the melter. It is a 381 mm (15 in.) stepped utility sleeve penetration with a stainless steel sleeve located at elev. 111.3' in the north wall of the Cell. The penetration has a lead shielding labyrinth wall plug.

Glass Pour Viewing:

The glass pour viewing penetration also has an optical periscope that, in conjunction with an infrared camera, is used to view the melter glass pour. It is located at elev. 111.6' in the east wall of the Vitrification Cell. Dimensions and material are the same as the melter viewing penetration described above.

Glove Box (Transfer Drawer):

Transfer drawer penetrations are straight-through penetrations that are used with transfer drawer assemblies to provide small parts transfer capability into the Vitrification Cell. The transfer drawer itself provides two shield blocks; one on the hot side of the drawer and one on the cold side to assure adequate shielding at all times. The transfer drawer penetration also provides seismic mounting for the transfer drawer assembly.

Two transfer drawers are located on the east side of the Cell. One transfer drawer is located on the north side of the cell. All three are at elev. 113'.

Sample Transfer:

The sample transfer cell is located outside the northwest corner of the Vitrification Cell. It will be used to transfer samples from the Vitrification Cell to the Analytical Lab for analyses (see figure 3-12).

The sample transfer cell has three penetrations into the Vitrification Cell: a 25 mm (1 in.) penetration for a stainless steel drain pipe, a 51 mm (2 in.) penetration at a 30° angle for a sample transfer port, and a 76 mm (3 in.) penetration for ventilation. The penetrations for the drain pipe and ventilation are offset. The drain pipe penetration is shielded by 76 mm (3 in.) steel plates.

Cell Cooler:

Cooler penetrations are straight-through holes in the Cell roof for the chilled water pipes that interface with the Cell coolers. The cooler is structurally designed to be supported at the penetration points. If removal is required, the cooler can be lowered by winch using the penetrations as hoisting points.

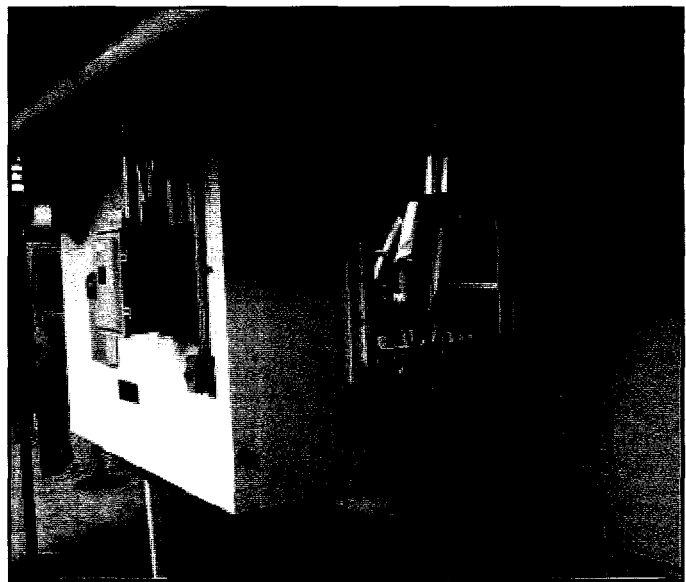


Figure 3-12. Sample Transfer Cell

Heating, Ventilation, and Air Conditioning (HVAC) Embedment:

The HVAC exhaust ducts from the Vitrification Cell are located on the south wall of the Cell and route the Cell air to the secondary filters. Steel embedments in the south cell wall are used to buildup the shielding where concrete thickness has been reduced to accommodate the HVAC exhaust duct work.

Thermocouples:

Thermocouple penetrations are 25 mm (1 in.) nominal pipes bent into a spiral shape that allows insertion of sheathed thermocouples. Shielding is provided by virtue of the spiral shape that eliminates radiation streaming.

Drains:

The sloped floors in the Vitrification Cell, transfer tunnel, Crane Maintenance Room (CMR), and Crane Maintenance Room Operating Aisle (CMROA) allow radioactive contaminants to drain or be washed to one of two sumps for removal through the waste header system. Contaminated liquids present in the waste header are eventually returned to the Waste Tank Farm where they are reintroduced into the vitrification process.

3.1.5 Shield Doors

Shield doors are made of carbon steel. The doors provide personnel shielding from the vitrification process and act as barriers between alike and different HVAC zones and atmospheres.

In the Vitrification Facility, there are three types of doors: tornado doors, radiation shielding doors, and one air-lock door. Doors #3, #4, #5, and #9 serve as tornado doors; Doors #1, #2, #3, #6, and #7 are radiation shielding doors; and Door #8 provides an HVAC air-lock. These special doors are located throughout the Vitrification Facility (see figure 3-13).⁷ The location of doors and door openings are as follows:

Door #1: Vitrification Cell to transfer tunnel shield door, 56.8 Mg (62.5 tons). The door opening is 4.3 m wide (14 ft, 1 in.) by 4.8 m (15 ft, 9 in.) high.

Door #2: Vitrification Cell to CMR shield door, 94.4 Mg (104 tons). The door opening is 12.0 m (39 ft, 4 in.) wide by 4.5 m (14 ft, 9 in.) high.

Door #3: Load-in Building to Equipment Decontamination Room (EDR) tornado shield door, 45.4 Mg (50 tons). The door opening is 3.8 m (12 ft, 6 in.) wide by 4.7 m (15 ft, 5 in.) high.

Door #4: Secondary Filter Room (SFR) door, 3.8 Mg (4.2 tons). The door opening is 2.5 m (8 ft, 2 in.) wide by 2.5 m (8 ft, 2 in.) high.

Door #5: Heating ventilating operating station (HVOS) door, 2.2 Mg (2.4 tons). The door opening is 1.6 m wide (5 ft, 3 in.) by 2.2 m (7 ft, 3 in.) high.

Door #6: Secondary Filter Room to EDR personnel access and shield door, 6.0 Mg (6.6 tons). The door opening is 1.1 m (3 ft, 7 in.) wide by 2.1 m (6 ft, 11 in.) high.

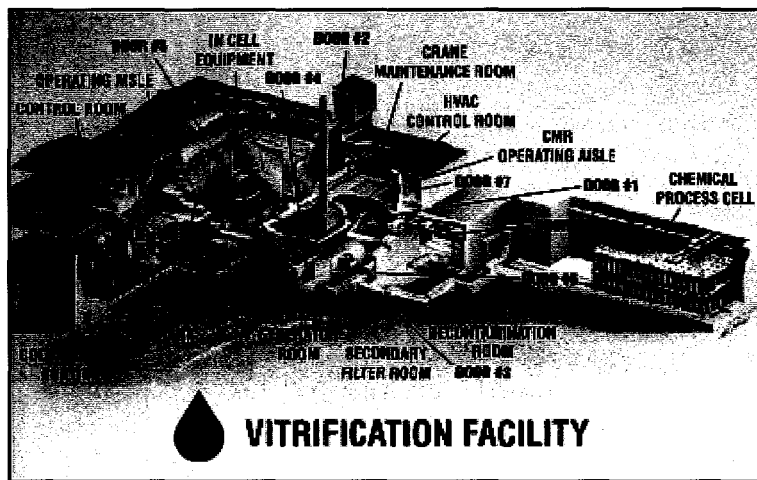


Figure 3-13. Shield Door Locations

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Door #7: CMR personnel access and shield door, 3.7 Mg (4.1 tons). The door opening is 1.0 m (3 ft, 3 in.) wide by 2.2 m (7 ft, 3 in.) high.

Door #8: Transfer tunnel to EDR door, 6.4 Mg (7.0 tons). The door opening is 3.7 m (12 ft, 2 in.) wide by 4.3 m (14 ft, 1 in.) high.

Door #9: Emergency Diesel Generator Room (DGR) door, 0.45 Mg (0.5 tons). The door opening is 1.6 m (5 ft, 3 in.) wide by 2.2 m (7 ft, 3 in.) high.

3.2 Vitrification Facility Operating Aisles

The VF has three floors that form the operating aisles that surround the Vitrification Cell on three sides; east, west, and north. These operating aisles provide access for viewing and control of remote equipment, and contain all the piping and control systems that feed chemicals, fluids, and gases to the components in the Cell (see figure 3-14). Piping, valves, and instrumentation are mounted on utility racks located in the operating aisles. The floors are located at elev. 100', 110', and 125'. The 110' level is the primary operating aisle for the Vitrification Cell and contains all the shield windows and the control stations for welding, sampling, and canister decontamination. The cranes and doors are also operated from this aisle. The 100' level contains the sample transfer cell and the closed-loop cooling water system. The 125' level contains the utility headers (steam, water, air), HVAC inlet air handling unit, decontamination acid feed tank, and piping/process control racks.



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Figure 3-14. Vitrification Facility Operating Aisle

The Vitrification Building that surrounds the Cell is constructed from structural steel framing with metal siding and roof. The Building's ceiling and exterior walls are insulated with blanket fiberglass, and the interior walls are faced with wallboard painted with Ameron 400, an epoxy paint. These ex-cell areas provide contamination/ventilation control and weather protection. Personnel doors isolate the east, north, and west aisles for contamination and pressure control. The main entrance to the facility is at the northwest corner and entry/exit is controlled by card readers. Personnel radiation monitors are located at the facility entrance and on the exit on the east side. One monitor is located at the entrance/exit of the 110' level. Continuous air monitors (CAMs) are located throughout the facility. A truck lock is located on the east side of the Building for removing equipment and a hatch in the northeast corner of the 125' elev. is available to move equipment and frit. A monorail system is used to remove manipulators and plugs, and for transport to the truck lock. The floor slab at elev. 100' is 305 mm (12 in.) thick reinforced concrete. The elevated floor slabs are 102 mm (4 in.) thick reinforced concrete placed on Q-decking and supported by structural steel. Allowable floor loadings at the 100', 110' and 125' elevations are 1,222 Kg/m² (250 lbs/sq ft) for live loads and 4.5 Mg (10,000 lbs) for concentrated loads.

3.2.1 Vitrification Main Control Room

All vitrification process functions are directed from the Vitrification Main Control Room. Most of the VF process functions are directly controlled from the operator workstations located inside the Main Vitrification Facility Control Room (VF Control Room). The remainder of process functions, such as the cranes, doors, and

transfer cart, are operated manually from the VF operating aisles. The VF Control Room is located on the west side of the Vitrification Building and has two elevations. The lower level, at elev. 114', contains the operators' work stations; and the upper level, at elev. 117', houses the shift engineer and shift supervisor work stations. The lower area is approximately 7.92 m (26 ft) by 6.1 m (20 ft), and the upper level is approximately 6.4 m (21 ft) by 6.1 m (20 ft).

The VF Control Room has its own dedicated air handling unit that maintains a controlled environment. All supplied air is filtered through a HEPA filter. A backup air handling unit has been provided that will come on-line in the event of failure of the primary unit.

All colors and fabrics in the room are coordinated, and the lighting is recessed to avoid shadows and glare. Dimmer switches allow the operators to select preferred lighting level. Sound deadeners are incorporated into the fabric design and walls to reduce noise levels.

The VF Control Room has two operator work stations, each with DCS monitors and computer-keyboards, an infrared level detection system (ILDS) monitor for canister level detection, and closed-circuit television (CCTV) monitors. The VF Control Room HVAC system control panel, the fire protection system monitoring panel, and various other facility and utility status indicators are located next to the operator work stations. The shift engineer's work station is equipped with a duplicate DCS monitor and computer keyboard, an ILDS monitor, and CCTV monitors. The shift supervisor's work station has the same equipment, with the exception of an ILDS monitor. Laser printers, mainframe terminals, telephones, radios, and supporting system documentation are also present on both levels of the Control Room (see figures 3-15 and 3-16).



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Figure 3-15. Vitrification Facility Main Control Room

3.2.1.1 Distributed Control System (DCS)

The vitrification process data acquisition and control system consists of a computer-based DCS. This control system has four redundant work stations that are located in the VF Control Room of the VF (see figure 3-17). The DCS allows for remote monitoring, control, and supervision of the vitrification processes. Control of process equipment can also be accomplished from local control panels located in operating aisles adjacent to the Vitrification Cell. Data collection and process control functions are performed for the: Cold Chemical Building; in-cell and ex-cell off-gas systems; ammonia supply and NO_x analyzers; VF HVAC; sludge mobilization system (SMS); cooling and utility water systems; steam, utility, and instrument air systems; canister turntable; waste header and vessel vent systems; primary vitrification process system; canister decontamination; and standby electrical systems.

Computer monitors display control function status in graphical form along with key operating parameters such as vessel levels, temperatures, valve positions, pressures, and flows presented in real time. Process inputs are audibly and visually alarmed. Certain key functions such as making set point changes have restricted operator access. Electronic permissives or interlocks are used to coordinate process control activities prior to their implementation.

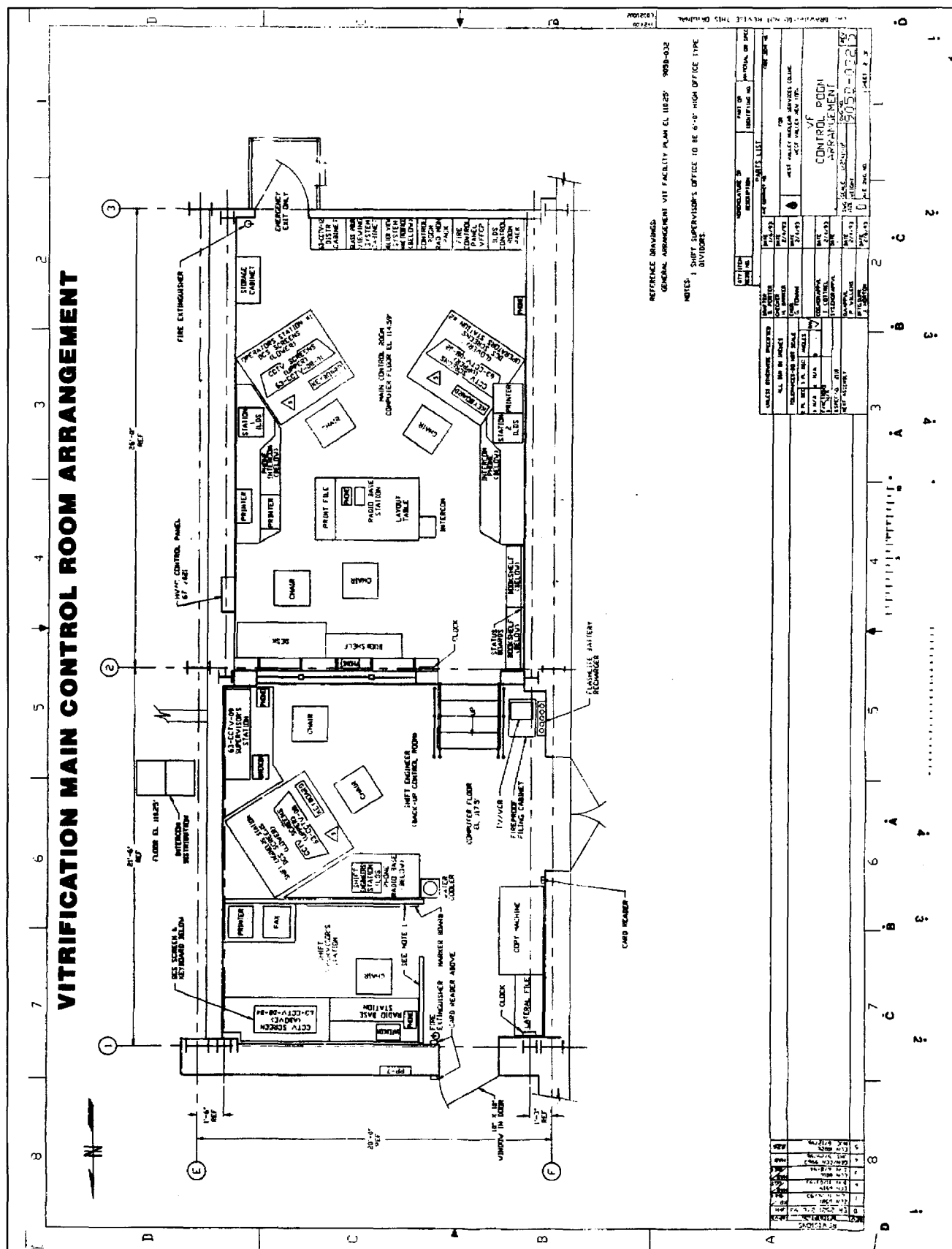


Figure 3-16. Vitrification Facility Main Control Room Arrangement

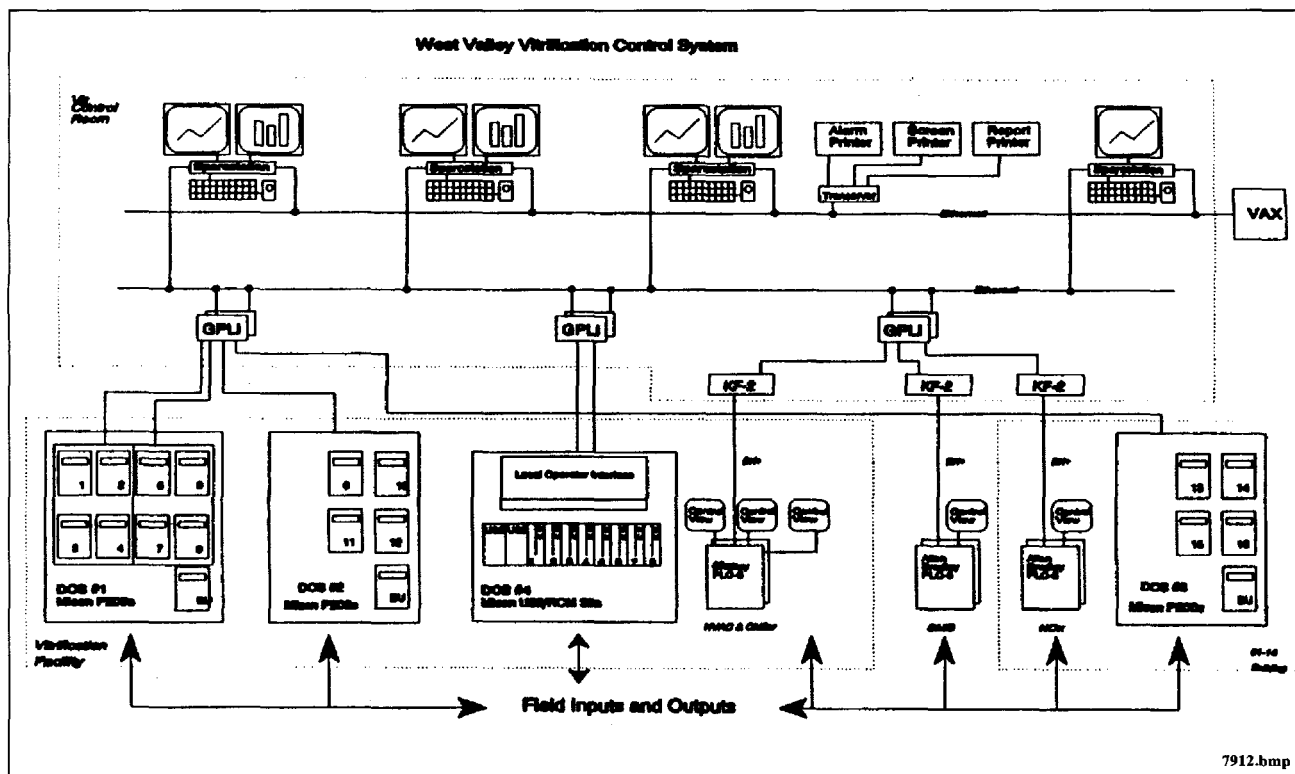


Figure 3-17. Distributed Control System Architecture

The DCS system receives its electrical power from a UPS that has a self-contained battery backup power source. The UPS is further supported by the VF standby diesel generator alternate electrical power supply.

3.2.2 Manual Controls

Operation of certain in-cell remote equipment was specifically designed so that it would be manually controlled from outside the VF Control Room at control stations located throughout the VF operating aisles. Manual operator controls are used for the operation of: the cell cranes, the shield doors, the transfer cart, certain CCTV cameras, sample handling, the in-cell telerobotic manipulator (in-cell robot), and the canister lid welder. Most of these component subsystems located in the Cell are controlled by embedded control systems provided by the equipment manufacturers. These components are stand-alone and do not have an interface with the DCS. Programmable logic controller (PLCs) are used for control of the transfer cart, the CPC 14.5 Mg (16 ton) crane, and for the CMR door, 63-M-002. Hardware relay logic is used for specific, manually controlled components including the cell cranes, manipulators, and shield doors. The CCTV system is the only component also controllable from the VF Control Room. The controls for the CCTV, canister lid welder, and telerobotic manipulator are personal computer-based. Control stations for all the manually controlled in-cell equipment were strategically located in the best operating aisle positions for command and control of tasks being performed.

The VF/transfer tunnel shield door (M-001) and the transfer tunnel/EDR air-lock door (M-008) are operated from a control station at the north viewing window of the Cell. The Chemical Process Cell (CPC)/EDR shield door (3-M-3) is controlled from the EDR viewing aisle on the east side of the EDR. The VF/CMR shield door (M-002) is operated from the CMR viewing window. The transfer cart is operated from the north window of the Vitrification Cell or the transfer tunnel, and at the CPC north window when the cart is in the CPC. The controls for each of the shield doors, as well as for the transfer cart, are interlocked to ensure safe and proper operation of canister movement throughout the various containment zones.

The Cell cranes are controlled from either portable operator control stations or from two larger crane control consoles located in the middle operating aisles. The cranes were designed so that they can be operated from any viewing window, including the CMR window.

Control of the canister welding process is from a control station at the weld station window. The computer program that controls the welder was designed so that the welding process is automatic once it is manually initiated from the control station. Critical parameters such as amperage, voltage, and weld speed are recorded and can be monitored as the weld progresses. Weld milling is also performed from a control station at this location.

3.2.3 Fire Protection

Fire protection is provided for all vitrification facilities, with the exception of the hot cells; namely the Vitrification Cell, CPC (High-level Waste Interim Storage or HLWIS), transfer tunnel, and EDR. These areas have been constructed using fire-resistant and noncombustible materials. Fire protection systems detect smoke and fires, actuate alarms for personnel evacuation, and initiate the appropriate responses to control and suppress fires located in the Cold Chemical Building, SFR, Vitrification Main Control Room, HVOS, DGR, CMR, Load-in Facility, operating aisles, stairways, and truck bays.

The overall fire suppression system is comprised of four subsystems: a pre-action sprinkler system, a deluge system, a wet pipe sprinkler system, and a Halon™ fixed fire protection system. Smoke and heat detectors and manual-pull stations are also located throughout the facilities. Detection of smoke in specific occupied areas results in the shutdown of air handling units and the subsequent closing of supply and return ducts. Portable fire extinguishers and hose stations have been provided for fire fighting local fires.

The VF Control Room is protected by a Halon™ fixed fire system and backed up by a pre-action system to prevent an unwanted discharge of water. The HVOS area is protected by a Halon™ system. A wet pipe system that provides protection from ordinary hazards is used for all occupied areas of the vitrification facilities. A deluge system is used to protect areas that are extra hazardous or have specific hard-to-extinguish fuels. The anhydrous ammonia tank area and the DGR use this type of system.

Alarms are audible and will signal on a fire control panel with subsequent signals to the VF Control Room and guard station.

Fire protection systems in the vitrification facilities comply with the specific national fire protection codes respective to each type of system; DOE Order 6430.1A and DOE Order 5480.7.⁸

3.2.4 Emergency Planning

Potential emergencies have been addressed in the VF by providing equipment such as first-aid equipment, fire blankets, eye washes, safety showers, and exits on the north, east, and west sides on all working levels of the VF. Both the VF fire detection and protection system, and the radiation monitoring and alarm system alarm, indicate the location of the problem in the VF Main Control Room. The fire detection and radiation monitoring detection and alarm systems are tied into the WVDP site alarm and monitoring systems, as appropriate.

The use of anhydrous ammonia (NH₃) as a catalyst in the NO_x Abatement System has been planned for by the performance of safety and hazard analyses to identify safety issues and the development of procedures and controls to assure safe handling and delivery of NH₃ to the site. To supplement the ammonia tank design and outdoor location, a seismic concrete pad, curbs, an integrated deluge system, and remote sensors were installed.

Emergency responses to off-normal conditions were developed and documented in WVDP-193, Emergency Action Derivation and Guidance Manual, along with the development of documentation detailing standard operating procedures and process safety requirements. Modification of the site-wide Emergency All-Page System to include a sheltering tone (alarm) was completed prior to NO_x Abatement System use. In addition, safety training was conducted for WVNS and local hospital and fire department personnel. HazMat equipment was also upgraded to include the necessary items for a specialized response.

3.2.5 Emergency Power

Electrical power for the normal operation of the VF and its support systems on the WVDP site is supplied from the Niagara Mohawk Power Corporation's (NMPC) 34.5 kilovolt utility system. The NMPC system has two independent power sources supplying the WVDP switching station. One source is from a station located at North Angola, NY, approximately 40 kilometers from the WVDP site. The other source is from a station located at Machias, NY, approximately 16 kilometers from the site. A failure of one NMPC source does not interrupt power service to the WVDP site.

The NMPC power service feeds four substations located on the WVDP site. Of the four substations, three supply power to the VF or its support systems. Substation A and B is a double-ended unit substation that feeds the VF and the WTF. One side of this substation is dedicated to the VF and the other side is dedicated to the power requirements in the WTF. The Main Plant Unit Substation and the Utility Room Unit Substation supply power to the Main Plant facilities and the 01-14 Building, which provide the necessary support systems to the VF.

Each of the unit substations in turn supplies other electrical power distribution equipment such as switchgear, motor control centers (MCC) and power distribution panels that are strategically located throughout the VF and Main Plant facilities. Within the VF the MCC's and power distribution panels are located throughout the various operating aisles and equipment rooms. Switchgear A1 is located in the VF Diesel Generator Room and Switchgear A2 is located in the HVOS room.

There are four stand-by diesel generators (SDG) installed on site that will supply stand-by electrical power to selected loads in the event of a complete loss of the off-site utility power source. Selected loads include instrumentation and controls as well as other process or safety-related equipment that must continue to operate during an off-site power outage. The VF SDG supplies stand-by power to Switchgear A1 & A2 which represents the selected VF loads fed from the VF side of Substations A & B. The Permanent Ventilation System (PVS) SDG supplies stand-by power to the PVS Motor Control Center (MCC)-A which represents selected WTF loads fed from the WTF side of Substations A & B. The primary load is the exhaust fans for the HVAC system in the VF. The Main Plant SDG supplies stand-by power to the selected loads fed from the Main Plant Unit Substation, and the Utility Room SDG supplies stand-by power to the selected loads fed from the Utility Room Unit Substation. The selected loads fed from the Main Plant and Utility Room SDG's include those required for the NO_x Abatement System in the 01-14 Building as well as other support systems for the VF.

The VF Distributed Control System (DCS) receives its electrical power from a series of Uninterruptible Power Supplies (UPS') located throughout the VF and the 01-14 Building. Each of these UPS units has an alternative power supply that is fed from one of the SDG's described above. In the event of loss of normal utility power and stand-by power, the UPS units will supply power to the DCS for a period of time sufficient to achieve a controlled shutdown of the VF process.

In the event of a prolonged loss of off-site utility power, the electrical power distribution system can be temporarily reconfigured to supply the VF melter with sufficient power to prevent solidification of the liquid glass within the melter. This would be accomplished by supplying power from the PVS SDG via a feed from PVS MCC-A to Substations A & B which in turn supplies power to the VF melter.

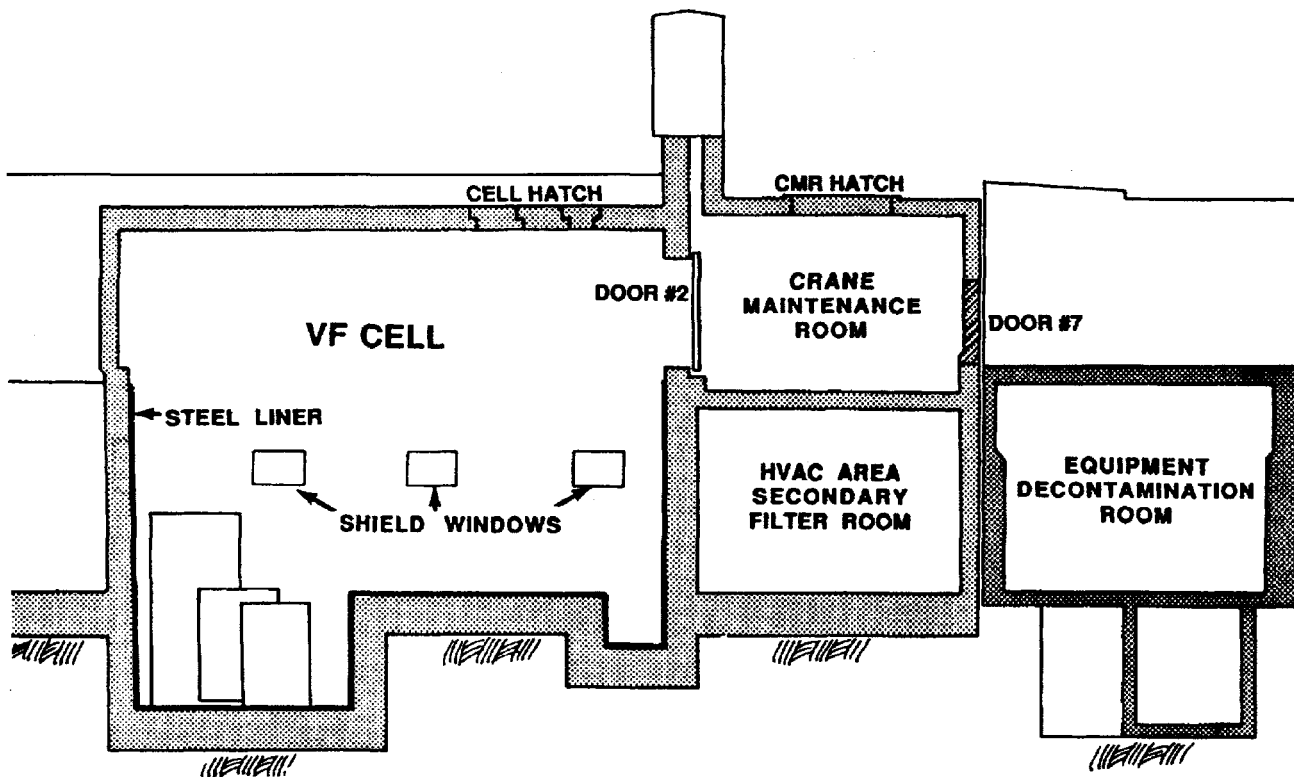
3.3 Crane Maintenance Room (CMR)

The CMR, which used to maintain and store cranes, is a reinforced concrete seismic structure with 610 mm (2 ft) thick walls, floor, and roof (see figure 3-18). The CMR has two hatches. One hatch, with dimensions of 5.18 m (17 ft) by 3.96 m (13 ft), is in the floor for access to the transfer tunnel. The other hatch, with dimensions of 3.96 m (13 ft) by 3.96 m (13 ft), is in the roof for equipment removal. The roof is designed to accommodate two hoists capable of lifting 12.7 Mg (28,000 lbs) each, which will be used to leap-frog the main process bridge crane with the backup bridge crane.

The CMR floor at elev. 124' has a 10-gauge stainless steel liner over the floor and coverage up the walls to 457 mm (18 in.) above the floor. There is a removable stainless steel cover over the top of the concrete floor plugs at elev. 124'.

Hatches between the transfer tunnel and the CMR are constructed of precast, reinforced concrete with a steel frame. Another roof hatch, a 3.96 m (13 ft) by 3.96 m (13 ft) opening, has a carbon steel cover.

Steel platforms, which support the crane rail and access stairways, are provided at elev. 131.33' in the area outside the crane rails.



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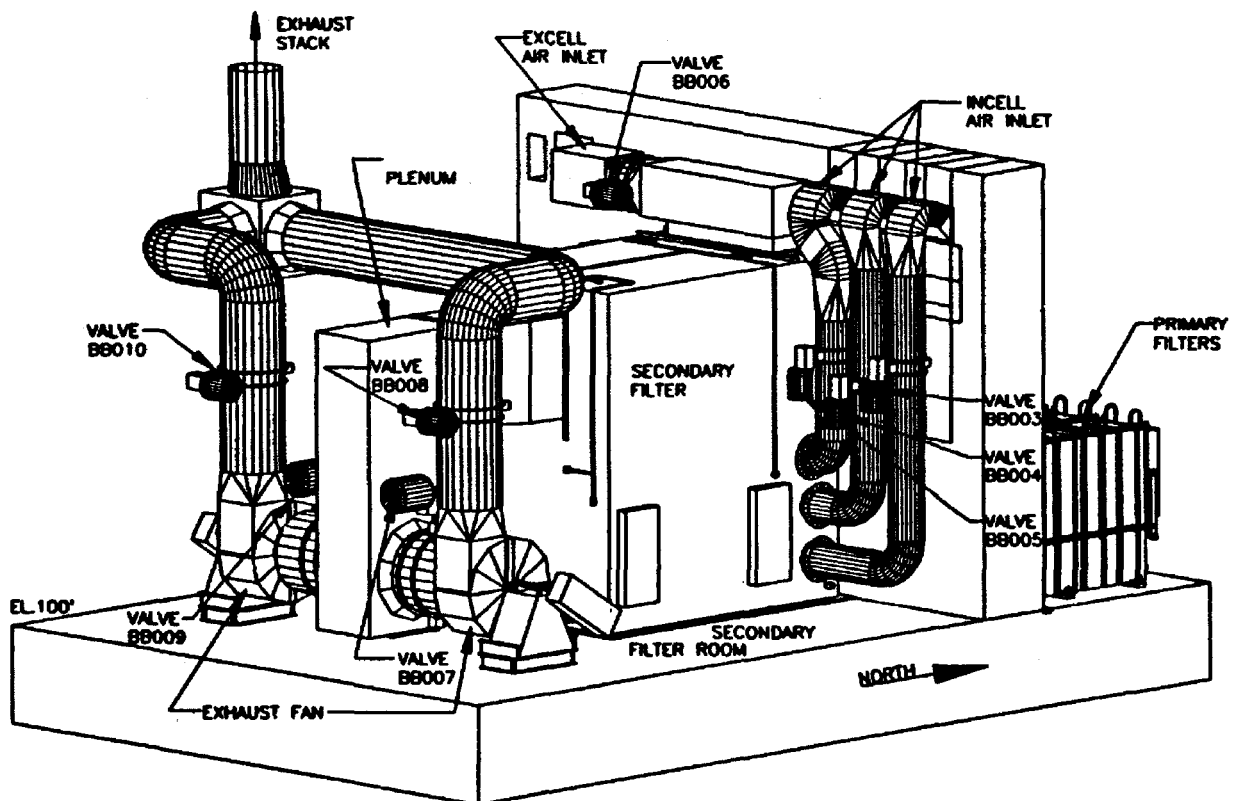
Figure 3-18. Crane Maintenance Room

3.3.1 Crane Maintenance Room Operating Aisle (CMROA)

The CMROA is structurally separated from the VF. The enclosure has a 305 mm (1 ft) thick reinforced concrete floor slab (elev. 131.33') for shielding, and a steel superstructure with insulated siding. The enclosure is supported on the 610 mm (2 ft) thick EDR building roof. The floor and interior walls are finished to facilitate decontamination. A 152 mm (6 in.) high concrete curb is provided on the perimeter of the enclosure. A shielded viewing window, centered on the CMR south wall, is used for viewing the CMR. A 1.83 m (6 ft) by 2.44 m (8 ft) opening in the roof of the operating aisle is provided for removal and replacement of equipment. The floor is designed for a 12.3 Mg (27,000 lbs) load distributed uniformly over a 1.22 m (4 ft) by 1.22 m (4 ft) area. Manipulators can be installed above the windows, although there is currently no plan for their installation. A 0.91 Mg (2,000 lbs) capacity monorail can be used to install the manipulator.

3.4 Heating Ventilating Operating Station (HVOS)

The HVOS/Diesel Room is at elev. 100'. It is a reinforced concrete seismic structure with 610 mm (2 ft) minimum thick walls, floor, and roof. The west portion of the roof is penetrated by the HVAC stack. The HVAC equipment station above the DGR has a 305 mm (1 ft) thick concrete floor at elev. 111.50' and access from the outside is provided. Figure 3-19 is a drawing of the HVAC exhaust system.



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Figure 3-19. HVAC Exhaust System

3.5 Secondary Filter Room (SFR)

The SFR is a reinforced concrete structure with approximate dimensions of 6.71 m (22 ft) wide by 9.75 m (32 ft) long. The floor is at elev. 100, and the ceiling is at elev. 122'. An additional area of 4.88 m (16 ft) by 4.27 m (14 ft) provides room for equipment and maintenance. The walls vary in thickness from 610 m (2 ft) to 1.22 m (4 ft). A window at approximately elev. 115' provides an emergency egress from the HVOS into the SFR (see figure 3-20).

Structural steel platforms at elevs. 109.17' and 112.25' provide access for removal of secondary filters from the duct bank. The platforms are rated for live loads of 978 kg m² (200 lbs) per sq ft. A 1.22 m (4 ft) high concrete wall is located outside the west side of the SFR at elev. 124'. The wall provides shielding and missile protection for the HVAC duct opening into the CMR.

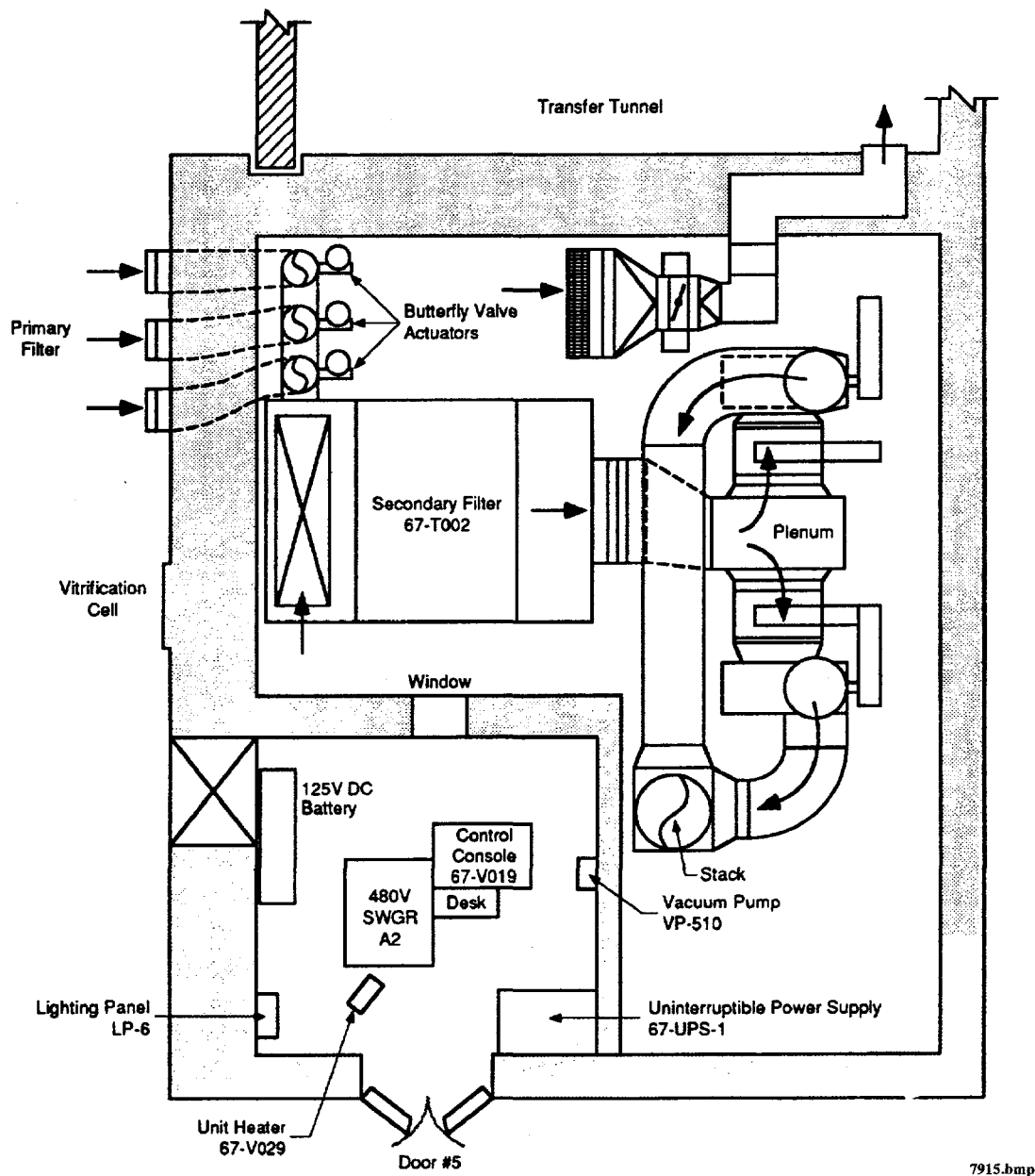


Figure 3-20. Secondary Filter Room

3.6 Transfer Tunnel

The transfer tunnel connects the Vitrification Cell to the EDR and is a pathway for canister transfers into the CPC (or HLWIS). The tunnel also acts as an airlock between the Cell and the EDR (see figures 3-21 and 3-22).

The tunnel is a reinforced concrete seismic structure approximately 4.88 m (16 ft) wide by 9.75 m (32 ft) in length, with 1.22 m (4 ft) thick walls for shielding. The floor and walls are lined with 10-gauge stainless steel to allow for decontamination. Drains in the floor are directed to a sump in the southwest corner of the Vitrification Cell. A header system with nozzles can be used to wash down the tunnel. Five removable hatch blocks provide shielding for the hatch opening.

HVAC systems will maintain a negative pressure on the tunnel and direct the flow of contaminated air into the Vitrification Cell. A CCTV camera mounted on the tunnel wall provides remote viewing capabilities.

3.7 Chemical Process Cell (CPC)/High-level Waste Interim Storage (HLWIS)

The former CPC of the main fuel reprocessing plant will be used for interim storage of vitrified waste.⁹ This facility is a shielded cell 28 m (93 ft) long by 6.70 m (22 ft) wide by 13 m (43 ft) high. Walls are 1.75 m (5 ft, 9 in.) thick and the ceiling is approximately 1.52 m (5 ft) thick. An epoxy coating has been painted on the interior walls to permit washdown and decontamination. Four shield windows permit viewing of the CPC interior from the outside viewing aisle. The transfer cart enters the facility through a shield door. Individual canisters will be unloaded from the cart by a 14.5 Mg (16 ton) crane with grapple attachment into storage racks. An additional crane is available for use in the CPC. A total of 11 storage racks, with a capacity of 36 canisters each, were installed in a two-tiered, interlocking seismically designed system. The facility can accommodate 396 canisters of high-level radioactive waste stored in this 11-rack canister storage system (see figures 3-23 and 3-24). An additional rack holds two cell

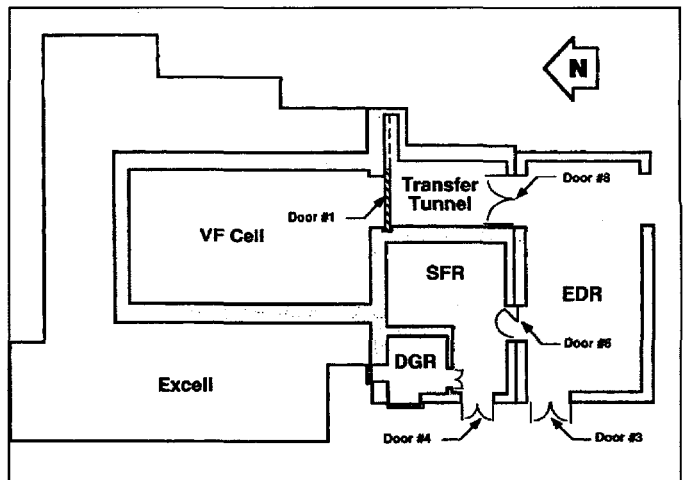


Figure 3-21. Transfer Tunnel Location



Figure 3-22. Transfer Tunnel Construction

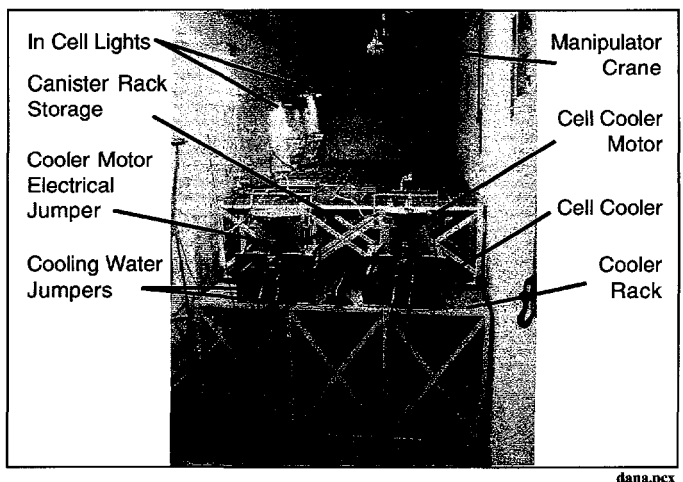
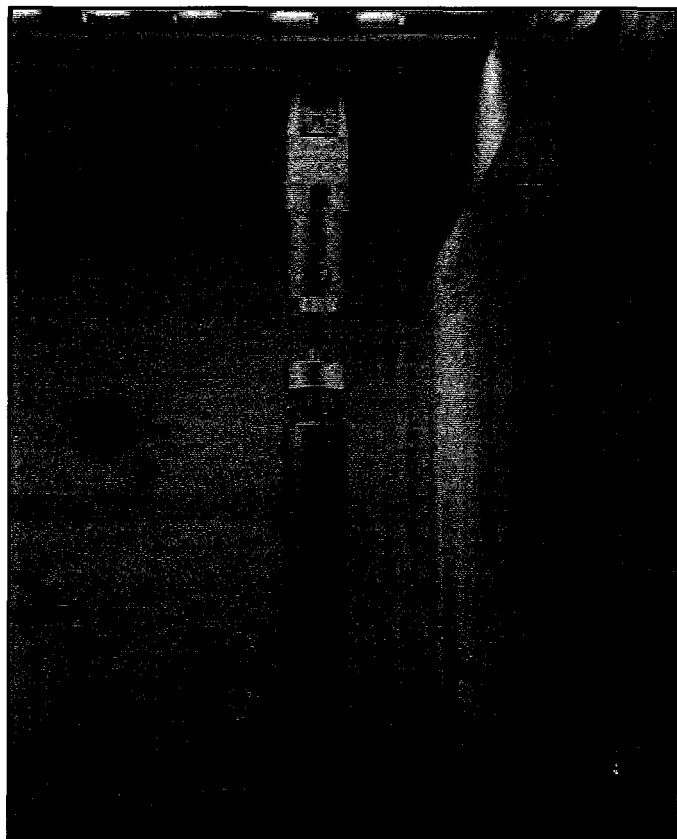


Figure 3-23. Chemical Process Cell/High-level Waste Interim Storage



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Figure 3-24. Chemical Process Cell (HLWIS) with Canister

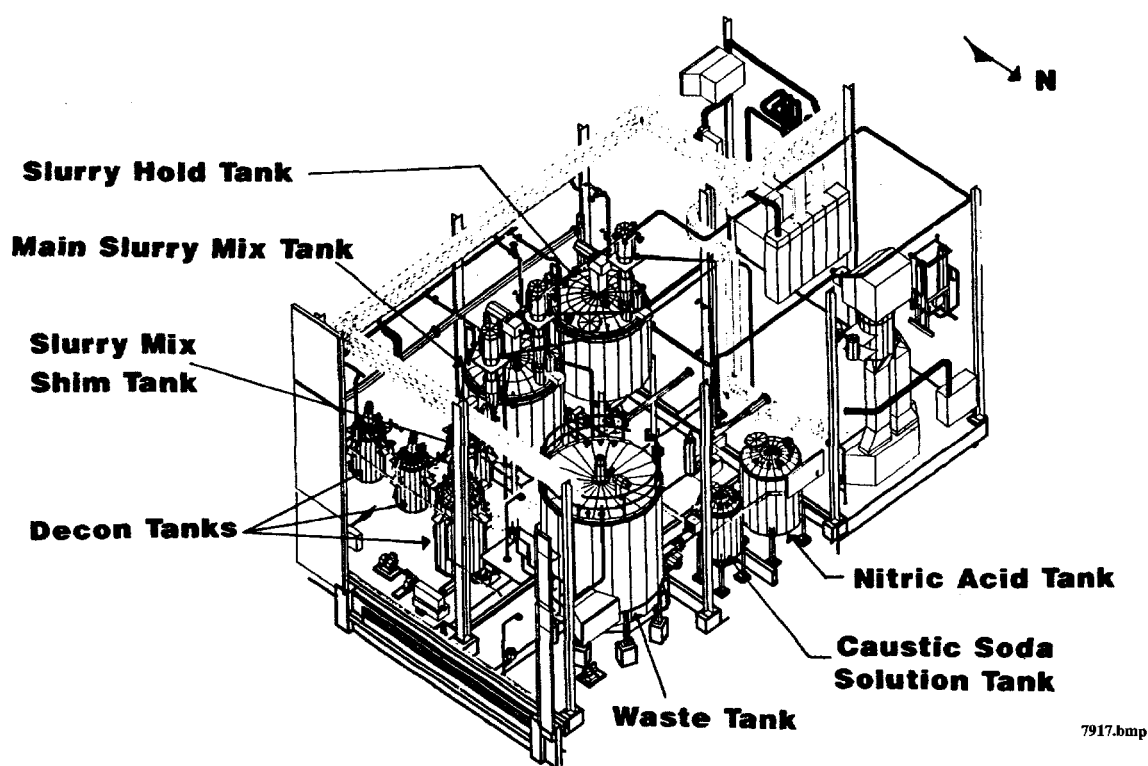
cooling units. Cranes requiring maintenance can be brought into the Chemical Crane Room (CCR) located above the EDR. The cell has two CCTV cameras for viewing unloading operations.

3.8 Auxiliary Facilities

Auxiliary facilities are stand-alone buildings or facilities that provide specific support functions and house large support systems. These are described below:

3.8.1 Cold Chemical Facility

The Cold Chemical Facility, in which batch chemicals are prepared for addition to the process, is housed in a separate independent facility attached to the west side of the VF. The building is comprised of metal siding over structural steel. Its approximate dimensions are 17.07 m (56 ft) by 10.36 m (34 ft) and the roof elevation is at 136' (see figures 3-25 and 3-26).



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Figure 3-25. Cold Chemical Facility Equipment Arrangement

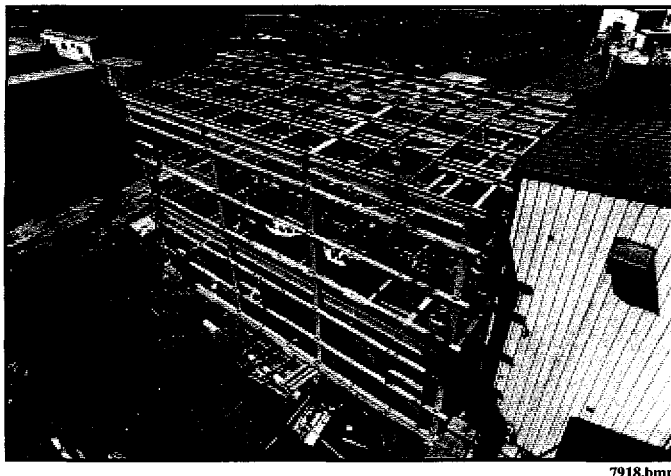


Figure 3-26. Cold Chemical Facility During Construction

13.6 Mg (15 ton) crane provides canister and equipment transfer capabilities. The building will also accommodate future load-out of the filled canisters into transportation casks.

The facility contains truck receiving and unloading capabilities, overhead crane coverage, empty canister handling provisions, a shielded canister port into the EDR for inserting canisters, heating and ventilation for comfort, and air flow control between the new building and the EDR for contamination control.

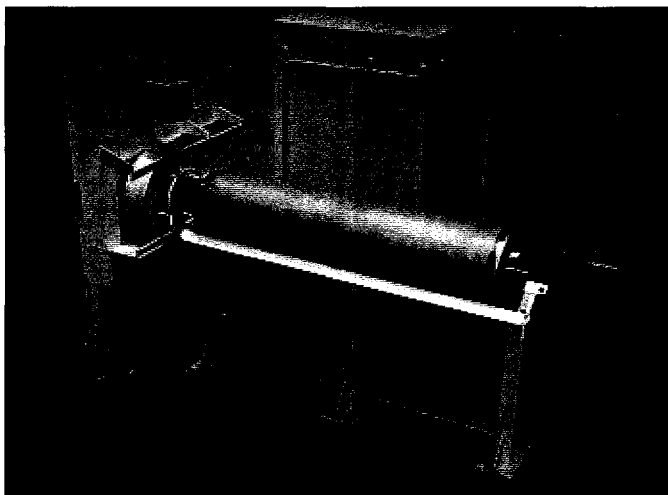


Figure 3-27. Canister Entry Port in Load-in Facility

(see figure 3-29). The EDR's concrete interior is epoxy-coated and has dimensions of approximately 8.75 m (29 ft) wide by 13.33 m (43.7 ft) long by 7.62 m (25 ft) high. The walls are 0.91 m (3 ft) thick reinforced concrete and the floor is 0.36 m (14 in.) thick concrete. The concrete roof is 610 mm (2 ft) thick. A ceiling hatch opens to the CCR located above for additional crane maintenance.

A shield door on the west side of the room is the prime equipment entrance and exit. On the south end a 1.22 m (4 ft) thick concrete and steel sliding shield door allows the transfer cart to pass into the former CPC.

This facility provides for the receipt, staging, and storage of nonradioactive process chemicals. The primary use of this facility is for the preparation and delivery of cold chemicals and shim mixtures to the primary process system. Housed in this building are hold tanks and tanks for mixing, shimming, caustic storage, and nitric acid temporary storage.¹⁰

3.8.2 Load-in Facility

The Load-in Facility is adjacent to the west wall of the EDR. It will be used as the primary access for moving empty canisters into the Vitrification Cell.¹¹ It is also an entry point for moving large components into or out of the hot cells. The floor is at grade elev. 100', and the roof rises to elev. 153'. A

Canisters are loaded from the Load-in Building to the EDR horizontally by conveyor. A removable shield plug blocks the entry port into the EDR. Canisters can enter the EDR when the shield plug is removed (see figures 3-27 and 3-28). A tipping fixture uprights the canisters for placement onto a transfer cart. An area of the Load-in Building is also used as a chemical staging area for nonradioactive chemicals used in melter feed preparation.

3.8.3 Equipment Decontamination Room (EDR)

The EDR is the entry port from the Load-in Building for empty canisters, large equipment placement (replacement), transfer cart maintenance, and for recharging the cart's battery pack

LOAD-IN FACILITY GENERAL ARRANGEMENT

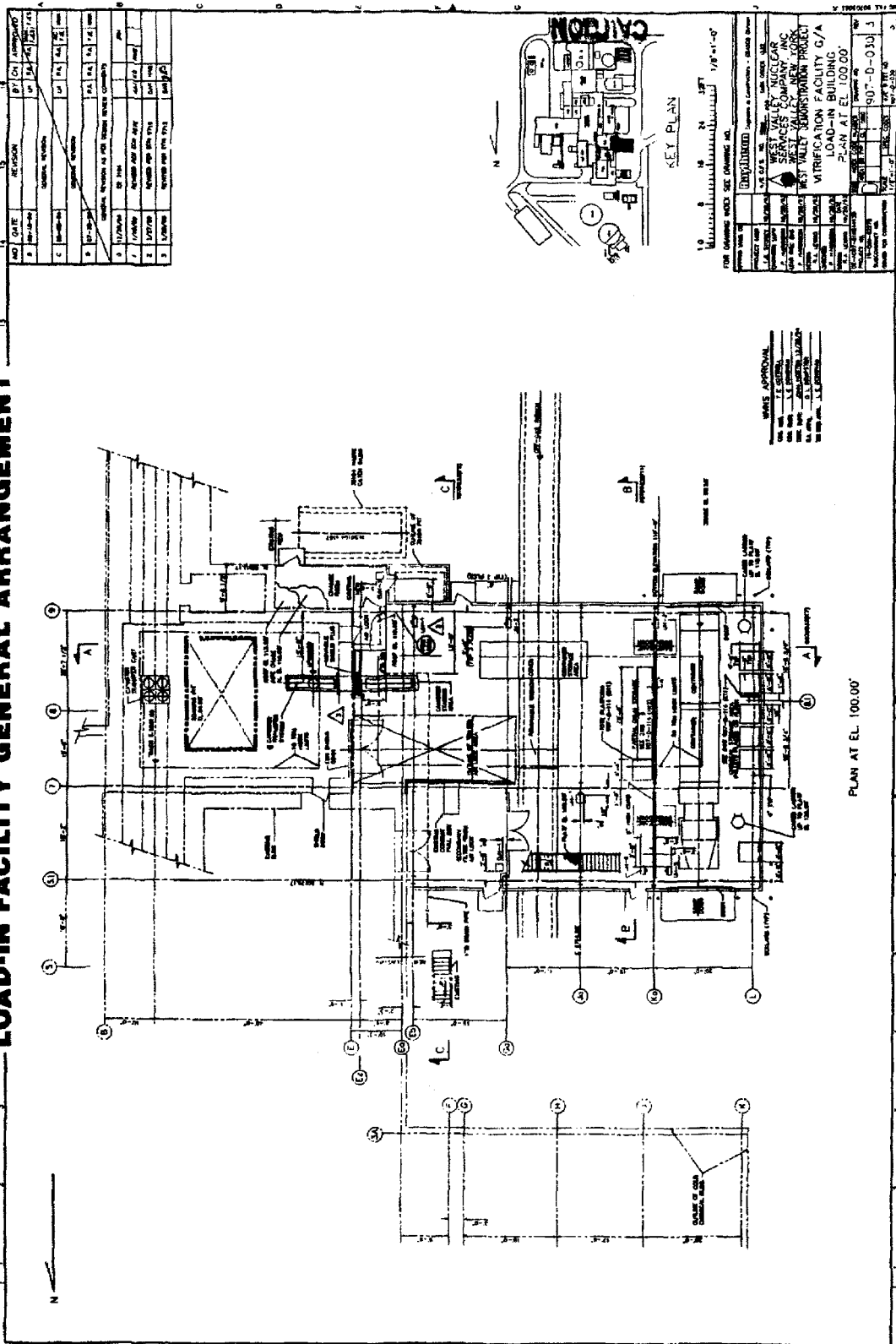


Figure 3-28. Load-in Facility General Arrangement

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The EDR is isolated from the adjacent VF structure by a minimum distance of 76 mm (3 in.) to prevent the impact of structures during a design basis earthquake. This separation joint is filled with Rodofoam™ construction filler material and is sealed at the roof level with flashing and a continuous 229 mm (9 in.) water-stop. Embedded steel shield plates are installed on the east and west sides of the separation joint for shielding.

3.8.4 Waste Tank Farm (WTF)

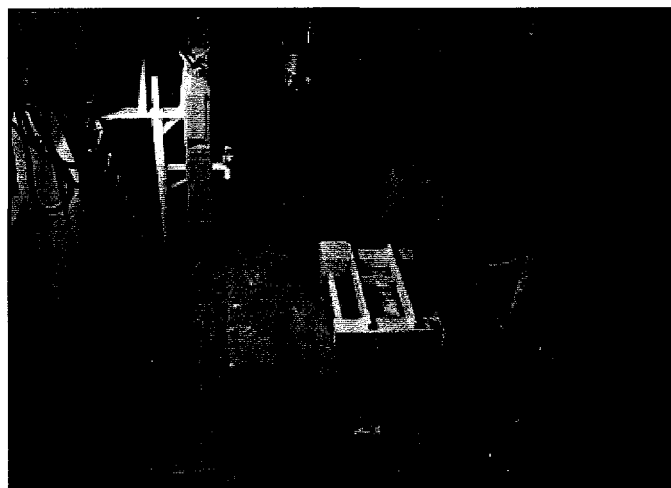
The WTF is located north of and adjacent to the VF. The WTF includes the sludge mobilization system (SMS) process equipment; the utility systems and buildings; and vaults, pits, and trenches in which the equipment is housed, shielded, and supported (see figure 3-30).¹² The SMS is used to transfer high-level waste from the WTF to the VF. The SMS embodies four pump pits: one each for Tank 8D-4, Tank 8D-1, Tank 8D-2, and Diversion Pit 8Q-5. Each of the pits and trenches are sized to accommodate the required process equipment and piping. Access to the process equipment in the pits or to the piping in the trenches is through the pit and trench removable covers. Contamination control is maintained by negative atmospheric pressure in the high-level waste tanks, the tank vaults, and the pump pits. The existing Waste Tank Farm Ventilation System (WTFVS) is used to maintain the confinement in the pits, vaults, and tanks. Figure 3-31 is an aerial photo of the WTF.

Equipment located in the concrete pump pits is designed for remote replacement. Contamination control in the pits is achieved by maintaining an inward air velocity across any pit access opening required for individual equipment manipulations.

Tank descriptions are as follows:

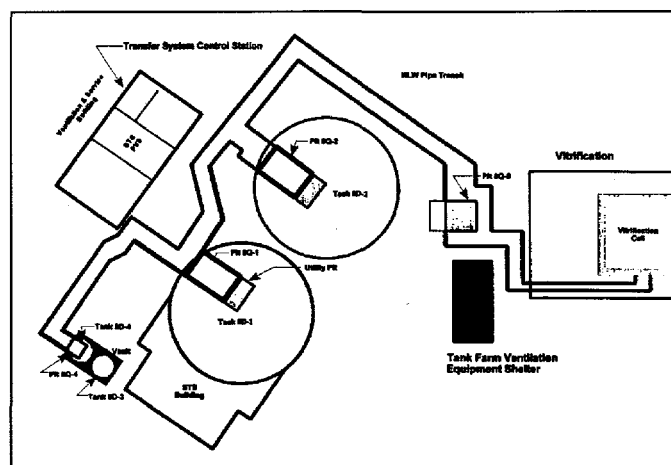
HLW Tank 8D-1 HLW Tank 8D-1 is an existing underground carbon steel tank with a diameter of 21.3 m (69.92 ft) and a height of 8.23 m (27.01 ft) located in a reinforced concrete vault.

HLW Tank 8D-2 HLW Tank 8D-2 is an existing underground carbon steel tank with a diameter of 21.3 m (69.92 ft) and a height of 8.23 m (27.81 ft) located in a reinforced concrete vault. This tank contains the combined high-level waste.



5438.pcx

Figure 3-29. Equipment Decontamination Room



7819.bmp

Figure 3-30. Waste Tank Farm Layout



7521.bmp

Figure 3-31. Waste Tank Farm Aerial

HLW Tank 8D-3 HLW Tank 8D-3 is an existing underground stainless steel tank with a diameter of 3.7 m (12.15 ft) and a height of 4.8 m (15.76 ft) located in a reinforced concrete vault with Tank 8D-4 at the north end of the HLW Tank Farm. This tank will be used for condensate returns from the Vitrification Cell.

HLW Tank 8D-4 HLW Tank 8D-4 is an existing underground tank. It is located at the north end of the WTF in a concrete reinforced vault that houses both the 8D-4 and the 8D-3 HLW Tanks. The 8D-4 HLW Tank is stainless steel and is 3.7 m (12.15 ft) in diameter and 4.8 m (15.76) high. This tank will be used for the return of waste from the Vitrification Cell.

3.8.4.1 High-level Waste Trench

Leading from the WTF to the VF is the concrete, high-level waste transfer trench that is used to transfer waste to the Vitrification Cell and condensate/waste back to the WTF (see figure 3-32). There are six pipes in the trench, two of which are spares. The primary pipes are 76 mm (3 in.) stainless steel with a 152 mm (6 in.) stainless steel guard pipe that envelope the primary pipe. There is leak detection between the two pipes. The trench runs between the WTF, north of the VF, and enters the facility at grade level on the north-west corner. Shielding from the high-level waste is provided at this corner of the facility by a 305 mm (12 in.) stair-stepped steel plate. Removable concrete covers have been fitted to the trench. The trench is approximately 137.2 m (450 ft) long, 914 mm (3 ft) deep, and 1.83 m (6 ft) to 762 mm (2-1/2 ft) wide. Concrete thicknesses in the trench walls range from 279 mm (11 in.) to 610 mm (24 in.). The trench covers are 610 mm (24 in.) thick.

3.8.5 NO_x Abatement Facility/01-14 Building

The four-story 01-14 Building was part of the original plant and reused as part of the vitrification facilities in keeping with the WVDP objective to reuse existing buildings as much as practical (see figures 3-33 and 3-34). Off-gases produced from operation of the melter contain radioactive and nonradioactive components. In this building, the melter off-gas is treated to remove oxides of

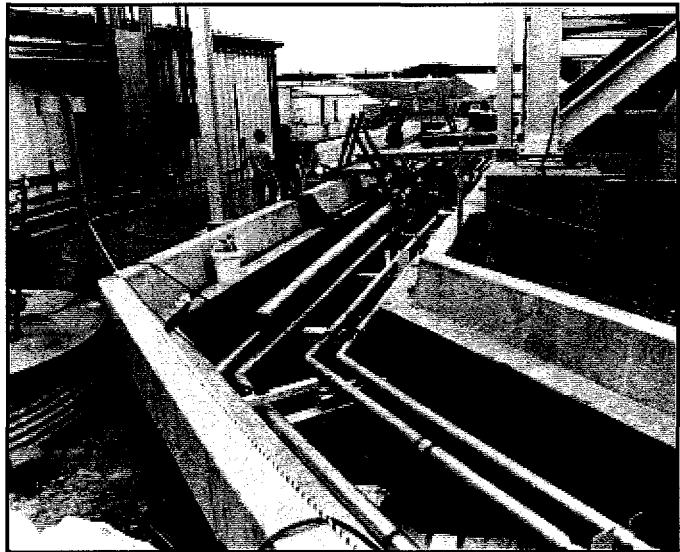


Figure 3-32. High-level Waste Trench

trench.bmp

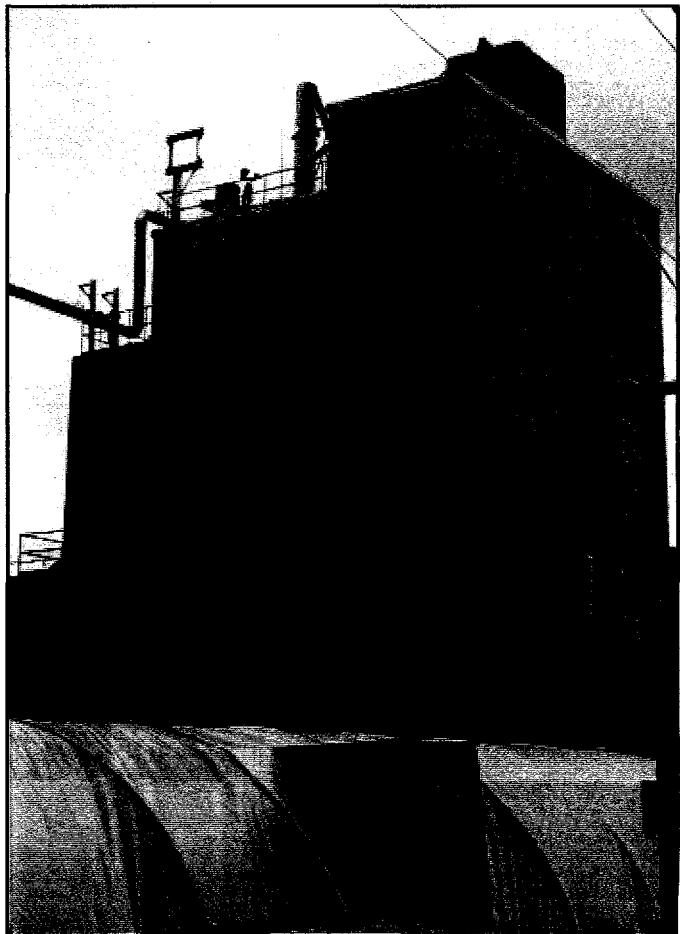


Figure 3-33. 01-14 Building Exterior

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nitrogen and any remaining radioactive particulate. The area used for vitrification-related off-gas components is 21.34 m (70 ft) by 9.15 m (30 ft) by 18.29 m (60 ft) high.

3.8 5.1 Off-gas Trench

The off-gas trench is a 305 mm (1 ft) thick concrete trench running from the VF to the 01-14 Building. The trench exits the Vitrification Facility at elev. 95.25' between column lines 4 and 5 and travels approximately 88.39 m (290 ft) to the 01-14 Building. Portions of the trench are cast-in-place. The trench also has removable concrete covers. Trench piping carries off-gases primarily from the ceramic melter to the 01-14 Building for processing (see figure 3-35).

In addition to the off-gas line, the trench has piping used for the Supernatant Treatment System (STS), a liquid waste treatment system.

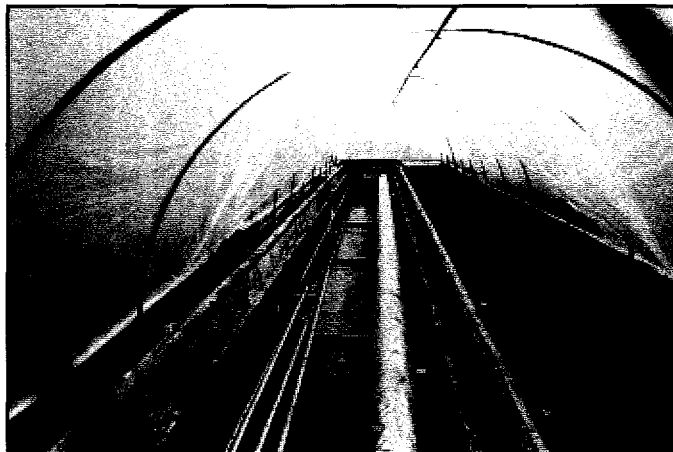


Figure 3-35. Off-gas Trench

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3.8.6 Main Plant Utilities

Utility services for water, air, and steam are delivered through piping headers that extend from the existing Main Plant to the VF. The headers enter the VF at the 115' elevation and have been extended around the perimeter at the 125' elevation.

HVAC for the EDR and CPC is provided by and located in the existing Main Plant and head end ventilation system. These HVAC systems maintain a negative pressure to minimize uncontrolled leakages.

Electrical connections for the VF are made at the northeast corner of the facility exterior at the main feed station. Emergency power is supplied from diesel generators located in the Permanent Ventilation System (PVS) Building, the Utility Room, and the new expanded Utility Room.

3.8.7 Diesel Generator Room (DGR)

The DGR, west and adjacent to the SFR, houses a 600 kW generator, switchgear, distribution cabling, and controls to provide backup power to selected loads in the event of a temporary or extended power outage (see figure 3-36). The DGR is designed to withstand the site's design basis tornado and design basis earthquake. Its dimensions are 5.79 m (19 ft) by 5.18 m (17 ft). Floor elevation is at grade level and the roof is at elev. 111.50'.

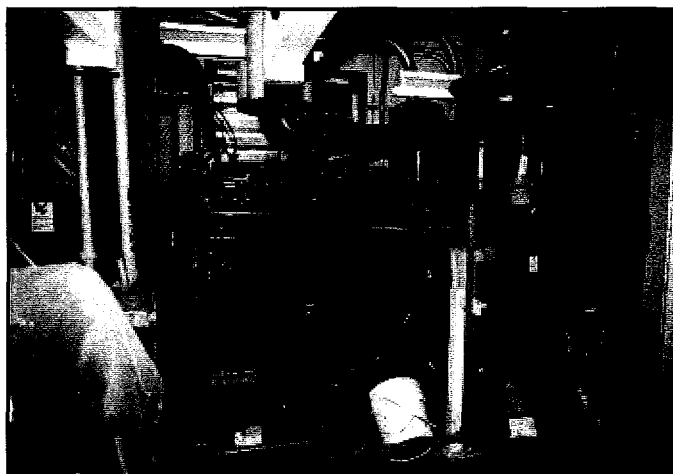


Figure 3-36. Diesel Generator

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4.0 VITRIFICATION PROCESS OVERVIEW

The actual process of vitrifying radioactive HLW into borosilicate glass involves numerous systems to mix, transfer, combine, heat, pour, sample, and store high-level radioactive waste. A general overview of the vitrification process is presented below with a separate section on the canister travel path added for clarity. Also described below are the two primary systems involved in controlling the by-products resulting from the vitrification process: the off-gas treatment and HVAC systems.

4.1 Glass Composition

The chemistry of the vitrification process is driven by the need for a glass that will hold the waste species and be processable as a feed material. The chemistry is also driven by DOE requirements, namely the Waste Acceptance Preliminary Specification (WAPS), the Waste Compliance Plan (WCP), and the Waste Qualification Report (WQR). These documents require that glass durability be measured via a Product Consistency Test (PCT).¹³ Not only must the glass composition hold the waste, it must do so in a stable way so as not to be subject to leaching. The above documents also require a radionuclide inventory of all material produced.

Process control requires the target composition provide acceptable viscosity for both the feed and the glass melt to ensure both mixing and pumping. There must also be accurate enough control to ensure that the actual composition produced is within the ranges specified for the target glass.¹⁴ The composition of all feed produced must be checked for acceptability of the resulting glass' predicted PCT. This is done so that there is assurance prior to melting that the glass will be acceptable.

4.2 Vitrification Process

The vitrification process, shown in figure 4-1, will convert stored radioactive wastes into glass for disposal. All of the waste has been pretreated and combined into one underground tank (see figure 4-2). Six mobilization pumps inserted into the high-level waste tank will be used to mix the waste into a homogenous mixture. The waste will be transferred into the CFMT in the VF in a batch process at a flow rate of 65 gpm.¹⁵

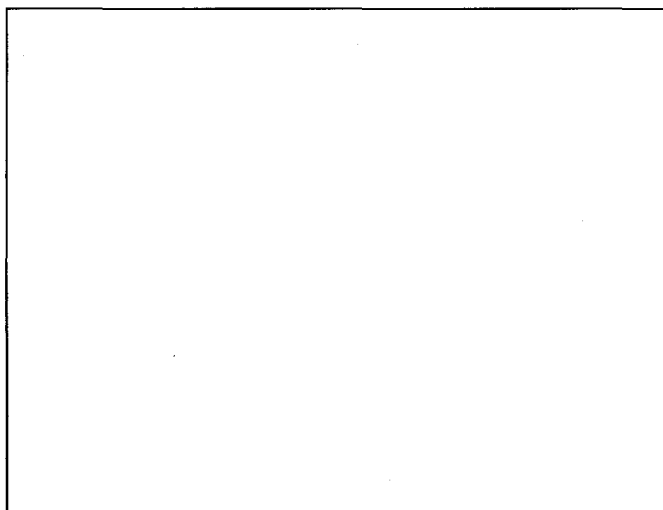


Figure 4-1. Vitrification Process

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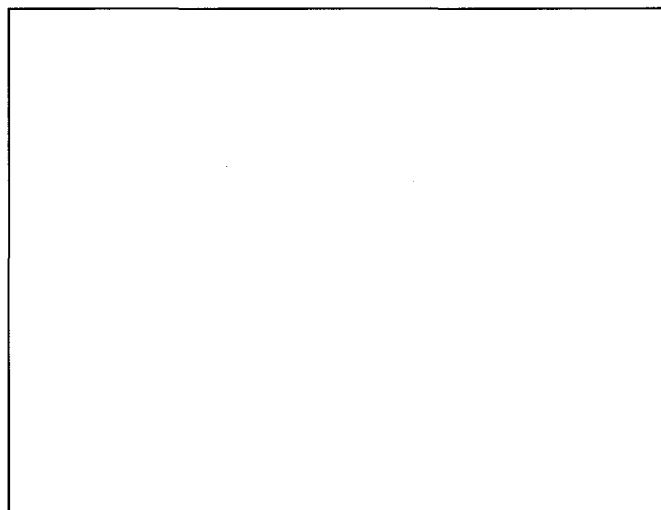


Figure 4-2. Combining Wastes

7926.bmp

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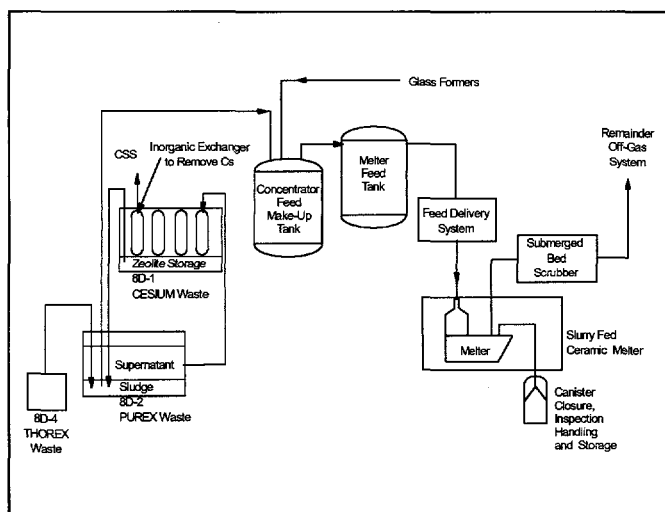


Figure 4-1. Vitrification Process

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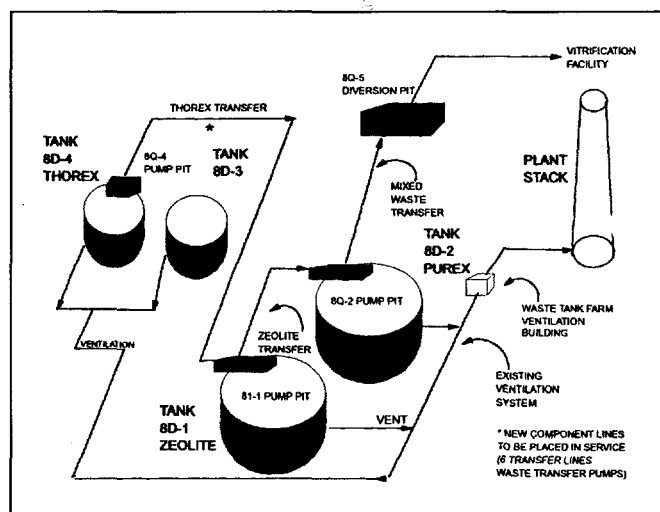


Figure 4-2. Combining Wastes

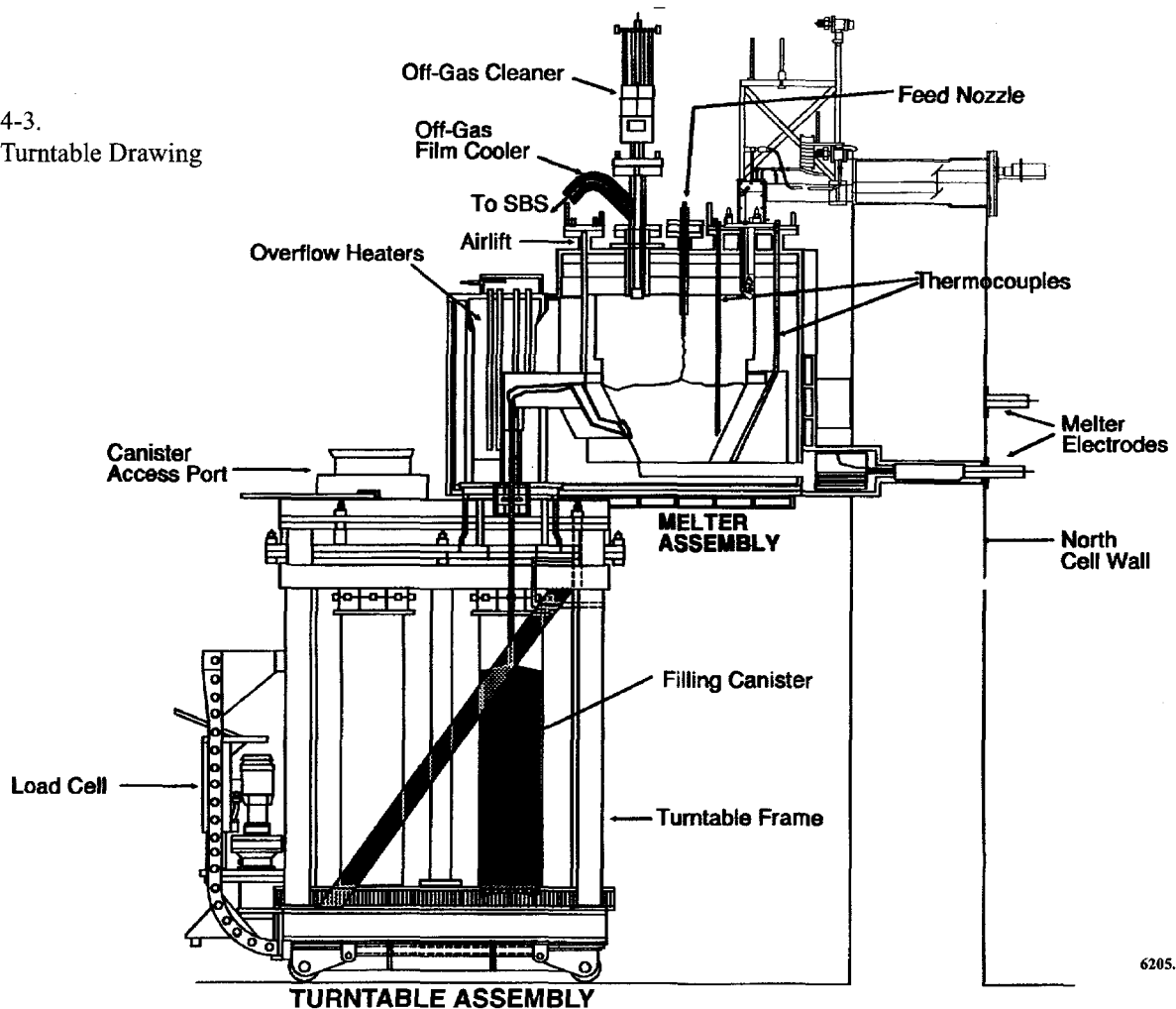
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The CFMT contents will be sampled by the sampling system and analyzed in the Analytical and Process Chemistry Laboratories.¹⁶ Chemicals from the cold chemical delivery system will be added to the CFMT waste mixture to form the correct composition that complies with waste form requirements. Excess water will be removed from the waste by evaporation while the waste sample is being analyzed and initial chemical additions are being prepared.

Following verification of the desired composition, the feed slurry batch will be transferred to the MFHT by a steam jet. The melter will be continuously fed from this tank by an air displacement slurry pump until the tank contents are reduced to the minimum acceptable level for adequate mixing at which point additional slurry will be transferred to the MFHT. The MFHT will be maintained in essentially continuous agitation during all processing operations. The slurry feed rate will vary depending upon the composition and concentration of the melter feed and the melter operating conditions.

In the melter, water will evaporate from the slurry and the remaining solids will calcify. Calcined wastes and glass formers will melt into the glass pool where they will mix by natural convection. Figure 4-3 is a drawing of the melter and turntable. The glass product will be in the melter for an average residence time of between 40 and 70 hours, depending on the slurry feed rate. Glass pour from the melter is initiated by an air-lift system that injects air into the riser section of the melter, reducing the density of the glass and initiating flow to the stainless steel canister. Approximately 10 to 15 air-lifts are required to fill a canister. The glass pour rate is about 30 kg/hr (66 lbs/hr), and the total time to fill each canister is about 63 hours. A total of 210 hours is required to process one batch of waste and chemicals.

Figure 4-3.
Melter/Turntable Drawing



6205.bmp

Canisters will be positioned under the melter pour spout by the turntable, a four-position, four-canister rotating stand. During normal operations, while one canister is being filled, two canisters are cooling, and the fourth position is accessible for canister removal and replacement.

Initial heat-up of the melt cavity is started by electric heaters above the glass pool. When the temperature of the glass reaches 800° C (1,472° F), the electrodes are energized to heat-up the glass to the operating temperature of 1,050° to 1,150° C (1,922 to 2,102° F). The nominal operating volume of the melter is 860 l (227 gal.). Feed is delivered to the melter by an air displacement slurry pump at a rate of 60 to 80 l (16 to 21 gal.) per/hr. Molten glass is air-lifted at an average rate of 30 kg (3 gal.) per/hr. Planned radioactive operation is expected to produce approximately 600,000 kg (1,320,000 lbs) of glass.

Canisters are placed into and removed from the turntable by a grapple attachment and crane. Viewing the canister fill level on the turntable is accomplished by an ILD system. This system is comprised of an infrared camera and live thermal video feed to a remote computer in the VF Control Room. It provides a quantitative indication of the glass level by recognizing the temperature gradient at the glass-air interface. The target fill level is 85 percent or about 2,000 kg (4,410 lbs) of radioactive glass per canister. The surface of the melter glass and the pour stream between the melter and the canister can be viewed by remote infrared cameras.

Lids are welded onto the canister flange by a remote weld head using an automatic pulsed-gas tungsten arc welding process. Tools are also available to weld a secondary lid, machine the weld area, and clean the flange.¹⁷

After lid welding, the canister is decontaminated using a bath of nitric acid and cerium (Ce) in oxidation state ⁺⁴ (Ce⁺⁴). Nitric acid and ceric nitrate solution are blended in-line in the ex-cell operating aisle and delivered to a decontamination tank. Decontamination is achieved by soaking a canister in this solution at 65° C (150° F) for six hours while agitating the solution using a gentle air sparge. The chemicals react to etch about 5 microns from the canister's surface. The amount of stainless steel removed from a canister is controlled by the temperature of the solution, residence time in the solution, and the concentration of ceric nitrate. After soaking in the bath, the canister is rinsed with a dilute nitric acid solution then with demineralized water. Neutralization of the decontamination solution is accomplished by the addition of hydrogen peroxide that reduces the Ce⁺⁴ to Ce⁺³. The decontamination solution is then transferred to the CFMT and recycled into the process.¹⁸

4.2.1 Sampling

Samples from the CFMT, MFHT, SBS, decontamination station, and glass shards taken at various stages of the vitrification process are used to assure that process control is maintained, a quality product is produced, and the required information is obtained for archiving and waste acceptance. The control of glass quality requires that: the chemical species of the combined melter feed are within the ranges specified by the WQR; both the CFMT and MFHT agitators are operated continuously for at least one hour prior to the transfer of feed slurry to maintain homogeneity; and the melter is maintained between 1,100 and 1,200° C (2,012 and 2,192° F) to control the glass-forming rate and the viscosity to assure the mixing and pouring of the glass. The processability of the slurry feed and glass requires that: the pH and percent weight of total solids of the feed slurry and the redox state of the glass be controlled to assure mixing and pumping ability to control behavior of the glass in the melter. The corrosiveness of the slurry feed requires that both the pH and minor species in the feed slurry be controlled so as not to be corrosive to the process equipment.

4.3 Canister Travel Path

Empty canisters are brought into the Load-In Facility by truck, off-loaded, and inspected. An overhead crane in the facility picks up a canister after it has been rigged with slings and then places it on a conveyor.

The canister is then manually pushed on a conveyor through the load-in port. A shielded plug rotates to expose the port opening between the Load-in Facility and the EDR. The canister is received by a tip-up fixture in the EDR that uses gravity to upright the canister as it progresses from the Load-in Facility to the EDR.

Once the canister is upright in the EDR, a crane lifts and places the canister onto the transfer cart that holds up to four canisters. The cart is remotely controlled and battery-powered with four independent drive trains, any one of which can drive the cart in either forward or reverse direction carrying a 9.1 Mg (10 ton) load. Under operator control, the cart travels on rails through the EDR to the transfer tunnel and into the Vitrification Cell (see figure 4-4). The shield doors transited en route are interlocked to ensure the proper sequence of opening and closing as the cart passes.

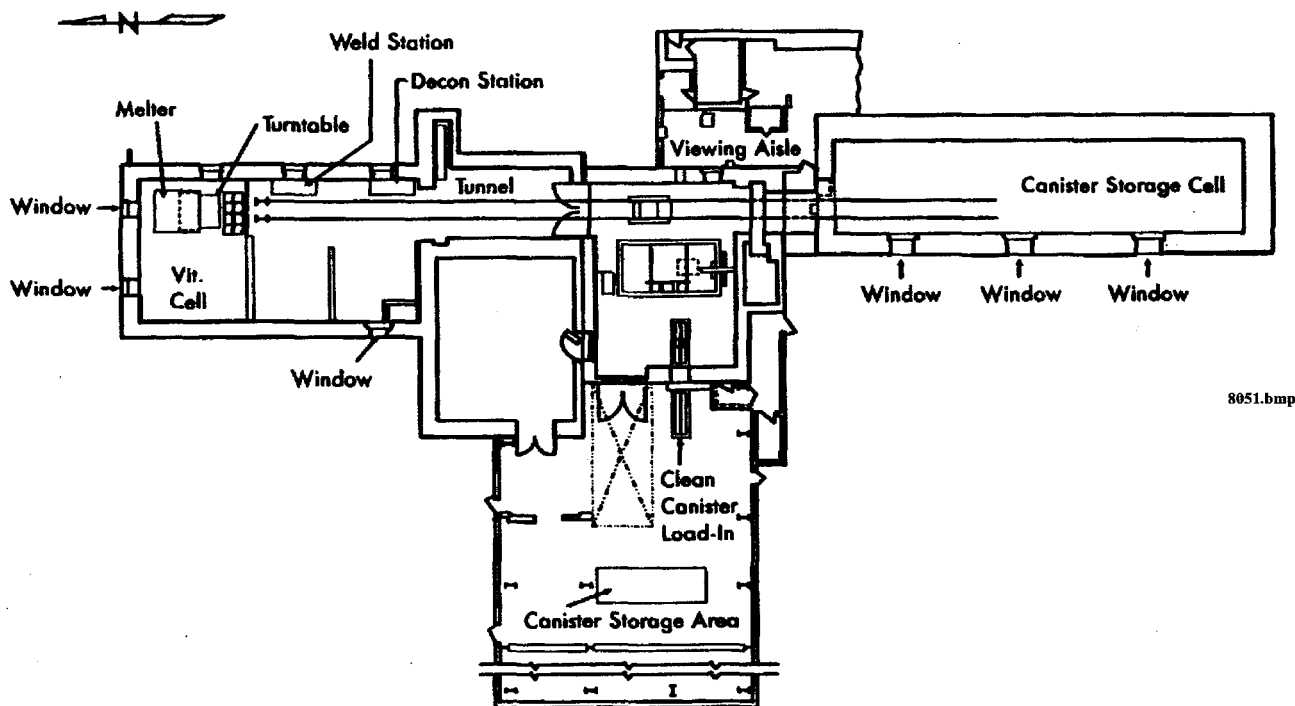


Figure 4-4. Canister Travel Path

Once the cart is in the Vitrification Cell, the canisters are unloaded from the cart by crane and grapple attachment and placed into the canister turntable or a storage rack. The turntable has four positions for holding canisters: one position for filling, and three positions for cooling. Empty canisters must be rotated into position for filling and then rotated from underneath the pour spout for cooling and removal.

Canisters can be transferred after filling into either of two positions: the canister weld station or the canister storage rack for staging if there is a canister already in the weld station. Once in the weld station, a permanent lid is welded onto the canister.

After lid welding, the canister is transferred by crane from the weld station to the decontamination station where the canister is decontaminated and then transferred by crane back into the storage rack or onto the transfer cart for removal from the Cell.

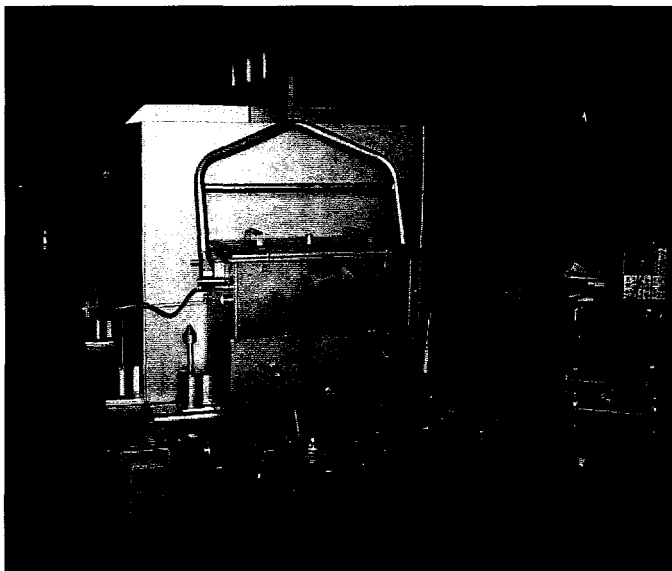
Upon leaving the Vitrification Cell, the cart moves through the transfer tunnel, back into the EDR, and into the CPC (see figure 4-5). Shield doors open to allow the cart to travel from the EDR into the CPC (or HLWIS) area.

Finally, the canister is picked off the cart by crane and placed into the two-tiered storage rack system capable of holding a maximum of 396 filled canisters.

4.4 Off-gas Treatment

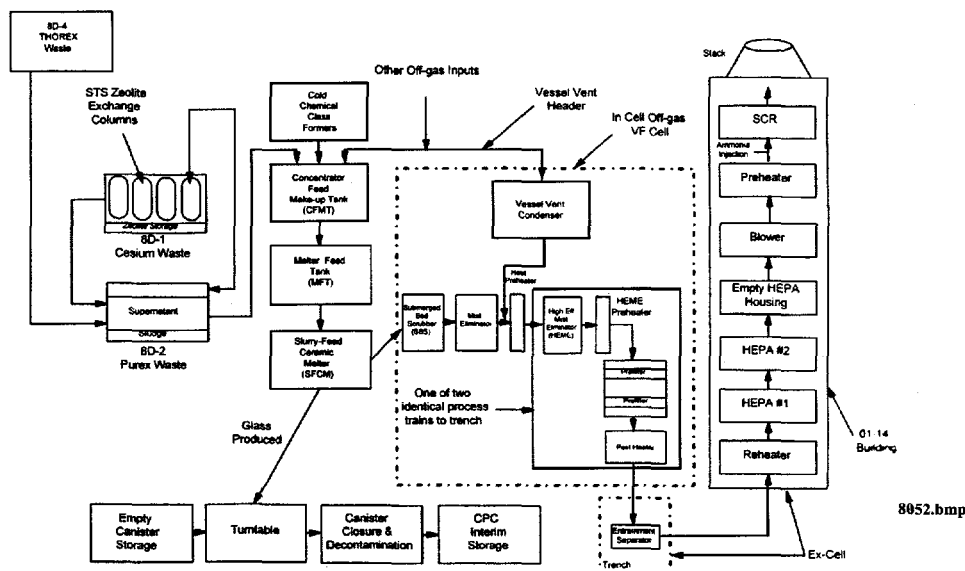
A product of waste/glass heating is melter off-gas, a gaseous effluent consisting primarily of water vapor and oxides of nitrogen plus particulate.

The melter off-gas system (depicted in figure 4-6) and its associated vessel ventilation system, provides for the safe removal of process gases from the melter while maintaining the melter and its related vessels and ducting at a slight vacuum (5 in. water) for contamination control. The off-gas system is also designed to remove radioactive particulates and oxides of nitrogen from the flow stream. The off-gas system has two sections: one located in the Vitrification Cell that removes particulate, and another located outside the Cell that removes additional particulate and the oxides of nitrogen. The off-gas system located inside the concrete Vitrification Cell accomplishes the goal of keeping radiation exposure to workers as low as reasonably achievable (ALARA) by removing the majority of the radioactive materials in the gaseous melter effluent. The off-gas system is designed for remote operation and maintenance by canyon remote techniques.



7279.bmp

Figure 4-5. Remote Transfer Cart



8052.bmp

Figure 4-6. Off-gas System

Off-gases are scrubbed in a SBS, processed through a high-efficiency mist eliminator (HEME), and are filtered through two HEPA filters in series. The off-gas system located outside the concrete Vittrification Cell provides environmental protection and is designed for remote operation and contact maintenance. In this section the off-gases are filtered through HEPA filters and approximately 90 percent of the oxides of nitrogen (NO_x) are eliminated by selective catalytic destruction before release.

4.4.1 Submerged Bed Scrubber (SBS)

The melter off-gases are delivered to the SBS at about 15 m/s (50 ft/sec.) in a 150 mm (6 in.) diameter jumper. Air is injected into the jumper to cool the melter exhaust and to provide vacuum control inside the melter due to the elevated temperatures at the jumper entrance.

The SBS is a passive device designed for aqueous scrubbing of entrained radioactive particulate from melter off-gases, cooling and condensation of melter vapor emissions, and interim storage of condensed fluids. Off-gases at the entrance of the SBS are quenched from about 120° C (250° F) to about 45° C (110° F). The SBS will provide a Decontamination Factor (DF) of about 120 for cesium-137, the radioisotope of primary concern.

The scrubber section consists of two concentric right cylindrical vessels. The inner vessel contains an 0.5 m³ (18 ft, 3 in.) packed bed of 10 mm (3/8 in.) ceramic spheres supported on an Inconel 690 support/gas distributor plate. The off-gases are introduced below the support plate through an Inconel 690 downcomer. The outer vessel has a solid bottom, is open at the top, and is kept filled with water.

The SBS functions by bubbling the melter off-gases through water in a packed bed. The rising bubbles cause the liquid to circulate up through the packing and hence downward in the annular space outside the packed bed where heat transfer equipment for cooling is located. The packing breaks larger bubbles into smaller ones to increase the gas-to-water contacting surface, thereby increasing the particulate removal and heat transfer efficiencies. The liquid circulation helps to prevent a buildup of captured material in the bed by constantly washing the material away. Heat absorbed by the water from the off-gases is removed by the heat transfer equipment. As the off-gases cool, water vapor condenses and increases the liquid water inventory. The excess water spills into the receiver, which completely envelopes the scrubber section, thereby maintaining a constant liquid depth in the scrubber section.

The SBS receiver vessel, a 3.4 m (11 ft) tall and 2.4 m (8 ft) diameter right cylinder, completely contains the SBS scrubber vessel and provides interim storage for up to 20.8 m³ (1,450 gal.) of accumulated condensate.

Leaving the SBS, the off-gases pass through a 150 mm (6 in.) thick knitted mesh mist eliminator pad to remove entrained liquid droplets thereby reducing the liquid burden at the HEME downstream. The pad is designed to collect droplets by impaction at 2.4 m/s (8 ft/sec.) while processing off-gas at 13.2 m³/min. (466 cfm). Coalesced liquid is drawn by gravity back to the SBS.

4.4.2 High-efficiency Mist Eliminators (HEMEs)

Before the melter off-gases are treated by high-efficiency mist elimination, vessel ventilation gases are blended into the melter off-gases, eliminating the need for a separate effluent treatment system. An electric heater is installed, should Operations personnel choose to employ the HEME as a dry filter. (The 50 kW electric heater is not expected to be routinely used.)

The HEME receives off-gases from the SBS, collects and coalesces any entrained liquid droplets, and drains the coalesced liquid back to the SBS. The HEME is 99.8 wt% efficient for droplets 3 microns in diameter and larger. The DF for cesium-137 at the HEME will be about 14. Submicron particulate are also collected from the gases.

The cylindrical HEME vessel is 1.1 m (3.5 ft) in diameter and 4.1 m (13.3 ft) tall, with a base skirt 600 mm (2 ft) high. The HEME pad consists of a cylindrical, wound glass fiber element 7.6 m (2.5 ft) in diameter and 3.0 m (10 ft) tall. The pad collects droplets and particles by Brownian motion and thus requires a low face velocity, between 2 and 12 m/min. (5 to 40 ft/min.). The HEMEs are designed so that the pads can be removed and replaced using an overhead bridge crane and a crane-suspended impact wrench.

4.4.3 Prefilters

The off-gases from the HEME pass through an electric heater before entering a prefilter housing. The 50 kW electric preheater is used to raise the off-gas temperature to about 85° C (185° F), well above the off-gas dew point of about 45° C, to assure that the prefilter elements do not become wet from entrained water droplets.

The preheaters are designed so that the heating elements can be removed and replaced using an overhead bridge crane and a crane-suspended impact wrench.

Consistent with the goal of minimizing radiation exposures to operators, the prefilter elements selected were those that would retain as much radioactive particulate in the Vitrification Cell as possible. HEPA filters were used since they are the most efficient systems commercially available. They are designed to remove 99.97 percent of particles larger than 0.3 microns. The elements are changed remotely by removing and replacing the entire prefilter housing assembly using an overhead bridge crane and a crane-suspended impact wrench. The replacement filter assemblies are dioctyl phthalate (DOP) tested after assembly, prior to being introduced into the Vitrification Cell.

4.4.4 HEPA Filters

The off-gases from the Vitrification Cell are directed through an insulated 250 mm (10 in.) diameter pipe to the out-of-cell, off-gas treatment equipment. The insulation and heaters preclude condensate formation between the Vitrification Cell and the final HEPA filters. Immediately upstream from the HEPA filters, the off-gases are processed through one of two redundant 60 kW electric reheaters connected in parallel, which restore the off-gases to about 85° C (185° F).

The off-gases then pass through HEPA filters. In each of two parallel filter trains are two HEPA filter elements connected in series. The gases pass through one filter train while the other remains available as an installed back-up. The purpose of the HEPA filters is to provide final environmental protection against dispersion of radioactive particulate. The integrity of the filter elements and the seals between the elements and the housing are verified by in-place DOP testing.

4.4.5 Blowers

Following filtration, the off-gases pass through one of three redundant, positive displacement, 37 m³/min. (1,300 cfm) off-gas blowers installed in parallel. One blower provides continuous service while the others provide reliable, full capacity, backup service. The blower provides the motive force to maintain all of the vitrification equipment upstream under a slight vacuum for contamination control. It also provides the motive force to discharge the treated off-gas to the atmosphere.

4.4.6 NO_x Destruction Equipment

From the blower, the off-gases pass through the NO_x abatement equipment. The purpose of this equipment is to destroy the oxides of nitrogen in order to meet the applicable NY State environmental regulations. The system removes approximately 90 percent of the NO_x. This is accomplished by selective catalytic reduction of the NO_x gases with ammonia to produce harmless water vapor, nitrogen, and oxygen.

The equipment includes redundant off-gas preheaters, an ammonia supply system, and redundant catalytic reactors (see figure 4-7).

The preheaters increase the off-gas temperature to promote the desired reaction, the ammonia supply provides the necessary reactant, and the catalytic reactor accelerates the desired reaction. Each preheater consists of two 100 kW elements in separate housings connected in series. They are used to increase the off-gas temperature to about 320° C (610° F).

The ammonia supply tank is designed to hold an 18-day supply of anhydrous ammonia and is equipped with two, redundant, 18 kW electric immersion vaporizers. The ammonia is supplied to the off-gas immediately upstream from the reactors and is controlled by one of two redundant mass flow controllers. The controllers modulate the ammonia flow based upon continuous NO_x analyses in the off-gases upstream from the reactors to assure an appropriate molar ratio of the reactants.

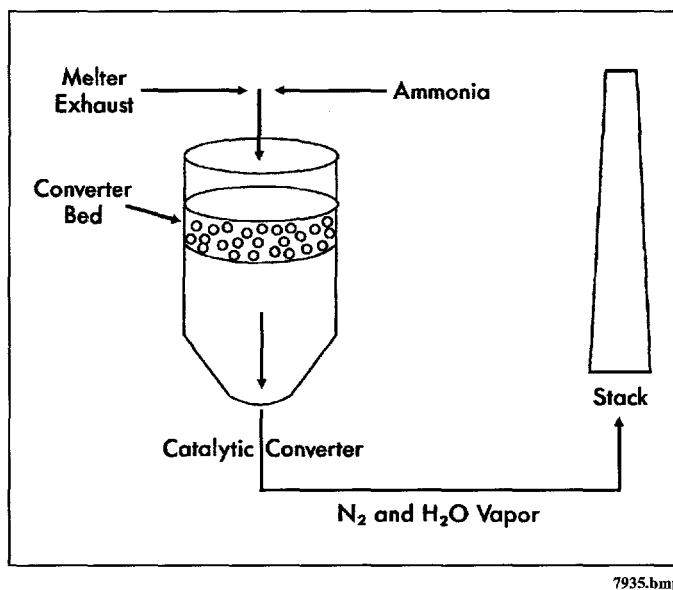
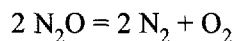
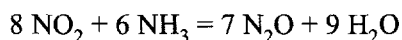
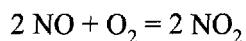


Figure 4-7. NO_x Abatement Catalytic Converter

The selective catalytic reactor vessels are right cylinders with conical ends, made from Type 321 stainless steel and designed for downflow. The overall height of each vessel is 3.4 m (11 ft) and the diameter of the cylindrical sections is 1.0 m (39.5 in.). The reactors are packed with catalyst on 890 mm (35 in.) of 6 mm (1/4 in.) Raschig rings; 230 mm (9 in.) of 1.6 mm (1/16 in.) extrudate in the polishing section.

The NO_x gases are destroyed by several competing chemical reactions involving NO₂, NO, N₂O, NH₃, and O₂. Test results indicate that, at the WVDP operating conditions, the following reactions dominate:



These reactions are all exothermic, so the off-gases become hotter as they pass through the NO_x reactor. From the reactors, the off-gases are directed to the existing process plant stack where they will be blended with existing plant ventilation air and sampled immediately prior to discharge to the atmosphere to assure compliance with the NY State operating permit and the Environmental Protection Agency (EPA) requirements.

4.4.7 Process Control

The temperature in the SBS is controlled to determine the amount of water that is discharged from the system in the form of water vapor directed to the stack. An increase in temperature at the SBS exit results in an increased water expulsion rate. The temperature must be kept low enough to prevent loss of scrub solution from the SBS and high enough to prevent excessive accumulation of liquid requiring subsequent processing. Temperature control is provided by modulation of the amount of cooling water sent to the heat transfer equipment in the SBS.

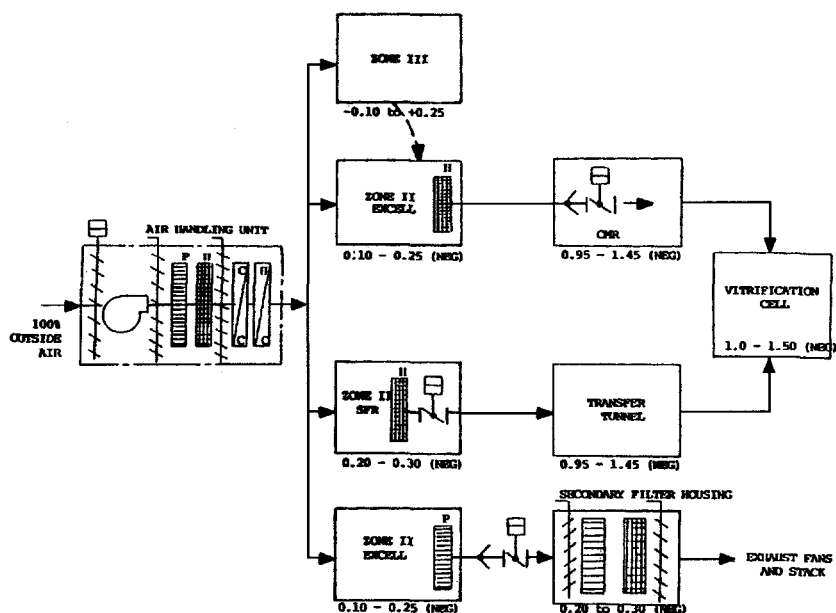
Vacuum control throughout the system is assured by maintaining a slight excess vacuum at the blower suction, which is accomplished by controlling the amount of ambient air bled into the system there. The in-bleed of additional air at the melter is then modulated to maintain the required vacuum.

4.5 Heating, Ventilation, and Air Conditioning (HVAC)

The Cell HVAC system is a critically important component of the VF. The HVAC system's primary function is to maintain a negative pressure on the vitrification in-cell area to prevent the escape of any radioactive contamination to the surrounding support areas or to the outdoors. The system's secondary function is to maintain the facility space temperatures at acceptable levels.

4.5.1 Confinement Zones

The VF HVAC system provides for confinement of airborne radioactivity by directing air flow from areas of low potential for contamination to areas of successively higher potential for contamination. This process is called "cascading." Three confinement zones are defined for cascading (see figure 4-8). Zone I consists of those areas that are expected to contain airborne activity during normal operations. This zone includes the VF in-cell area, transfer tunnel, and CMR. Zone II consists of the operating areas and other potentially contaminated areas surrounding Zone I. Zone III designates areas inside the Vitrification Building that are expected to be free of contamination (e.g., the VF Control Room, stair towers, and truck wells).



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Figure 4-8. HVAC Confinement Zones

The VF is operated in a constant purge mode, (there is no air recirculation). Conditioned outdoor air is delivered to the Zone II (ex-cell) areas by the main air supply unit. From there, approximately 2/3 of the air is exhausted immediately through the ex-cell branch of the exhaust system. The other 1/3 (approximately) is transferred into the Zone I/Vitrification Cell from where it is then exhausted through the in-cell branch of the exhaust system.

The in-cell/Zone I area is maintained at minus 1.25 in. water to the atmosphere, while the ex-cell/Zone II area is maintained at minus 0.10 in. water to minus .25 in. water. The Zone III areas are maintained at positive pressure.

The pressure relative to the atmosphere within the spaces/zones is caused by the differential between the quantity of air supplied and the quantity of air exhausted to/from that zone. The pressure differentials established between the zones and to the outdoors causes the contamination control/cascade air flow effect to occur.

Containment of radiological and hazardous materials located in Zone I both during and after the occurrence of the design basis accident is provided by the HVAC system.

4.5.2 HVAC Components/Locations

The principal components of the VF main HVAC system include: a main supply air handling unit, two main exhaust fans, four Zone II to Zone I transfer ducts, HEPA filter housings, three in-cell/primary filter units, one secondary filter unit with in-cell and ex-cell airstream sections, the VF Control Room HVAC system, four in-cell coolers, electrical controls, and operator interfaces for monitoring and controlling the HVAC system and subsystems.

The prefilters and initial HEPA filters that filter the exhaust from the Vitrification Cell are located in the Vitrification Cell. The filter elements are changed-out remotely when required. There is one redundant filter bank that will allow change-out without disturbing the Cell exhaust flow rates. The second set of HEPA filters are located outside the Vitrification Cell and those filters can be changed manually by a "bag-out/bag-in" process. Again, redundant filter banks are provided in order to perform maintenance and filter change-out. Two redundant, 100 percent, exhaust fans are installed that have diesel power backup in the event of main line loss of power to the fans. The exhaust flow out of the stack, 24,000 cfm, is monitored by three radiation monitors.

5.0 FACILITIES DESIGN

Vitrification facilities were designed according to federal and state criteria, as well as to accommodate general site characteristics and criteria established in the WVDP Act and NYSERDA/DOE agreement. These are described in detail below:

5.1 Philosophy of Design

Design of the vitrification facilities evolved from the criteria outlined in the WVDP Act, the selection of the method of waste solidification by vitrification, and the general practices followed in the nuclear industry.

Briefly, the DOE, NYSERDA, and WVNS adopted a management approach to reuse existing facilities to the maximum extent practical in order to reduce the cost of new construction and limit the amount of low-level waste generated at the site. The design philosophy was to use existing, tested, and proven technology and designs whenever possible.

The radioactive nature of the constituents to be vitrified dictated remote operations and the use of radiation shielding and contamination control for the protection of operating personnel, the general public, and the environment. Additionally, naturally occurring phenomenon at the WVDP site and surrounding areas influenced the structural design of the vitrification facilities with regard to specific atmospheric, environmental, and geological conditions, and the probabilities of natural phenomenon occurrence.

From these rather broad criteria, further design requirements evolved that influenced component and facility designs to control radiation and contamination confinement, operation, maintenance, remote handling, ventilation, fire protection, human factors engineering, and future decontamination.

The original design of the vitrification facilities followed the criteria outlined in DOE Order ID-12044.¹⁹ In 1984, WVNS agreed with the DOE to follow the basic design requirements in draft DOE Order 6430.1 as general guidelines.²⁰ A specific design criteria document for the high-level waste solidification facilities was written, approved, and first published in January 1986.²¹ In 1991, after a thorough design evaluation, WVNS and the DOE agreed that the design of the vitrification facilities conformed with DOE Order 6430.1A in the areas of health, safety, and environmental requirements.

As mentioned earlier, other significant design criteria documents were developed for the WTF Sludge Mobilization System (SMS), HLWIS, and the Load-in Facility. The Preliminary Safety Analysis Report (PSAR) for High-Level Waste Solidification Operations was issued and approved in 1991 and the Final Safety Analysis Report (FSAR) was issued June 1995.²²

This section includes a detailed description of WVDP safety classes and quality levels as they pertain to the VF and other information describing the design requirements imposed by the use of existing buildings, existing technologies, the vitrification process, natural phenomenon, remote handling, and new facility construction.

5.1.1 Rationale and Application of WVDP Safety Classes and Quality Levels

WVNS developed a safety classification system using a specifically designed technical and administrative approach²³ and DOE Orders for safety analysis and review²⁴ as the safety basis. This WVDP Safety Classification System was used to determine the importance of facility components, systems, and structures relative to ensuring the safety of workers and the general public during all phases of the Project.

Structures, components, and systems at the WVDP were classified by hazard class, safety class, and quality level. The hazard classification system conforms to DOE Order 5481.1B, DOE-ID Order 5481.1B (SD), DOE Order 5480.23²⁵, and is implemented by the WVNS Safety Review Program.²⁶ The purpose of the hazard classification system is to determine authorization level (i.e., level of safety analysis review and approval) for site facilities or activities.

The Safety and Hazard Classification Systems are complementary in that design of engineered safety systems can take place only after the level of hazard is known. In general, Safety Class A codes and standards are those used at nuclear power plants and other facilities (e.g., nuclear fuel reprocessing plants) that process radioactive materials with a potential for very large releases of radioactivity. Safety Class B codes and standards are those used in nuclear facilities that have the potential for moderate releases of radioactivity. Safety Class C codes and standards are similar to those for Safety Class B, but less restrictive. Safety Class N codes and standards are for commercial use and/or manufacturer standards.

5.1.1.1 Quality Level Classification

The Quality Level Classification System is used to implement the WVDP Quality Assurance (QA) Program.²⁷ Quality levels are based on the safety class and reliability/replacement considerations. The system consists of four quality level classes: A, B, C, and N as described below:

Quality Level A is assigned to structures, systems, or components where the consequence of failure could have major environmental, public health and safety, or programmatic impact. Quality Level A is generally used for facilities having nuclear reactors. Quality Level A is not used at the WVDP since there are no facilities here of this type.

Quality Level B is assigned to structures, systems, or components where the consequences of failure could have off-site environmental, health and safety, or programmatic impact.

Quality Level C is assigned to structures, systems, or components where the consequences of failure could have on-site environmental, health and safety, or programmatic impact, but do not require the quality assurance categorization as Quality Levels A or B.

Quality Level N is assigned to structures, systems, or components where the consequences of failure do not have significant impacts. Quality Level N is generally assigned to commercial systems or components.

To assure that each system is designed, procured, fabricated, and installed in accordance with the proper codes and standards, a quality level was developed and assigned for each safety class. At a minimum, the quality level must equal the safety classification for the system, structure, or component.

The quality level specifies the degree of review, application, and control of applicable criteria commensurate with their importance to safety and desired reliability. The quality level guides the graded approach to implementation of the WVDP Quality Assurance Program which is based on the eighteen criteria of the American Society of Mechanical Engineers (ASME), quality assurance program.²⁸ The application of quality programs is as identified below:

Quality Levels A and B: Quality Levels A or B require full implementation of the applicable procedures established for compliance with applicable quality assurance requirements. These include procedures for personnel qualification, process qualification, analytical work activities, design activities, procurement, operational activities, maintenance, inspection, testing, and independent verification.

Quality Level C: Quality Level C requires the application of the WVDP Quality Assurance Program; however, only those program elements determined essential by collaborative agreement of the cognizant performing organization(s) and Quality Assurance need be applied. This distinction is important, because intelligent judgement of essential controls will permit considerable cost and schedule savings.

Quality Level N: Quality Level N, the lowest quality category, does not require formal application of the WVDP QA Program; however, use of selected controls may be instituted.

5.1.2 Basis of Assignment for Vitrification Facility (VF) Safety and Quality Levels

Hazard classification and safety levels for the VF were assigned during the conceptual design phase of the Project.

5.1.2.1 Vitrification Facility (VF)/Design Basis Accident

A scoping analysis conducted during preparation of the PSAR²⁹ of potential accidents involving the Component Test Stand (CTS)/vitrification system and its enclosure indicated that the event leading to the most serious radiological consequences was a rupture of the melter off-gas line at the melter interface. Since this is a credible event that might be initiated by an earthquake or through human error in design, fabrication, installation, or operation, it was considered to be the Design Basis Accident (DBA) at that time.

Based on this analysis, the vitrification process was assigned a Moderate Hazard Classification as defined in WVNS Safety Review Program, and DOE ID Order 5481.1. The basis for this assignment was because the maximally exposed off-site individual for an accident involving the rupture of the melter off-gas line would exceed the 0.5 Rem annual limit given in DOE Order 5480.1A.

Although the Design Basis Accident definition changed during the FSAR³⁰, the result remained the same; confinement of the vitrification process was required. Additional assignments of safety classes were made at that time that have since proved to be conservative in that the design basis often exceeds the safety requirements.

Structures:

All vitrification structures that provide confinement for the radioactive vitrification process were assigned a Safety and Quality Classification of B. This includes the Vitrification Cell and all of its components, shield windows, large penetrations through the Cell, remote manipulators that penetrate the Cell boundary, Cell shield plugs, and components that are inserted in the Cell boundary utility sleeves.

In addition, all cells that adjoin the Vitrification Cell were considered an extension of the confinement boundary even though they are normally isolated by shield doors. This determination was made since the shield doors may be in the open position at the time of the DBA. The transfer tunnel connecting the Vitrification Cell and the EDR; CMR; and the Sample Cell (located on the 100 ft elevation) were considered as an extension of the confinement boundary and were assigned a Safety and Quality Classification of B. This included all large penetrations, shield windows, and components that became part of the wall by its inclusion in a manipulator or utility sleeve.

Any item that would cause an on-site dose of 3 Rem, if it failed to perform its intended design function, was assigned a Safety and Quality Classification of C. With the high radiation levels inherent in the process and in the glass canisters, any item whose failure to function as designed that could result in workers having to work in areas of elevated radiation were assigned a Safety Classification of C. This also included the shielding provided by the CPC, the CCR, and the EDR; and all radiation-shielding elements associated with these cells.

The building that houses the NO_x removal process (01-14 Building); the high-level tank concrete vault; and the high-level waste/off-gas trenches; were assigned a Quality Level C. The structure that protects the HVAC exhaust ventilation system was designed to a Quality Level B. This also included protection for the SFR, DGR, and HVOS.

All other structures were assigned a Safety and Quality Classification of N.

Ventilation Systems:

At the time of the conceptual design phase, the safety scoping analysis required that a negative pressure be maintained in the radioactive process cells to preclude a major potential off-site dose. The exhaust ventilation system; including all of its components, cell dampers, controls, and standby power sources; was assigned a Safety and Quality Classification of B.

The exhaust systems and its controls, components, and standby power for the CPC, EDR, and the NO_x removal facility were assigned a Safety Classification of C to preclude exposure to on-site personnel.

All other ventilation systems were assigned a Safety and Quality Classification of N.

Radiation Protection:

Tanks and waste transfer lines that would pose an on-site radiological safety hazard if they failed to function as the design was intended were assigned a Safety Classification of C. These included the HLW tanks, transfer lines, pumps, components, and sample transfer system.

In addition, radiation monitors were classified as Safety Class C since their failure could result in undetected exposure.

All other systems, structures, and components in the VF were assigned a Safety Classification of N.

5.1.2.2 Radiation

The principle of "As Low As Reasonably Achievable" (ALARA) has been applied to all aspects of radiation exposure. Under this principle, all facilities have been designed to permit the lowest radiation dose rates possible with due consideration to all operational requirements. On-site personnel exposure levels less than one-fifth of the DOE Order 5480.11³¹ dose equivalent limits have been used as a design objective.

Shielding thicknesses were based on the waste containing the greatest radionuclide inventory and emitting the highest energy radiation. Penetrations through shielding walls for windows, manipulators, instrumentation, piping, ventilation ducts, etc., were designed to provide shielding equivalent to the walls. Concrete shielding was designed in accordance with American National Standards Institute (ANSI) code³² to provide primary protection from radiation. Other appropriate materials were used as needed in specific locations.

During initial radioactive processing, the first canister will contain reduced levels of radionuclides. Radiation readings will be taken throughout the facility to confirm the shielding design and construction. Additional readings will be taken as the radionuclide inventory is increased in the Vitrification Cell.

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Shielding Analysis and Verification:

An extensive shielding analysis was performed during the design of the vitrification facilities and documented in WVNS-SR-012, "Vitrification Facility Shielding Verification Report." These analyses were conducted by WVNS, Westinghouse-Hanford Co., and Rathyeon (Ebasco Division). Refer to the above mentioned report for shielding calculations, drawing lists, shield window dose rates, wall penetration index, construction specifications, etc.

In general, the results of the analyses confirmed that adequate shielding has been designed and constructed to provide protection to personnel. The results also confirmed the previous calculations and the expected operating limitations and requirements. Access limitations were documented to ensure that personnel are properly protected.

Shielding analyses were conducted for the Vitrification Cell, its penetrations, the CMR, the transfer tunnel, the EDR, the CPC, and the WTF. These analyses concluded that the strongest influence on the shielding is when a radioactive canister is in near proximity to the cell wall. The radiation values for the aisles surrounding the Vitrification Cell and the CPC are very low. The VF Control Room can be occupied continuously. Certain restrictions are required during transport of canisters from the Cell to the CPC. Access to the CMR, Crane Maintenance Operating Aisle (CMOA), and the east side of the EDR will be limited access during canister movement.

Limited access is required on the third floor of the VF whenever a filled radioactive canister is on the in-cell crane hook in an elevated position. During a canister lift, the analysis predicts that the third floor (above elevation 120') of the VF and the CMR will be a radiation area (up to 45.0 mR/hr).

In addition to analyses, several physical walkdowns were performed for every cell, wall, and trench where radioactive material would be present. The walkdown teams were comprised of individuals experienced in radiation streaming, radiation and safety, seismic structural design, and persons familiar with the existing cells. Some modifications to the facilities resulted from these walkdowns. Shield blocks were added for the CMR door cable carrier slots. Shielding was added for the HVAC penetration on the west side of the EDR. Modifications were made to the Sample Cell shielded sample holder tray. Grouting was added to several penetrations in the floor and walls of the CPC. Shield plates were added for the CPC coolant penetrations in the east wall. Shield covers for thermocouple/electrical utility sleeves in the Cell were added. Other design changes were made to seal air leakage paths into the Vitrification Cell and the CMR. During the walkdowns, closure of block valves and placement of caps on the Cell wall penetrations were also verified.

Construction turnover packages were reviewed to confirm concrete density and associated installation documentation. All concrete placement records document that the concrete used throughout the facility has a density greater than 142 lbs/ft³. Documentation also indicates the use of proper curing methods and duration, reinforcing steel construction, formwork removal, and satisfactory repair of concrete voids. All concrete was placed, cured, and repaired in accordance with technical specifications and American Concrete Institute codes to assure acceptable shielding characteristics.

Additional shielding was required in only two locations. Shielding was added to the canister load-in penetration in the Load-in Building. Shielding was also added to the 3 in. separation gap on the east side of the Transfer Tunnel/EDR interface. Radiation streaming around previously installed shielding could have possibly created radiation levels higher than the design limits. These modifications adequately mitigated any potential streaming problems.

Radiation Dose Rates for Various Areas:

The facility was designed to the following dose rates:

1. The maximum radiation dose rate for a full-time occupancy area is 0.25 mRem/hour. A full-time occupancy area is one in which an individual(s) may be expected to spend all or most of his or her workday.
2. The maximum radiation dose rate for a full-time access area is $2.5/t$ mRem/hr, in which "t" is the maximum average time in hours per day that the area is expected to be occupied by any one individual. A full-time access area is one in which no physical or administrative control of entry exists.

Area Occupancy:

The VF process cell and the CPC were designed for remote operation with no planned manned entry into either of the cells during radioactive operations. The VF Control Room has been defined as a full-time occupancy area. All other areas of the VF are defined as full-time access areas.

A. Contamination Confinement:

General Requirements

Confinement of radioactive materials has been accomplished using three primary design principles:

1. Using sufficiently air-tight physical boundaries to keep contamination as close to the source as practical.
2. Using multiple barriers. Each zone is bounded by barriers; such as negative pressure in the process pipes and vessels, cell liners, concrete walls, different pressure zones, and building walls.
3. Maintaining pressure differentials between each confinement zone and between the outermost zone and the outside atmosphere. Air flow travels from zones of lesser contamination potential to zones of greater contamination potential under normal and off-normal conditions.

B. Ventilation Requirements:

A ventilation and filtration system was designed to maintain release of radioactivity and airborne particulate within limits of DOE Order 5480.1, Chapter XI, "Requirements for Radiation Protection," and other applicable federal requirements.

HEPA filters have been provided to ensure that inadvertent backflows are filtered. The means to positively seal all Zone I penetrations has been provided.

Outdoor air intakes have been located so that they are protected from the weather. The intake design considered the effects of high winds, rain, snow, and airborne debris so as to prevent blockage or restriction. Supply air is filtered by HEPA filters, conditioned, and distributed.

Potentially contaminated ventilation air flow is filtered by two fire-resistant HEPA filters in series prior to exiting to the atmosphere.

Dampers or valves were located so that a bank of filters can be completely isolated from the operating ventilation systems during filter replacement operations. Each exhaust filter housing has a rigid mounting frame for the filter. Openings in these housings permit filter removal and replacement with minimum exposure to personnel and with minimum release of contaminants to the outside of the housing. Test ports for in-place filter testing with DOP using ANSI requirements have been provided on the filter housings required to protect the environment from radioactive releases.³³ HEPA filter systems have been tested in accordance with military specifications after filter installation using a "cold DOP" test.

Filtered air will be discharged to the environment through a stack. There are three radiation monitoring systems on the stack, with alarm panels in the VF Control Room.

Heating and ventilating systems in contaminated or radioactive areas have been constructed of welded stainless steel; including duct work, in-line components, and filter housings; to minimize contaminated rust traps and for future clean-up and decontamination/decommissioning. The remaining duct work in uncontaminated or nonradioactive areas was constructed of galvanized steel.

Devices have been provided to control and indicate pressure differentials between confinement zones. Alarms have been provided in the VF Control Room to indicate when pressure differentials are not within a prescribed range.

An air conditioning unit has been provided to maintain the VF Control Room temperature and humidity at levels that are suitable for the controls, associated instrumentation, and personnel. A backup air-handling unit is also installed.

C. Design Basis:

All structures that form the Zone I confinement boundary and the associated ventilation and filtration exhaust system have been designed to continue to perform their contamination confinement function during and after the occurrence of a design basis event, accident, or credible fire or explosion.

D. Criticality:

Nuclear criticality safety control provisions meet the requirements of DOE Order 5480.1, Chapter V, "Safety of Nuclear Facilities."

5.2 Use of Existing Buildings

The DOE/NYSERDA agreement specified the reuse of existing buildings to minimize the design and construction of new facilities at the former nuclear fuel reprocessing site. In 1984, a comparative analysis was performed to determine where to locate the radioactive VF. This study evaluated alternative locations for the HLW processing facility in addition to conversion of the CTS. The CPC, EDR, and various extraction cells were evaluated as other viable locations; however, size, increased radiation dose to workers, estimated costs, and schedule rendered these locations unsuitable. The existing location of the CTS was determined to be the best alternative and a decision was made in 1985 to convert the CTS to a radioactive facility.

The comparative analysis also determined the reuse of the former plant's CPC for canister storage; the EDR for equipment removal and storage; and the 01-14 Building to house the ex-cell off-gas treatment system.

5.3 Use of Existing Technologies

In keeping with management guidelines, existing technologies were to be adapted for solidification efforts and new designs and development minimized. Adapting proven equipment designs from industry and other DOE facilities would serve to reduce costs and, more importantly, ensure that equipment functioned properly when put into radioactive service. Development of new component designs was necessary when site-specific activities could not be accomplished using existing technologies.

Designs for hot cell penetrations, including shield windows, utility sleeves, thermocouple penetrations, pass-throughs, and remotely removable jumpers and remote PUREX connectors were adapted from facilities in use at the DOE's Hanford facility. Designs for the ceramic melter, SBS, evacuated canister, periscopes, melter viewing, canister decontamination, film cooler, and bubblers were based on components at PNNL. Additional designs, modified from industry, were the designs for the VF Control Room's DCS, canister ILD system, canister lid welder, and NOx catalytic convertor. Designs for the CCTV cameras and transfer pumps were developed from components at the DOE's Savannah River facility. Design of the in-cell lights was developed by the Idaho National Engineering Laboratory (INEL). A portion of the design for the Load-in Building was adapted from a building design at the Waste Isolation Pilot Plant (WIPP). Remote controls for the transfer cart were developed at the Oak Ridge National Labs (ORNL). The design and equipment for the pneumatic transfer system were procured from the French company, Societe Generale pour les Techni ques Nouvelles (SGN).

Equipment to be used for vitrification activities was designed for a service life of seven years to provide sufficient time for nonradioactive testing and checkout, as well as operational time.

Radiological design considerations were based on the total radiation (exposure from all radiation sources) affecting the particular equipment. For all organic or elastomeric material exposed to greater than 1.0 times 10^4 rads total integrated dose (teflon 1.0 times 10^3 rads), the following was evaluated: 1) use of another material, 2) use of local shielding, or 3) designing the particular equipment for ease of replacement.

5.4 Process Requirements

Process design requirements for vitrification facilities were determined by FACTS testing and the lessons learned resulting from both successful equipment operation and equipment failure.

Process requirements include the ability to: receive waste into the VF from the WTF, mix the high-level waste with glass formers, move the melter feed from preparation equipment to the vitrification equipment, vitrify the feed, position the canisters, detect canister glass levels and weight, decontaminate the canisters, limit radioactive releases to the regulated limits, recycle the wastes, sample and sample transfer, heat and cool process fluids, and provide redundancy where necessary.

5.4.1 Sampling and Transfer to Labs

Sampling and laboratory analysis and/or monitoring is provided to the extent necessary to safely control the process operations and to provide the data to satisfy the federal waste acceptance requirements for each canister.

The sampling system for the VF provides for extracting samples of various waste and process streams, including the vitrification waste product, and transporting the samples to the Analytical Laboratories via a sample transfer cell and/or retaining the samples for archiving. These samples are then analyzed for process control and product verification. The sampling system consists of three sampling devices: a slurry sampler, a C-sampler, and a shard sampler. The slurry sampler, located at the slurry sample station, is used to collect HLW and slurry samples from both the CFMT and MFHT. Samples are collected by a Hydragard™ in-line, closed-loop sampler. This sampler was designed for radioactive service and handling by remote techniques. An air displacement slurry (ADS) pump transfers samples from these tanks to the sample station and then back to the tanks. The C-sampler is a portable unit used to collect liquid samples from the SBS and the decontamination station. This sampler was designed as a vial holder assembly and an eductor assembly with a nozzle for remote connection to a utility air line for actuation. The shard sampler, located at the canister weld station, is used to collect glass fragments from process canisters prior to capping. It was designed as two major components: a sorter assembly and a vacuum pickup assembly. Both are operated remotely by manipulators.

All samples are transferred in vials into a seismically designed sample transfer cell located on the exterior northwest corner of the Vitrification Cell. As the samples are received into the Cell they are dropped into round plastic containers (or rabbits) to encase the glass sample bottle. The rabbits are then either temporarily stored or placed directly into a sending unit (transfer tube) for immediate transfer to the labs. The sample transfer cell was designed with provisions for decontaminating a sample using a demineralized water rinse. A pneumatic system provides the vacuum to send the rabbits to the Analytical Lab hot cell for analysis. Rabbits are tracked through the transfer tubing by installed passage detectors that energize panel-mounted signal lights as the rabbit passes each detector. Provisions have been made to activate a reverse transfer in case a rabbit fails to accomplish full travel to the Analytical Lab.

5.5 Natural Phenomenon

Design of the facilities to be used during high-level waste solidification were based on the specific natural phenomenon for the West Valley, NY site.³⁴

The structures and components that are required to confine radioactive material hazardous to the public or site personnel have been designed to prevent the release of radioactive contamination and the loss of facility safety function capabilities during a Natural Phenomena Hazard (NPH) event. These structures and components were designed in accordance with DOE-ID-12044 and later evaluated against the requirements of DOE Order 6430.1A. (The NPH design criteria document referenced in DOE 6430.1A is the University of California Research Laboratories [UCRL], Guideline 15910.³⁵) NPH design basis events established for the site were compared with the hazard magnitude determination guidelines set forth in UCRL 15910. The magnitude of NPH events established for the site were confirmed to be equal to or more conservative than values selected using UCRL 15910 Guidelines.

Structures that are not required to confine radioactive material have been designed to the New York State Building Codes.³⁶

NPH design basis events for the site are:

5.5.1 Design Basis Earthquake

The WVDP Design Basis Earthquake (DBE) was established and accepted by the DOE in 1983 as having a Peak Ground Acceleration (PGA) of 0.10 g horizontally and 0.067 g vertically, and is quantified in engineering terms using the Nuclear Regulatory Commission (NRC) Regulatory Guide, 1.60 response spectra.³⁷ Current DOE guidance requires a review of the state-of-the-art of NPH assessment methodology and of site-specific information every 10 years and recommendations made on the need for updating existing NPH assessments based on the identification of a significant change.³⁸

In 1994, an evaluation of the ground motion hazard at the WVDP was made by Dames & Moore using publications relevant to the seismic hazard at the closest nuclear power plant to the WVDP site. Using hazard analysis methodology of the Electric Power Research Institute and the guidance of DOE Standard 1024³⁹, estimated values of the PGA at the 1 times 10^{-3} and 5 times 10^{-4} annual probabilities to be 0.053 g and 0.078 g, respectively. The WVDP site DBE defined as a PGA of 0.10 g was, therefore, determined to be conservative.

The design includes a validated computerized dynamic analysis of the confinement structures against the site DBE. Components that make up the Vitrification Cell ventilation, exhaust, and backup electrical power systems were seismically qualified by analysis and/or testing to the site DBE. The passive confinement structure for the VF (Cell, transfer tunnel, and CMR) has a seismic margin of 2.1 to greater than 10.0.⁴⁰ The HVAC exhaust system has a seismic margin of 2.1 to 10.0.

5.5.2 Design Basis Tornado

The Design Basis Tornado (DBT) was specified for the WVDP in a Nicholas and Egan report, in 1983.⁴¹ The DBT definition was based on detailed analyses of all tornado occurrences in Western New York State. The characteristics of the DBT were derived from a study performed by the Lawrence Livermore National Laboratory.⁴²

Characteristics of the DBT are outlined below:

- A. Maximum wind speed 71.5 m/s (160 mph)
- B. Tornado radius of 45.7 m (150 ft)
- C. A tornadic rotational wind velocity of 49.2 m/s (110 mph)
- D. A translational wind velocity of 22.35 m/s (50 mph)
- E. A peak pressure differential of 2,413 Pa (0.35 psi) from ambient atmospheric pressure.
- F. A rate of pressure change of 1,034 Pa/s (0.15 psi/sec)
- G. Penetration and crushing effects of small, high-velocity missiles: wooden plank 0.10 m by 0.30 m by 3.65 m (4" by 12" by 12'), 63 kg (139 lbs) weight at a velocity of 38 m/s (85 mph); and steel pipe 0.076 m (3 in.) diameter by 3.05 m (10 ft), 33.4 kg (76 lbs) weight at a velocity of 22.35 m/s (50 mph).

Radiological confinement was designed to assure confinement under DBT conditions. In general, confinement barriers may be damaged, but not breached due to DBT conditions. In the event that breach prevention is not possible or cannot be demonstrated, additional analyses were performed. The radiological consequences of any breach of containment was demonstrated to be less than the maximum dose limits allowed for the safety classification of the confinement barrier.

5.5.3 Design Pressure Differential

Concrete building structures were designed for negative pressures with respect to the outside atmosphere. The interior design pressure is a negative 745 Pa (minus 3 in. water).

5.5.4 Design Wind Forces

Building structures and the equipment on the exterior of the buildings were designed to a 100-year wind of 128.72 km/hr (80 mph) with peak gusts of 156.07 km/hr (97 mph). Wind pressure was analyzed using the methods specified in accordance with ANSI exposure conditions.⁴³

5.5.5 Design Snow Loading

Buildings and outside structures were designed for a snow load of 1,915 Pa (40 lb/ft²).

5.5.6 Reference Design Flood

A flood is not considered to be a hazard to the facility due to site characteristics.

5.6 Remotability

Due to the levels of radiation expected inside the Vittrification Cell, other shielded areas of the Vittrification Facility, and radiation existing in previously contaminated areas of the former plant, the ability to remotely operate, remove, maintain, or replace equipment was essential. Design requirements of components located within these areas, in addition to those requirements imposed by radioactive service, were predicated by their operation, maintenance, removal, or replacement by cranes and crane attachments, impact wrench, manipulators, and a robot. All services provided to components in the Vittrification Cell, such as chemicals, steam, water, gases, electrical and instrumentation, were incorporated into remotely installed jumpers that have PUREX connectors actuated by an impact wrench. Movement of components into and out of the Cell and into and from the transfer tunnel, EDR, and HLWIS required the design of a remotely operated transfer cart.

The service life for remote equipment was met by: 1) specifying the quality and reliability for the equipment; 2) designing the equipment for replacement; or 3) specifying redundant backup equipment.

5.6.1 Maintenance

Maintenance areas have been designed for performing decontamination and repair of manipulators, cranes, etc. The use of low-maintenance process equipment in radioactive areas has been maximized, and remotely operated decontamination capabilities for cells, cubicles, and internal and external equipment surfaces have been provided to the extent necessary to support required maintenance.

The basic plan for maintenance of the vitrification components and systems is remote removal and replacement of equipment. Systems and components in contaminated areas have been designed to be either remotely maintainable in place, or remotely removable and replaceable. Components with a high probability of failure have been located outside the remote areas to the maximum extent possible. Spares have been provided for critical components or for components that have a high probability of failure during operation. Typical candidates are seals, motors, agitators, pumps, electronics, CCTV cameras, lights, thermocouples, and crane components.

The CMR provides for parking and decontamination of the crane, and subsequent hands-on maintenance. Hatches are provided in the roof of the CMR so that crane trolleys and large components can be removed from the facility.

Electrical systems have been designed so preventive and corrective maintenance can take place on primary and secondary power without compromising safety or environmental protection.

5.6.1.1 Remote Requirements

Systems in the VF Cell have been designed for remote operations and maintenance. For the VF, changeout is used to denote remote replacement, and remote maintenance is used to denote in situ maintenance.

A. Design

To provide adequate remote capabilities, certain design features have been provided:

1. Installation of remotely removable valves, pumps, etc., on jumper assemblies have been used to enhance remote changeout. These items are located in the VF Cell. The VF Cell is provided with remote-handling equipment.
2. Equipment such as tanks, vessels, filter housings, and agitators located in the shielded VF Cell have been designed to permit remote replacement. Thus, space has been provided for equipment removal with reasonable disassembly and removal of adjacent equipment.
3. During remote transfer of radioactive items and materials, personnel radiation exposures will be maintained ALARA. Viewing of routine remote operations use normal window viewing angles. Where viewing through a window is not feasible, CCTV cameras with movable in-cell support assemblies have been provided.
4. Remote process equipment accessibility has been considered for operational and maintenance requirements.
5. In-cell mechanical and electrical equipment (windows, CCTV, manipulators, electrical enclosures, etc.) have been sealed or otherwise protected from corrosive solutions and gases.
6. In-cell lights are remotely replaceable.
7. Tool storage areas and work tables have been provided in the Cell to support maintenance requirements.

8. Retrieval systems for remote in-cell cranes and manipulators have been provided for both normal and off-normal conditions.
9. Dedicated operating or maintenance areas have been considered and defined on arrangement drawings. Field run or installed equipment such as piping, electrical, instrument, or HVAC have been designed so as not to violate a dedicated space. Clearances (dedicated space) for manipulator operation, as well as insertion and removal, have been considered.
10. Connectors, bolts, flanges, wrenches, sockets, extensions, etc. have been standardized to the maximum extent practical to reduce the need for multiple tools and frequent tool changes.
11. Equipment is movable, maintainable, and replaceable with a minimum disturbance of adjacent equipment.
12. Modular equipment, components, and subsystem designs were used where possible, to facilitate removal and replacement.
13. In-cell equipment vertical access envelopes have been provided to assure accessibility with overhead handling equipment. In addition, visibility, accessibility, and interferences have been considered during design.
14. Developmental or unproven state-of-the-art items are unacceptable unless the concepts/equipment are able to be proven by remote mockup prior to incorporation into the facility design. In addition, remote tooling and equipment were maintained as practical, straightforward, and simple as possible. Standardization (sizes, shapes, arrangement) has also been maximized.

B. Facility Requirements

To accomplish remote requirements, the VF has included certain facility features:

1. Adequate viewing windows, manipulators, and Cell door installations.
2. Cell access through ceiling hatches as far as practicable.
3. Bridge crane(s) and rotating trolley to provide complete Cell coverage.
4. Control stations for in-cell crane(s) are located adjacent to viewing windows to permit local remote operation.
5. Dedicated areas that can be isolated from the process area for crane maintenance.

5.7 New Vitrification Facility Designs

New facilities have been designed to: maintain internal and external radiation exposures to operating and maintenance personnel ALARA, assure that design guidelines are not exceeded, and provide the capability to control contamination during routine and emergency operating conditions and during all hands-on and remote maintenance activities.

5.7.1 Vitrification Facility Fire Detection and Protection

Fire protection systems and components were designed in accordance with national standards and federal fire codes.

All egress corridors and door openings meet national fire codes. The size and arrangement of interior corridors accommodate personnel traffic flow patterns, safety of building occupants, movement of equipment, and ultimate decontamination and decommissioning of the facility. Working areas outside the Vitrification Cell have been constructed of fire-resistant and noncombustible material. Equipment such as fire hose racks, cabinets, and drinking fountains have been recessed in corridors and have been grouped together whenever possible. Storage areas for combustible material have been physically isolated from equipment areas by fire-resistant walls or storage cabinets and have been manufactured for housing combustibles.

Occupied areas are protected by an automatic wet-pipe system. The Control Room and HVOS have additional protection by a Halon™ system compatible with electronic equipment.

5.7.2 Protection and Security Design Requirements

Security administrative and design functions are combined to provide an effective protection system. Safety and security alarm and monitoring systems provide input to both the VF Control Room and the WVDP security alarm system.

The vitrification facilities are designed with the minimum number of external access points consistent with safe and efficient access and egress. Personnel access is limited to authorized personnel using a card reader system. Locking and alarming the appropriate cells and access doors to the process cells are used to further enhance security. An extensive analysis of facility security was conducted to assess vulnerability to sabotage.

5.7.3 Testing

All of the components and systems were tested prior to delivery to the site and again after installation. This involved vendor tests, construction tests, component tests, startup testing, and finally the integrated tests of the entire facility. Test requirements were considered during design, and provisions such as electrical and piping connections, valves, plugs, etc., were included to accommodate test activities. For clarification, typical examples were:

- A. Sufficient monitoring points for checking pressure, differential pressure, flow rates, and flow path.
- B. Calibration points for pneumatic systems.
- C. Provisions for power supply load-testing and to confirm the compatibility of instrument signals from detector to readout.
- D. Methods for flushing and hydrostatic testing of piping systems.
- E. Provisions to permit load-testing of cranes and hoists.
- F. Special jumper(s) for testing.
- G. Devising a plan that outlined what tests were to be performed at the vendor, during construction, and during startup of the facility.

5.7.4 Decontamination

The VF and systems are designed to facilitate post solidification decontamination. This includes decontamination of the structures and equipment, and removal of sources of hazardous and radioactive materials to acceptable levels or concentrations. Equipment installed in the VF includes features to enhance decontamination during the vitrification campaign and later for decommissioning. Design features include:

1. The VF decontamination system permits flooding and flushing the inside surfaces of equipment in contact with contaminated process liquids and solids. Decontamination fluids (mild acids and detergents) can also be introduced into all chemical pipes and vessels.
2. Process piping design has minimized nondraining low points or pockets. Where low points or pockets were unavoidable, provisions have been made to drain or flush the piping.
3. Vessels were designed for the complete removal of process and decontamination solutions. Interior and exterior crevices have been minimized.
4. Horizontal surfaces were avoided. Sloped surfaces are utilized to facilitate drainage of decontamination solutions.
5. Process valves have been provided with flushing and draining capabilities.
6. Cell floors are lined with stainless steel. Cell walls are also lined with stainless steel to a height that was deemed appropriate for the process. Surfaces that are not lined with stainless steel have been protected with epoxy coatings.
7. Cell floors are adequately sloped for drainage to sumps that can be jetted to the waste tanks.
8. All the components, jumpers, and structures in the Cell were designed to be removed. In the ex-cell area, the components were mounted on modular racks that can be easily removed from the facility.
9. A vacuum canister was provided to remove the residual glass out of the melter at the completion of the campaign.
10. Hatches were provided in the roof of the Cell for equipment removal during decommissioning.
11. HEPA filters were provided for the Cell exhaust and melter off-gas lines to keep the radioactive material in the Cell and to reduce ex-cell contamination and the load on the ex-cell filters.
12. Where possible, the number of jumpers were reduced.
13. A suction pump was provided in the SBS to remove the radioactive sludge or particles. The filter pads in the HEME can be back-flushed to remove particles.
14. The tanks were designed to leave a minimum heel, and cooling coils were placed on the outside of the tanks, where practical.
15. The Cell penetrations, all of the equipment in the Cell, and the Cell HVAC exhaust system were constructed from stainless steel, titanium, or Hastelloy™ to minimize corrosion and to make the decontamination process easier.

16. Hot side covers were provided inside the Cell so that the shield windows would not become contaminated.
17. All of the trenches were designed with removable covers for ease in decommissioning.

5.7.5 Electric Power Supply

Electrical design considerations were:

- A. ***In-cell Conduit.*** In-cell electrical conduit is stainless steel pipe with welded connections with the exception of electrical jumpers. The conduit is sealed to ensure the integrity of the HVAC pressure zones.
- B. ***Electrical Design.*** Electrical systems were designed to national fire codes and National Electric Codes (NEC).⁴⁴
- C. All connectors into the cell have spare pins.

5.7.6 Piping

Piping for the vitrification facilities was designed to ANSI codes⁴⁵ with the following additions:

- A. A second containment provided for all HLW lines that are embedded or exterior to the shielded cell(s):
 1. The containment is in the form of double-wall welded piping.
 2. All inner pipe welds for double-wall pipes were radiographed.
 3. The volume between the containments is monitored for possible leaks.
- B. Other HLW piping radiography and leak-testing were specified line-by-line by the design engineer.
- C. Slip-on flanges, lap joint flanges, socket welded joints, and threaded joints were not used for HLW lines. In the few instances where there was no alternative but to use threaded connections in HLW lines, joints were seal-welded.
- D. Openings through Cell walls such as holes, blockouts, etc. were sealed to allow HVAC balancing.
- E. Where "line slope" and "avoidance of pockets" are essential, this information was included on the drawings.
- F. Bolts, flanges, nuts, externals, etc. used with stainless steel valves and piping, are also stainless steel. Nitronic 60TM was used on studs/nuts to prevent galling.
- G. Piping systems that penetrate the Zone I boundary have been designed to prevent the backflow of solutions from contaminated to clean areas. The design uses elevation differences, check valves, isolation valves, and air purges to prevent spreading contamination through facility piping.
- H. Valves shown on the Piping and Instrumentation Drawings (P&IDs) required an individual number.

5.7.7 Instrumentation/Control/Alarms

Instrumentation used to monitor and control process systems, safety and fire protection systems, and radiation monitoring systems use an automatic control system with manual backup. An electronic system for process control, process monitoring, data acquisition, and report generation was provided as a part of the facility and is located in a centralized VF Control Room. The design includes provision to allow easy calibration and testing during operation without process interruption. Instrumentation was selected on the basis of simplicity, reliability, and availability. To simplify the inventory, spare parts were standardized whenever possible.

Alarms are provided for the safety system, and process variables of the VF are alarmed in the VF Control Room. The centralized alarm system provides a display of the VF alarms. The alarms have been set to provide a warning when the system or process is off-normal, but still provide sufficient response time to respond to or correct the off-normal condition.

5.7.7.1 Radiation Exposure

Instruments are retrievable from the radiation fields for repair or replacement. Wherever possible, only the instrument-sensing device, such as a thermocouple, was located in the high-radiation field, while the transmitter or mechanical device was located in a nonradiation area.

5.7.8 Standby Electrical Power

The VF and NO_x abatement systems receive normal ac power from dual feeds from the off-site, commercial utility system at the 34.5 kV level. The VF electrical power distribution system (EDS) steps this 34.5 kV level down to the 480 V which is further stepped down to 240/120 V and 208/120 V to feed various VF system loads. The EDS also includes the vitrification on-site standby diesel generator (SDG) and the UPS' that provide standby electrical power to key selected loads in the event of loss of the off-site power. The HVAC exhaust fan, in-cell off-gas heaters, lighting panel, power to the fuel oil storage, backup power to UPS', Load-in Building lighting, condensate pump, backup closed loop cooling water pump, and power panel supplying the radiation monitoring system are considered to be the key selected loads and are fed from the SDG.

The VF SDG is located in the DGR and is designed to withstand the effects of the site DBT and the DBE. The VF SDG is designed for starting and automatic acceptance of the largest single load (either HVAC exhaust fan) in order to maintain proper Cell negative pressure. When required, other loads can be administratively loaded to the VF SDG.

In the event of loss of normal (off-site) and standby (on-site) power, uninterruptible power is provided to essential control, instrumentation, and computer systems. The source of this power is provided by a UPS, located in the VF HVOS (elev. 111.5'), and two UPSs located at elev. 100.0', in the northwest area of the Vitrification Building.

The UPS in the HVOS is sized to provide 10 kVA supply at 120 Vac for a period of one hour upon loss of power. UPS' located in the northwest area of the Vitrification Building are each sized to provide 20 kVA supply at 120 Vac for a period of one hour upon loss of power. They provide control power to HVAC control panels, two 480 V switchgears, and various equipment in the VF Control Room, including three of the four DCS work stations, the ILD system, the Halon™ control panel, and a radio base station. Power is also provided to the VF instrument racks; DCS cabinets #1, #2, and #4; and the fourth DCS work station in the VF Control Room.

Besides the VF SDG, there are three other diesel generators on site that supply power to the VF in the event of a loss of power to the site. The 1,200 kW diesel generator located in the expanded Utility Room and the 600 kW diesel generator located in the Main Plant Utility Room supply power to the 01-14 Building NO_x Abatement System. The primary loads for the 600 kW diesel generator in the WTF are the WTF ventilation fans and the transfer pumps installed in the tanks. The design also includes provisions to connect the 600 kW diesel generator to the melter, if required, during an extended power outage.

Key equipment loads in the NO_x Abatement System receive standby power from the two Utility Room diesel generators, 30-P-2 and 30-P-5, in the event of loss of off-site utility power. The 30-P-2 diesel generator provides standby power for UPS 64-B-010, Off-gas Blower 64-K-003B, the off-gas reheaters, and various HVAC equipment in the 01-14 Building. The 30-P-5 diesel generator provides standby power to Off-gas Blower 64-K-003C.

5.7.9 Cell Cranes and Doors

Crane bridges have been provided in the VF Cell and are used for normal operations such as canister replacement, sampling operations, jumper removal, and high-capacity lifts. The process crane has a rotating trolley that can reach all three walls of the Cell with a 4.09 Mg (4.5 ton) capacity. The maintenance crane has a capacity of 22.7 Mg (25 tons). The bridges and trolleys for both cranes are interchangeable. Crane(s) are retrievable back to the CMR in the event of a failure.

Remote and fixed control stations have been provided for each crane. The Vitrification Cell cranes can be operated from multiple stations located at the shield windows and in the CMROA. The CPC (or HLWIS) and the EDR cranes are operated from their respective operating aisles.

The VF Cell cranes were designed and tested in accordance with national crane standards. The allowable design stress limits reflect the appropriate duty cycle. Operational and rated load tests have also been performed in accordance with national standards.⁴⁶

Operation of the crane is not required during a seismic event, but the bridge and trolley have been designed to remain in place on their respective runways with their wheels prevented from leaving the tracks during a seismic event. The crane is retrievable back to the CMR after a seismic event.

The VF doors have been sized to allow removal of the largest component. Permanent air-locks have been provided for the entrance and removal of components, such as the canisters that have a high frequency of replacement or removal. Temporary air locks may be used for infrequent operations such as the removal of a turntable. Cell and CMR removable roof hatches have been provided as deemed appropriate during design.

5.7.10 Utilities

The VF provides a means for distributing utilities to or from the systems or components requiring them. Existing utilities have been used to the maximum extent practical. The utilities used in the Vitrification Cell are steam, cooling water, utility air, instrument air, demineralized water, electrical power, and chilled water.

6.0 CONSTRUCTION

Construction of the vitrification facilities included conversion of existing buildings, decontamination and modification of facilities previously used for nuclear fuel reprocessing, erection of new buildings, and connection of these contaminated areas with new buildings. Construction activities began in late 1982, with the early decommissioning and decontamination work on the former fuel reprocessing cells, and ended in 1995.

6.1 Construction of the Component Test Stand (CTS)

The CTS was built as the facility to house testing equipment for FACTS operations. The civil/structural construction of the CTS began in 1983. This construction consisted largely of the placement of a foundation mat. The 1.37 m (4 ft, 6 in.) thick foundation mat was constructed at two elevations. The lower section of the foundation at the north end of the cell has a top-of-mat elev. of 86.00'. The upper section of the foundation has a nominal top-of-mat elev. of 100.00'. This section would be used to support ancillary process equipment.

The exterior of the CTS was comprised of metal siding over structural steel members (see figures 6-1 and 6-2). Floors consisting of metal grating were constructed at elevs. 110' and 125'.

The electrical/mechanical portion of the CTS was installed in 1984 upon completion of the CTS metal building. Piping headers were installed that connected the utility systems in the existing fuel reprocessing plant to the CTS. Electrical connections were made to the main feed station located at the northeast corner exterior to the CTS metal building.

Process components were next installed in the pit area at the 86' elevation. These components consisted of two concentrator tanks, one SBS, the ceramic melter, and the canister turntable. Filter banks and other supporting equipment were located at the 100' elevation.

Construction of the CTS was completed in November 1984.

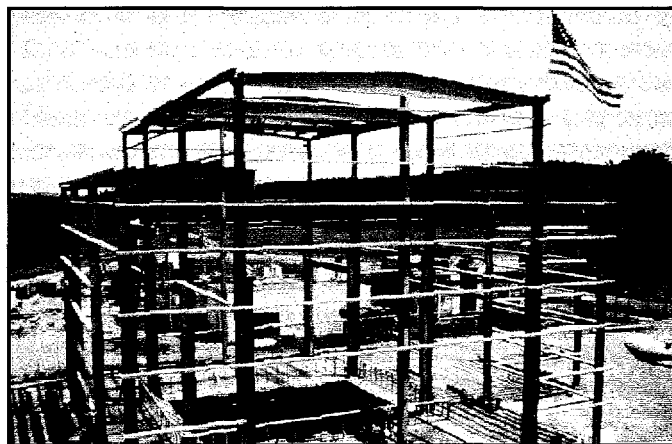


Figure 6-1. CTS Structural Steel

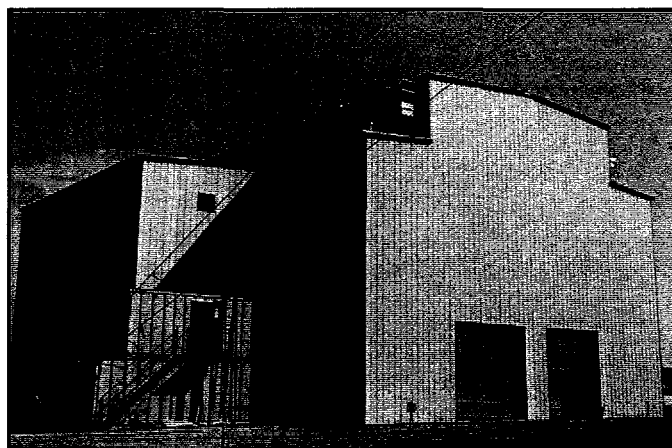


Figure 6-2. CTS Exterior

6.2 Decommissioning and Decontamination of Other Facilities

One of the first jobs performed after the DOE assumed responsibility for the WVDP, was to prepare a facilities utilization report that characterized and described the various areas, structures, and process cells available for use at the WVDP.⁴⁷ Each area and cell were reviewed and evaluated as follows: radiation level; general condition; location, size, wall thickness and type for shielding; size of openings for personnel and equipment access; cranes and manipulator availability and capacity; viewing window condition; and potential for reuse as well as the service facilities for continued use.

Three areas in the Process Building were decontaminated to provide for access to and storage of the solidified HLW. These are the CPC (or HLWIS), the EDR, and the CCR. Decontamination of these facilities was completed in January 1987.⁴⁸

A description of the decommissioning and decontamination activities follows:

6.2.1 Chemical Process Cell (CPC)

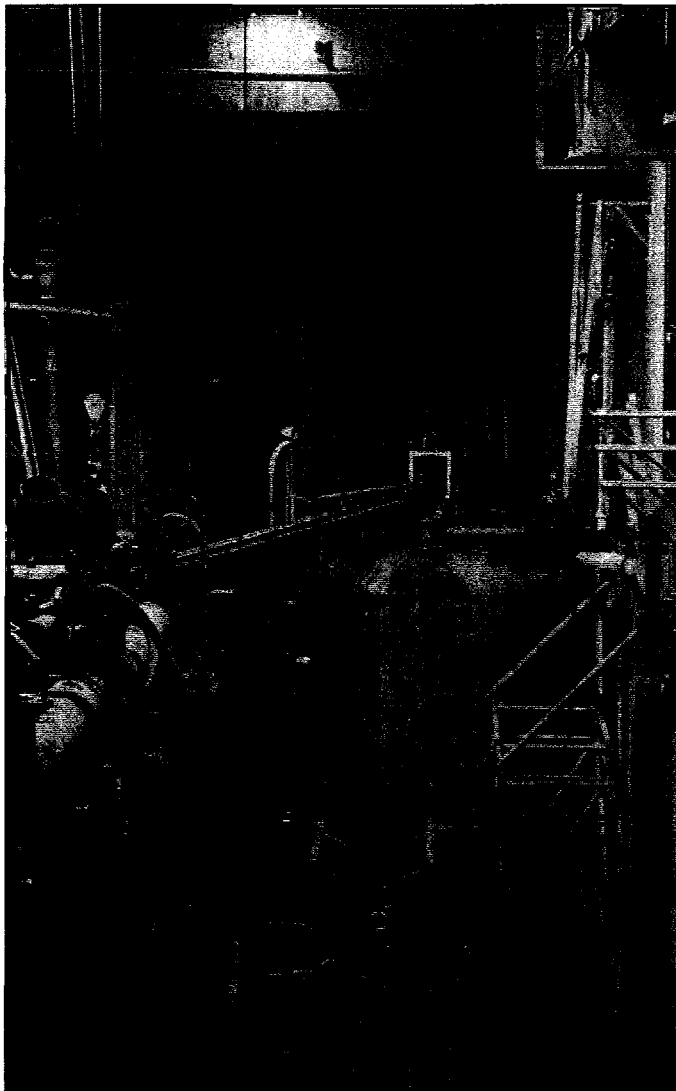
The CPC was designed by NFS to be a remotely operated hot cell of the canyon-type design for commercial nuclear fuel reprocessing. This operated from 1966 to 1972. The Cell housed tanks, dissolvers, and piping necessary for the dissolution of spent fuel. The overhead bridge cranes delivered chopped fuel in baskets to the dissolver tank, and assisted in maintenance and other remote handling operations. There are two separate bridge cranes on two sets of crane rails. A 14.5 Mg (16 ton) and a 1.8 Mg (2 ton) trolley in the upper bridge passes over the top of a 1.8 Mg (2 ton) trolley and PaR (power) manipulator combination on the lower bridge. Because of the expected radiation levels in the CPC during reprocessing operations, the CPC was designed with Hanford-type connectors for remote disassembly and change-out of components. The 6.71 m by 28.3 m by 13.1 m (22 ft by 93 ft by 43 ft) Cell has walls approximately 1.75 m (5 ft, 9 in.) thick. The Cell was built with four leaded glass, oil-filled viewing windows.

The CPC was built with an internal rail system that extends 23 m (74 ft) into the Cell for transport of equipment. Equipment was disassembled in the Cell and boxed using the overhead cranes and moved out of the cell using a transfer cart.

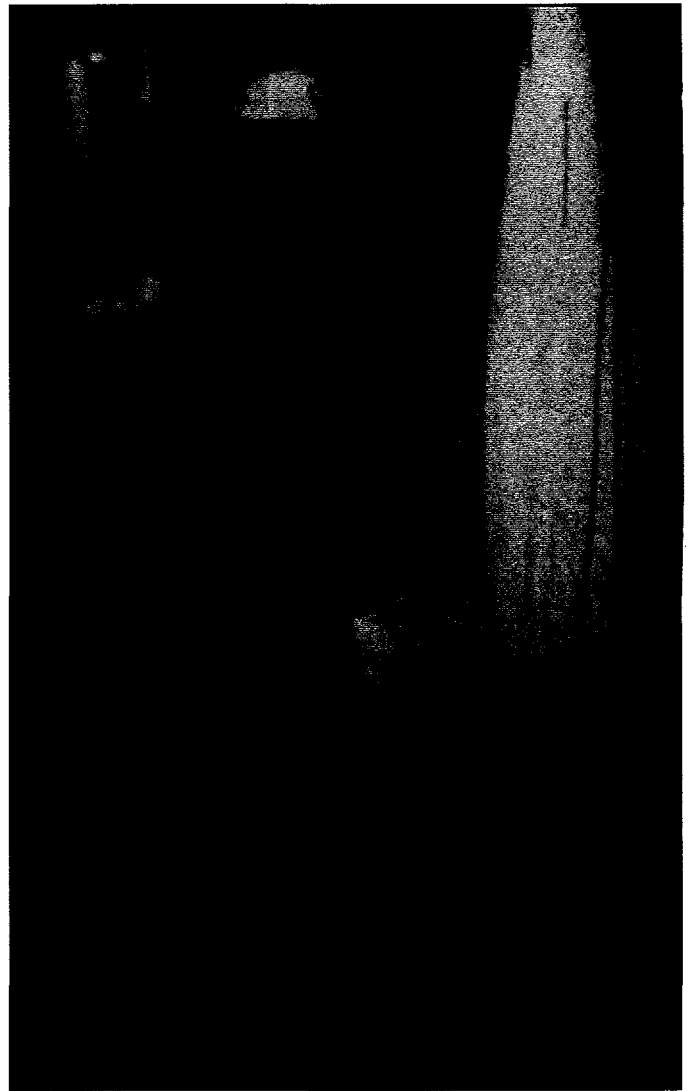
Decontamination of the CPC began in January 1985 (see figure 6-3). All of the existing CPC equipment was remotely removed to prepare the Cell for decontamination and canister storage. The major process vessels and components and jumpers were removed from the Cell. The remaining stubs were cut off where necessary so as not to project into the cell by more than 610 mm (2 ft) on the east side and 381 mm (1.25 ft) on the south side. Two 20 Mg (22 ton) and one 4.5 Mg (5 ton) neutron absorbers were also removed from the Cell. These concrete cores were located at the annulus of the spent fuel dissolver and were used to prevent criticality.

The major Cell operations involved: (1) vacuuming the Cell floor (2) applying foam cleaning chemicals to the Cell interior (3) high-pressure rinsing and scarification (4) disconnecting vessels (5) cutting Cell piping (6) cutting and removing three concrete pedestals and (7) loading waste into boxes and transferring them out for storage.

The Cell dose rate was reduced from an average typical whole body dose rate of 12 to 56 R/hr to 0.2 to 1.2 R/hr at the completion of the decontamination activity. Vessel removal and clean-up was completed March 1987.



5888.bmp



6060.bmp

Figure 6-3. Decommissioning and Decontamination of the Chemical Process Cell

The following items were finished during the second phase of refurbishment of the CPC:

- The inside surface of the Cell was remotely painted with epoxy paint to fix any residual activity and to improve Cell brightness for subsequent remote operations.
- Permanent jumpers were installed for the sump steam jets and sump level detection instrumentation.
- Cell lighting was replaced.
- A CPC hatch filter was installed.
- Refurbishment of the in-cell cranes with new motors, power cable retrieval, and PLC control.
- Replacement of the PaR manipulator.
- Installation of canister racks.

- Installation of Cell coolers and jumpers.
- Installation of a HVAC duct for return air.

All decontamination operations were performed remotely utilizing two overhead cranes, an electromechanical manipulator, and a 6-wheel mobile robot.

The CPC shield walls provide sufficient shielding to meet the 0.25 mRem/hour full-time occupancy area and the 2.5/t mRem/hr full-time access area radiation criteria with racks containing all of the vitrified HLW storage canisters (each having a maximum dose rate of 7,500 rads/hr at contact).

The canister racks installed in the Cell are seismically designed to the Uniform Building Code (UBC) and the American Institute of Steel Construction (AISC) Manual for the condition of the racks being fully loaded with 100 percent filled canisters.⁴⁹ A dynamic seismic analysis was also conducted.

The 11 racks were placed side by side in the CPC and stacked two high allowing for the storage of 396 filled HLW canisters (see figure 6-4). Storage of failed equipment is available in a 9.45 m by 3.35 m (31 ft by 11 ft) area at the north end of the Cell.

An analysis was performed to demonstrate that natural convection within the canister storage rack system in the CPC provides sufficient cooling to maintain the canister centerline temperature below 400° C (752° F).⁵⁰

6.2.2 Equipment Decontamination Room (EDR)

To support construction of the VF, several modifications to the EDR were required. The EDR was an existing Cell of the former NFS' reprocessing plant and had loose and fixed contamination on the internal walls and floor of the Cell. The EDR modifications involved cutting 4.27 m (14 ft) high by 3.66 m (12 ft) wide doorways in the west and north walls of the EDR, the removal of the existing 4.57 m (15 ft) high by 4.27 m (14 ft) wide by .91 m (3 ft) thick EDR shield door, and the removal of the shield door foundation.

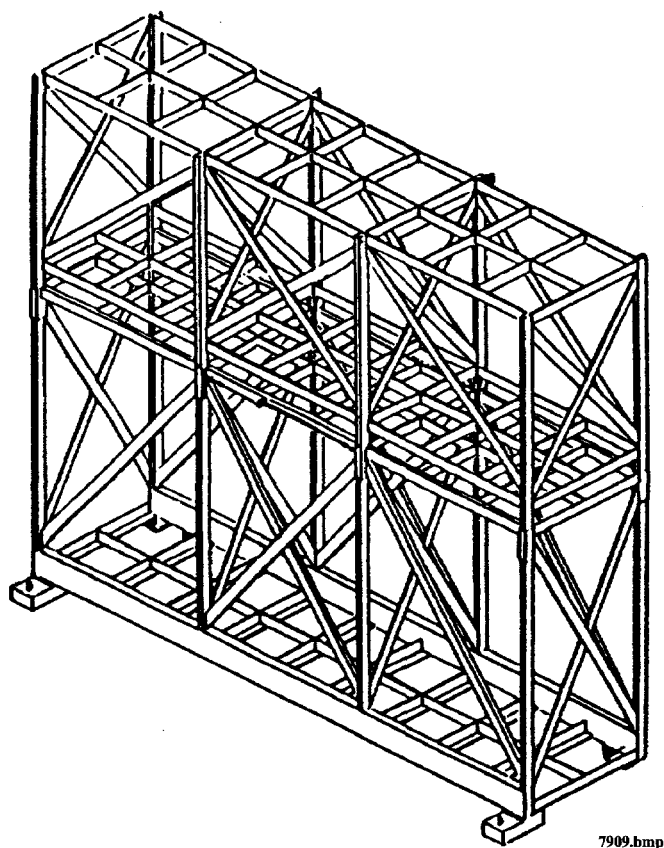


Figure 6-4. Chemical Process Cell Canister Storage Rack

The primary method of cutting was with a special, high-pressure abrasive/water jet cutting tool called the "Deep Kerfer." The kerfer can cut a 28.58 mm (1-1/8 in.) wide kerf into steel-reinforced concrete to a depth of 1.52 m (5 ft).

The EDR modification project involved working to an aggressive schedule while using a prototype piece of equipment as the main tool. The deep kerfer system was proven to be a technically and economically sound method to cut large sections of steel-reinforced concrete for subsequent removal.

The EDR was decontaminated to provide a waste packaging and transfer area for decontaminating the CPC. Decontamination was accomplished by: (1) packaging and removal of wastes (2) grinding concrete floor surfaces (3) emptying and cleaning the soaking pit (4) washing and painting the walls and (5) refurbishing the utilities. Decontamination operations also included refurbishing the transfer car and load-testing the cranes.

Decontamination was initiated in September 1983 and continued until May 1985. Average radiation fields were reduced from 90 mR/hr to 29 mR/hr. A total waste volume of 62.5 m³ (2,210 ft³) was generated and packed into 143 drums with a capacity of 0.2 m³ (7.5 ft³) and 13 boxes with a capacity of 2.5 m³ (88 ft³).

Conversion of the EDR into a facility to support vitrification included the addition of equipment and refurbishment of existing equipment. This work included:

- Charging shoes were added to provide electrical power to the transfer cart.
- A canister tip-up was installed, along with an EDR canister load-in port.
- CCTV cameras were added to aid in remote handling inside the EDR.
- All electrical service was reinstalled.
- New emergency lighting was installed.
- The man-way air lock was replaced.

6.2.3 Chemical Crane Room (CCR)

The CCR was used for the storage and servicing of bridge cranes and an electromechanical manipulator used in the CPC. Operations involved: (1) removing air lock surface contamination (2) establishing containment (3) vacuum cleaning (4) damp wipe-down (5) floor and wall surface grinding (6) grinding and acid descaling of crane rail surfaces (7) painting and (8) adding rail shielding.

CCR decontamination operations began in December 1982 and were completed in April 1983. General exposure rates were reduced from between 5 to 2,000 mR/hr to 5 to 200 mR/hr. Forty-nine 208 l (55 gal.) drums of waste were removed from the CCR.

The CCR was completed to fully support vitrification operations by performing the following work:

- Adding shielding along the crane rails.
- Installation of a CCTV camera system.
- Installation of a retrieval wrench to recover a failed waste handling crane.
- Refurbishing both cranes by replacing all electrical systems and performing mechanical upgrades.
- Removing all scrap/old equipment after performing the upgrades outlined above.

6.3 Vitrification Facilities Construction

The CTS was approved by the DOE as the site of the future VF in 1985. The conversion of the CTS to the VF (Cell and operating aisles) was accomplished in phases in order to: minimize construction and testing interferences, permit some concurrent development/operations and construction work, and fit the delivery dates of major equipment. The four major phases of construction that occurred over a six year period included new civil/structural construction, modification of the existing CTS structure, mechanical/instrumentation and control/electrical, and the ex-cell off-gas facility. An artist's rendering of the vitrification facilities is shown in figure 6-5.

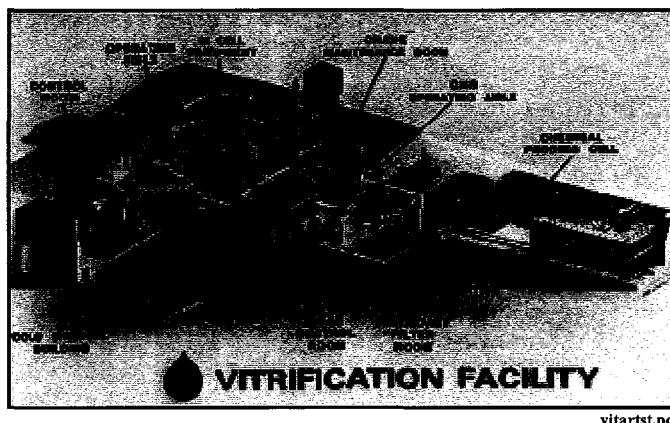


Figure 6-5. Artist's Rendering - Vitrification Facility

Construction phases and radioactive tie-ins of the WTF and hot cells are described below:

6.3.1 Civil/Structural Construction

The civil/structural construction focused on two areas. The first area was located between the CTS and the existing Fuel Reprocessing Building. This area contained portions of the Vitrification Cell, transfer tunnel, Secondary Filter Room (SFR), HVOS, and the CMR. All of these areas are shielded and built to withstand a seismic event; thus the bulk of the construction work was in the form of heavily reinforced concrete floors, walls, and ceilings. Problems to contend with included: 1) working around contaminated buildings and soil near the existing Process Building 2) avoiding guy wires from the main exhaust stack 3) working around scheduled transfers of radioactive liquid to the Cement Solidification System (CSS) through the trench located in the area 4) inclement weather and 5) providing continuous access to the test facility.

Construction of the Vitrification Cell occurred in two stages. The first stage included installation of six concrete columns to elev. 120' and a wall behind the melter up to elev. 110'. The columns' dimensions are approximately 1.22 m (4 ft) by 1.22 m (4 ft) and 6.1 m (20 ft) in height. The second stage included installation of walls from elev. 120' to 146' and part of the roof. Openings that would eventually form the Cell were framed.

Near the end of this stage, FACTS testing was completed and the CTS was dismantled. The test melter, associated piping, electrical systems, and equipment were removed (see figure 6-6). Main piping headers were left for reuse. The demolition effort required close coordination among two subcontractors and WVNS personnel. Selected equipment was salvaged to be reinstalled in the new facility.

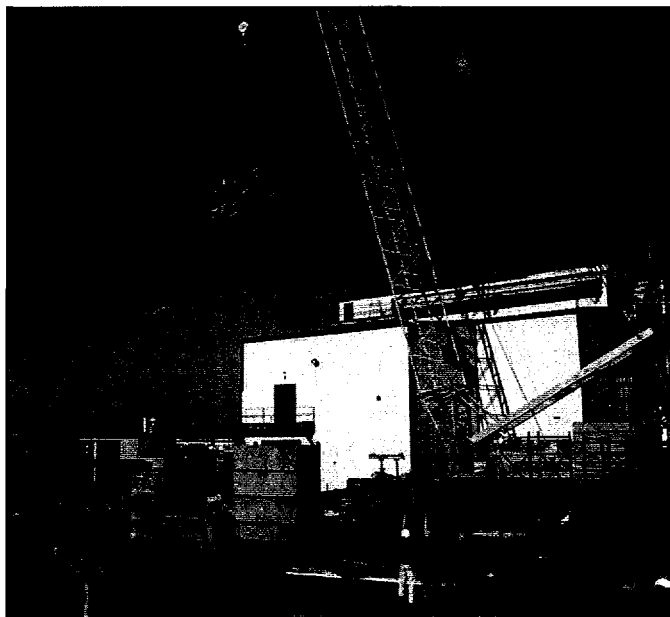


Figure 6-6. FACTS Melter Removal from the CTS

One of the unique construction features of the Vitrification Cell was the wall modules. These special walls were fabricated off site (to facilitate continued testing) in a manner that allowed them to be installed between the concrete roof and the columns that had been installed before the testing started. Soon after the CTS was dismantled, five of the seven wall modules were installed. These large stainless steel modules, averaging 4.7 m (15 ft, 5 in.) wide by 7.1 m (23 ft, 4 in.) high by 1.2 m (3 ft, 11 in.) thick, were prefabricated in a vendor's shop complete with all shielded piping and electrical penetrations, window liners, and manipulator and shield plug ports. The installation included adding reinforcing bar (or rebar), which was tied to the existing columns using threaded rebar screwed into embedded couplings in the columns. The installation of these prefabricated modules was successfully completed as planned and saved a considerable amount of time (see figure 6-7).

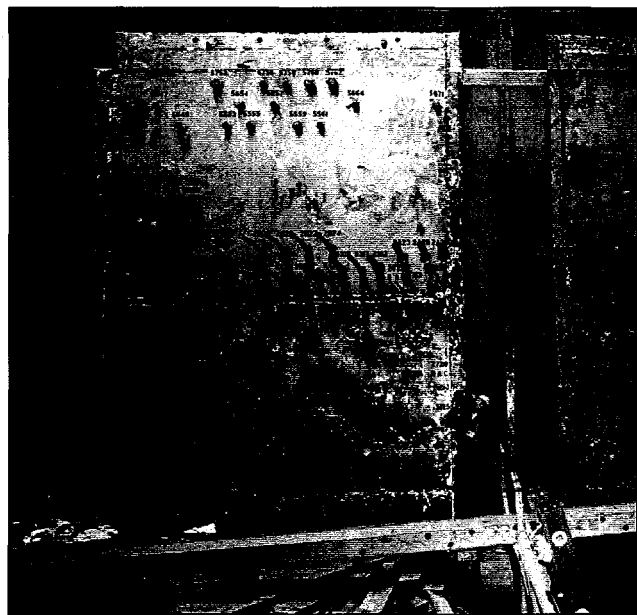


Figure 6-7. Wall Module Installation

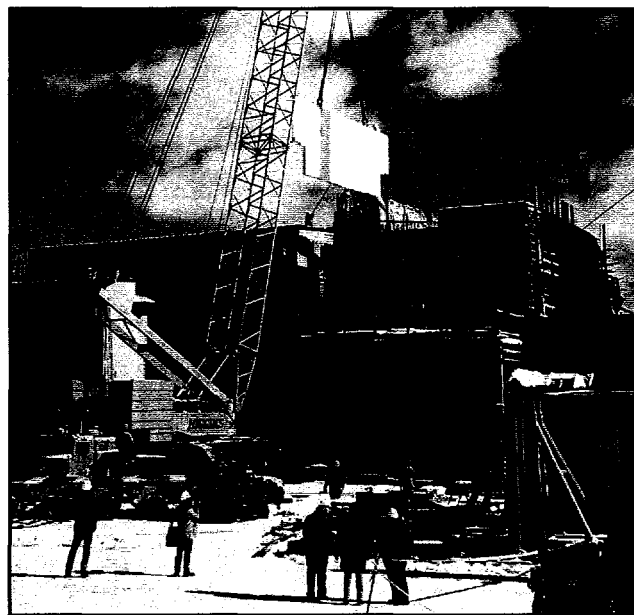


Figure 6-8. CMR Shield Door Installation

Eight radiation shielding doors were installed as the construction proceeded. The largest of these shield doors, a 95.3 Mg (105 ton) CMR door, required using a 317.8 Mg (350 ton) mobile crane (see figure 6-8). This was problematic due to the small working area; the crane had to be positioned between the west side of the Vitrification Building, the stack's guy wires, and the Cold Chemical Building excavation.

The second major construction of this phase included areas west of the CTS, where the Cold Chemical Building was built. This building houses tanks, pumps, and grinders used to mix the chemicals and glass formers before they are pumped to the Vitrification Cell to be mixed with the radioactive sludge. The Cold Chemical Building is a structural steel building with metal siding. The bottom floor is concrete with curbs and sumps to contain potential chemical spills. The second floor is steel with grating around the tops of vessels. Completion of the structural steel portion of this building was delayed until the dismantling of the temporary cold chemical system was completed because the existing tanks were to be reused for the final system. The tanks were installed as the building was being erected (see figure 6-9).

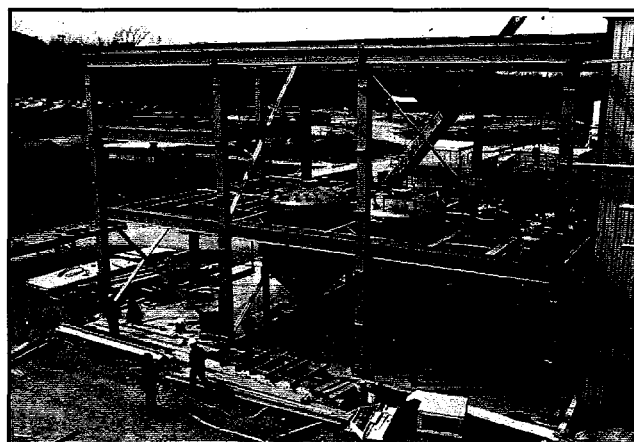


Figure 6-9. Cold Chemical Building Tanks

6.3.2 Civil/Structural Modification

This civil/structural construction contract, completed in 1991, modified the CTS Building to bring it to its final configuration and to allow for installation of the process equipment. Specifically, it modified the structural steel building, added more floor space, and installed underground fire sprinkler mains and floor drains. This portion of the work was relatively straightforward in that the WVNS Construction Department controlled the area and no operational facilities were adjacent to the CTS Building.

The wall modules, installed by the first contract, had a stainless steel face on the radioactive or hot side of the Cell wall to be used as the interior form work for placing concrete. The unique portion of this work was placing concrete in these wall modules.

WVNS and the DOE consulted with the NRC on the issues involved in forming the wall modules. All parties were interested in developing a method of concrete placement that would ensure no voids within the concrete interior of the wall modules. It was decided to construct a prototype wall to demonstrate the placement of the specially developed concrete mix. The concrete was placed in the prototype wall, with the procedures and techniques used for placement being carefully watched and critiqued. The wall was then evaluated by destructive examination and this indicated that the concrete did flow around the numerous wall penetrations. The placement of concrete in the actual modules progressed well as a result of the lessons learned from the prototype (see figure 6-10).

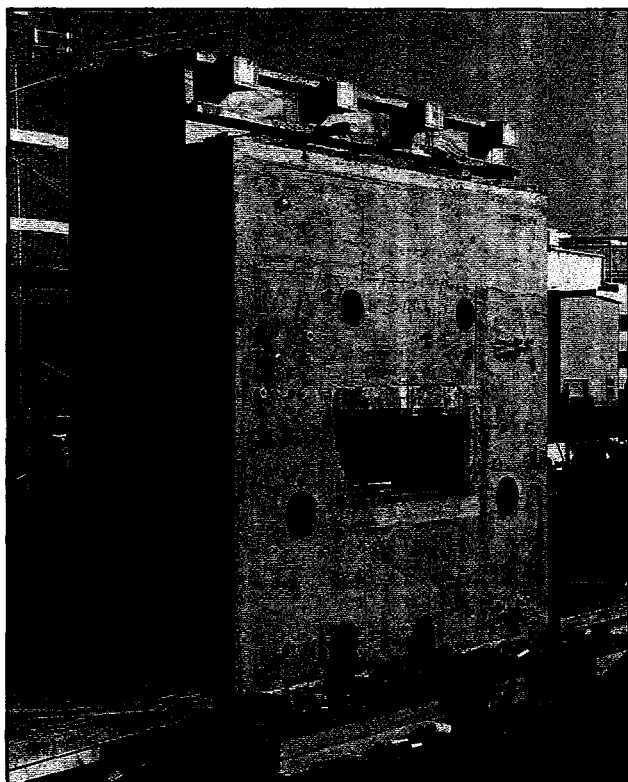


Figure 6-10. Wall Module Mock-up

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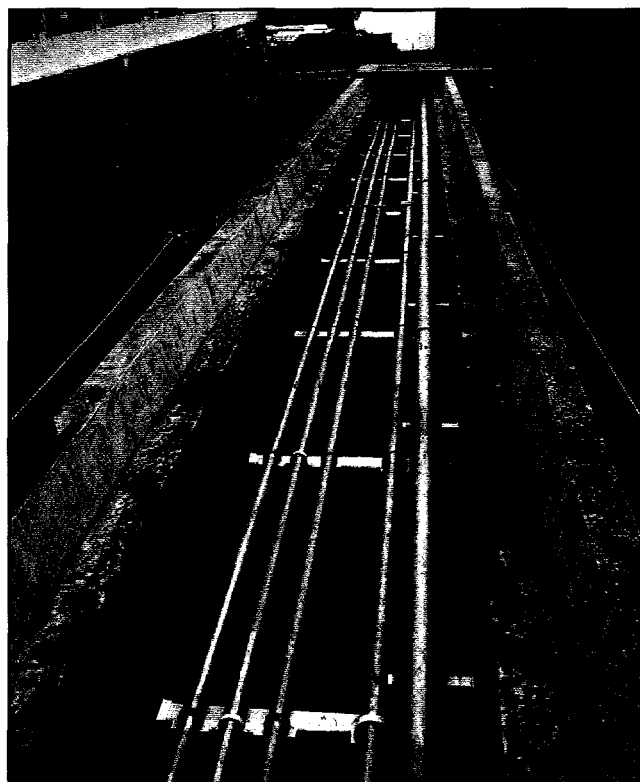


Figure 6-11. High-level Waste Trench

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The other major portion of this contract installed the HLW trench that extends from the WTF to the Vitrification Cell. This trench consisted of a 0.31 m (1 ft, 2 in.) thick concrete floor, 0.5 m (1 ft, 8 in.) thick concrete walls, and 0.61 m (2 ft) thick removable concrete covers. The floor and walls were cast-in-place using conventional form work. In addition, there were four concrete valve and jumper pits constructed adjacent to the trench (see figure 6-11).

The concrete covers were fabricated off site at a precast concrete contractor's shop. There were several different sizes and shapes that were cast in custom steel forms. The quality of these covers was acceptable, with tight dimensional accuracy. The covers fit the cast-in-place concrete trench with only minor grinding.

6.3.3 Mechanical/Instrumentation and Control/Electrical

Mechanical, instrumentation and control (I&C), and electrical construction, completed in 1994, installed all of the in-cell process equipment including vessels, jumpers, pipes, the off-gas system, the ventilation system, and the electrical systems. The contract also installed all the controls, electrical, piping for utilities, and equipment located outside the Cell to support and operate the in-cell processes.

The layout of in-cell process equipment provided some opportunities for innovative installation methods. One method required the installation of 60 stainless steel pipes and conduits from the hot face of the Cell wall to the stub wall. The hot face of the Cell wall and the stub wall are perpendicular to each other and the space allocated for this installation was 1.0 m (3 ft, 3 in.) from the hot face by 3.3 m (10 ft, 10 in.) from the stub wall by 2.0 m (6 ft, 7 in.) high. Approximately 120 field welds were made in this area. The sequence of installation was critical; one pipe installed in the wrong sequence could make it difficult to install additional pipes at a later date.

Many areas of the facility had been modeled three-dimensionally on a computer to check for interferences. It was decided to use this modeling to create the isometric drawings and provide them to the subcontractor. Using this approach saved several weeks in the planning and approval cycles, and allowed the cell equipment to be installed earlier than scheduled (see figure 6-12).

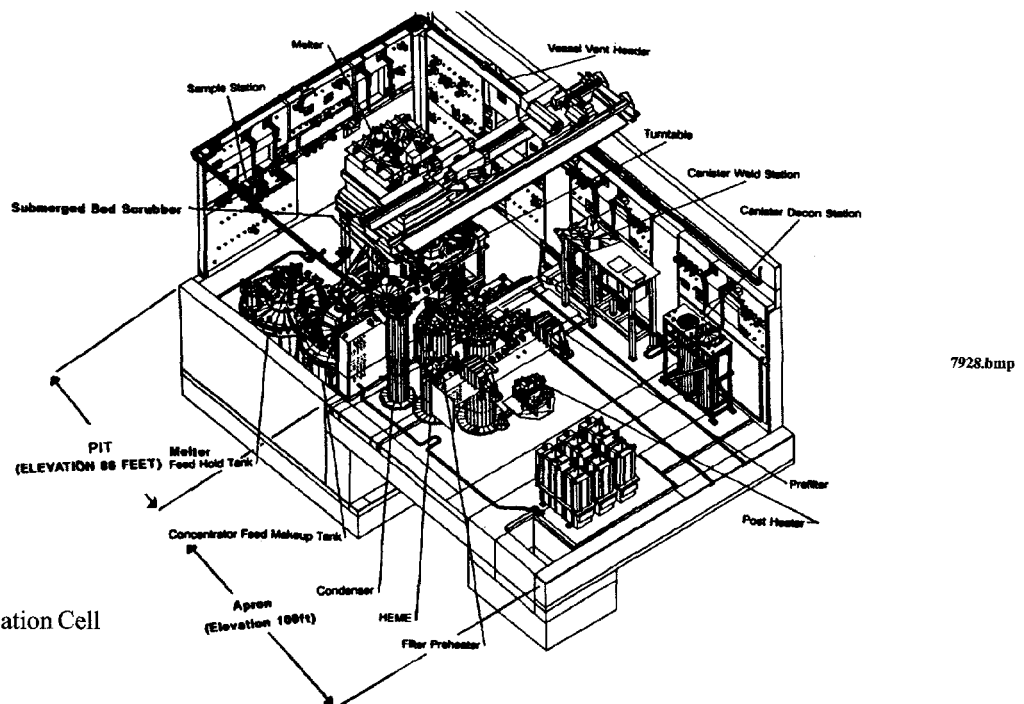


Figure 6-12.
Computer Model of Vitrification Cell

The HLW transfer pipe was also installed in the HLW trench as a part of this contract. The trench is 137.2 m (450 ft) long and from 762 mm (2-1/2 ft) to 1.83 m (6 ft) wide. There are 762 m (2,477 ft) of Schedule 40 stainless steel transfer pipe encased by a Schedule 40 stainless steel guard pipe. The pipe was placed in the trench on multiple layers of pipe supports with tight tolerances and critical slopes for drainage. This work required careful planning to ensure that 100 percent of the transfer pipe joints could be radiographed. The installation and field radiography took place in a physically tight area that required confined space entry qualified personnel.

The final seismic evaluation caused some redesign of the transfer piping in the HLW transfer trench. This was done before the subcontractor began shop fabrication of the transfer pipe, thus minimizing the impact to the overall schedule. After all of the piping was installed and inspected, the trench covers were placed on the trench, the joints caulked, and the covers and upper side of the trench insulated.

6.3.4 Ex-cell Off-gas Facility

The ex-cell off-gas facility construction, completed June 1995, modified and added to the existing 01-14 Building to create a NO_x Abatement Facility. The existing building was made of reinforced concrete and included hot cells, Ventilation Room equipment, controls, and on-going processing of liquid waste. The construction additionally included modification of the off-gas trench to accommodate the off-gas piping. This trench was also used for shielding the liquid transfer line.

Construction of the 01-14 Building was one of the most challenging parts of the vitrification facilities. The challenge arose because one half of the building was being used by Operations to process liquid waste and the off-gas trench was being used for transferring liquid waste. The utilities and controls were located on both sides of the building and careful scheduling and coordination were necessary to allow production to continue. This construction included the challenge of sequencing the demolition of various systems during operations and relocating operating systems with only short duration shut downs. Also, the building expansion took place in the winter and construction areas had to be winterized with temporary heat and additional shelters erected. Maintaining access was difficult and it became necessary to install more stairs, walkways, heating systems, and lighting.

Most of the construction in this phase was performed in a radiological buffer area. Other hazards associated with this phase of construction included asbestos abatement of insulation around vessels and roof penetrations, excavations in radiologically contaminated areas, installing fasteners in contaminated concrete, performing 25 radiological hot taps, and performing the majority of work in confined spaces, as required by DOE Orders, consistent with the Occupational Safety and Health Administration (OSHA) requirements. Furthermore, all crane work had to be sequenced carefully to accommodate limited operating areas and areas that were populated by workers.

6.4 Safety

In 1994 and 1995, during the peak building period, construction safety at the WVDP had one of the lowest Total Recordable Case Rate (TRC) of any active DOE site; finishing 1994 with a TRC of 3.34 and 1995 with a TRC of 3.44. This is significantly less than the construction industry average of 12.2 and the DOE construction average of 7.5. The overall TRC for all construction on this Project, including subcontractors, is 4.9. This figure represents 11 years and 2.5 million person-hours.

6.5 Vitrification Facility Hot Tie-ins

Minor construction tasks were required to complete the connection or tie-in of existing radiologically contaminated (hot) facilities of the former reprocessing plant and the WTF with the VF. The work activities for these tie-ins were organized into four specific areas/operations: 1) EDR/CPC 2) Tanks 8D-3 and 8D-4 3) 8Q-5 Jumper Pit and 4) pneumatic sample transfer (manufacturer by SGN) system.

Preparatory activities finished in advance of the tie-in work included Vitrification Cell closure, sample transfer cell closure, final preparation of procedures, testing, training, control interlock checks, final equipment/instrumentation preparation, and final inspections. A Line Management Self-Assessment (LMSA) was conducted to confirm readiness for various phases of vitrification startup. LMSA release-point 9 provided the final confirmation that all work required for radiological operations, including the hot tie-ins, has been completed.

Construction activities for the tie-ins took place during April and May 1996.

6.5.1 EDR/CPC Tie-in

Connection of the EDR and CPC (or HLWIS) consisted of the following activities:

- Closing Door M-001.
- Removing the HVAC isolation barrier in front of Door #8 and the contamination barriers in the EDR.
- Disposing of contaminated material.
- Adding shielding in front of the CPC door.
- Adjusting the cart track elevations.
- Installing the cart charging shoes.
- Functionally testing the canister transfer hardware from canister receiving to insertion at the EDR.
- Functionally testing cart movement and battery charging.
- Demonstrating canister transfer and storage in the CPC.
- Monitoring air flows and pressure differentials.
- On-going clean-up and decontamination.

6.5.2 Tanks 8D-3 and 8D-4 Tie-in

Connection of Tanks 8D-3 and 8D-4 in the WTF to the VF consisted of the following activities:

- Installing the containment tent.
- Installing piping spool pieces (2 double-wall lines).
- Inspecting welds.
- Removing the containment.
- Insulating the piping.
- Installing back-fill, shielding, and installing concrete barriers.

6.5.3 8Q-5 Jumper Pit Tie-in

The 8Q-5 Jumper Pit, located between HLW Tanks 8D-1 and 8D-2 and the VF, required the installation of remotely removable jumpers to enable the transfer of high-level waste into the facility (see figure 6-13). The following steps were necessary to make the connection:

- Verifying valve line-up.
- Installing temporary shelter and heater connections.
- Removing blind flanges and blank connectors.
- Verifying limit switch function on jumpers.
- Installing waste transfer jumpers (3 lines).
- Making electrical connections.
- Leak-checking the jumper installation.
- Installing labels and completing photography.
- Verifying pit leak detection and final closure approval.
- Removing pit drain plug/vent plug, installing last pit covers, and sealing the pit.
- Installing valve handles and labels.
- Removing the temporary shelter.
- Installing the fiberglass enclosure and seal.
- Completing the electrical hook-ups (heat, lights, etc.) to the enclosure.

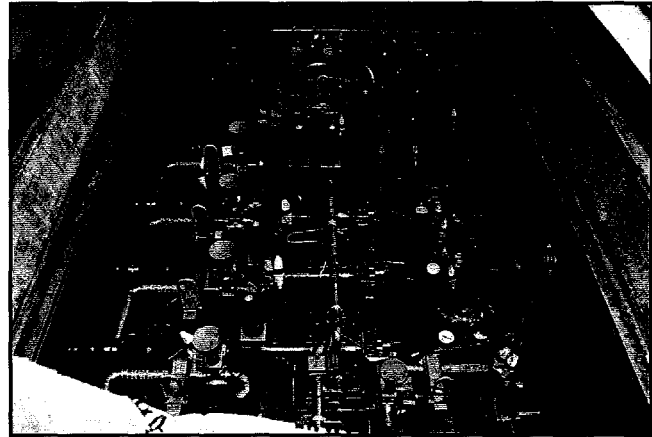


Figure 6-13. 8Q-5 Jumper Pit

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6.5.4 Pneumatic Transfer System Tie-in

Connection of the pneumatic sample transfer system, adjacent to the Vitrification Cell, to the Vitrification Labs for the transfer of sample rabbits consisted of the following activities:

- Final logic checking and verifying the final configuration.
- Testing rabbit transfer from the sample sell.
- Testing rabbit transfer from the Supernatant Treatment System (a separate transfer route).

6.6 Shielding

A final verification of shielding for the tie-ins was completed by Vitrification Operations and the Radiological Controls groups.

7.0 WASTE VITRIFICATION

Vitrification technology, from waste-form composition to the equipment needed to produce canistered waste forms, has been developed and tested for immobilization of the HLW stored at the WVDP. At the inception of the WVDP, two wastes were stored in underground tanks. The majority, 2,300 m³ (607,000 gal.), was neutralized PUREX waste. Another 40 m³ (10,566 gal.) of partially processed THOREX waste was also stored. The PUREX waste was washed to minimize the sodium and sulfate salts to be vitrified. The original PUREX supernatant and wash solutions were decontaminated using a zeolite ion-exchange process to retain the cesium. Presently, PUREX, THOREX, and zeolite wastes have been combined and are ready for vitrification.

A series of potential waste-form compositions, based on borosilicate glass formulations, were tested against the DOE Office of Environmental Management Waste Acceptance Product Specifications (EM-WAPS).⁵¹ Based on the results of these tests, a target composition (termed Reference 6) was selected for the radioactive vitrification campaign. This composition meets the waste-form acceptance requirements for eventual disposal in a deep, geologic repository.

The following sections describes development of the waste-form recipe:

7.1 Waste-form Development

As discussed above, the WVDP high-level wastes have been pretreated and combined, forming a single stream to be vitrified. The estimated composition of the individual wastes and the blended stream are shown in figure 7-1.

Component	PUREX*	THOREX	Zeolite	Waste Streams Total	Glass-Forming Additives	Final Glass	Ref. 6 Glass, %
Al ₂ O ₃	4.1E+03	1.0E+03	9.8E+03	1.5E+04	1.4E+04	2.9E+04	6.0E+00
B ₂ O ₃	3.0E+01	2.7E+02	0.0E+00	3.0E+02	6.1E+04	6.2E+04	1.3E+01
CaO	1.7E+03	1.0E+01	4.6E+02	2.2E+03	1.3E+02	2.3E+03	4.8E-01
Fe ₂ O ₃	5.3E+04	2.8E+03	2.0E+03	5.8E+04	0.0E+00	5.8E+04	1.2E+01
K ₂ O	0.0E+00	1.2E+02	1.9E+04	1.9E+04	4.4E+03	2.4E+04	5.0E+00
Li ₂ O	4.0E+00	0.0E+00	0.0E+00	4.0E+00	1.8E+04	1.8E+04	3.7E+00
MgO	4.0E+02	1.0E+01	4.4E+02	8.5E+02	3.4E+03	4.3E+03	8.9E-01
MnO	2.7E+03	4.0E+01	0.0E+00	2.7E+03	1.2E+03	3.9E+03	8.2E-01
Na ₂ O	7.0E+03	2.4E+02	1.2E+04	1.9E+04	2.0E+04	3.8E+04	8.0E+00
P ₂ O ₅	5.7E+03	5.0E+00	0.0E+00	5.7E+03	4.5E+01	5.8E+03	1.2E+00
SiO ₂	7.1E+03	6.0E+01	3.8E+04	4.5E+04	1.5E+05	2.0E+05	4.1E+01
ThO ₂	0.0E+00	1.7E+04	0.0E+00	1.7E+04	0.0E+00	1.7E+04	3.6E+00
TiO ₂	1.0E+00	0.0E+00	3.3E+02	3.3E+02	3.5E+03	3.8E+03	8.0E-01
UO ₃	3.0E+03	4.2E+00	0.0E+00	3.0E+03	0.0E+00	3.0E+03	6.3E-01
ZrO ₂	1.2E+02	0.0E+00	0.0E+00	1.2E+02	6.2E+03	6.3E+03	1.3E+00
Other†	7.3E+03	6.0E+00	7.4E+02	8.0E+03	1.2E+02	8.1E+03	1.7E+00
Total	9.2E+04	2.2E+04	8.3E+04	2.0E+05	2.8E+05	4.8E+05	1.0E+02

*Washed PUREX sludge.

†Oxide components that individually constitute less than 0.5 percent of the glass.

Figure 7-1. Estimated Oxide Content of the WVDP Glass, by Source (kilograms)

Two sets of glass properties form the acceptance criteria as the waste-form composition evolved: the waste glass had to be processed using demonstrated technology and it must have high leach resistance (durability) as measured by the Product Consistency Test (PCT) protocol. The technology at this time was a joule-heated melter using Inconel™ electrodes. This implies an oxidizing glass melted at a maximum average temperature of 1,150° C (2,102° F).

To assure that the glass was consistent with this technology; viscosity, electrical resistivity, and liquidus temperature limits were established. These glass property limitations are shown in figure 7-2.

Parameter	Acceptance Criteria	Reference 6 Glass
Viscosity at 1,100° C	$20 \leq \mu \leq 100$ poise	50 poise
Liquidus Temperature	$\leq 1,050^\circ \text{C}$	1,000° C
Glass Electrical Resistivity at 1,100° C	$\geq 5 \Omega - \text{cm}$	$\sim 10 \Omega - \text{cm}$
Glass Transition Temperature	$\geq 400^\circ \text{C}$	450° C
Normalized PCT Results:	boron < 16.8 g/l	0.6 g/l
	lithium < 9.0 g/l	0.7 g/l
	sodium < 13.3 g/l	0.7 g/l

Figure 7-2. Glass Selection Process Constraints

To achieve the second glass development measure, durability, the candidate waste glass leach rate must be lower than a glass standard. More specifically, the target glass composition performance has to be statistically demonstrated to be superior to the Environmental Assessment (EA)⁵² glass using the PCT. This performance criterion is stipulated by the EM-WAPS.

Component	Glass Composition (weight %)						
	WV-183	WV-192	WV-205	ATM-10	Ref. 4	Ref. 5	Ref. 6
Al ₂ O ₃	2.40	2.46	2.83	6.50	6.47	6.45	6.00
B ₂ O ₃	15.50	13.94	9.96	9.26	10.29	12.89	12.89
CaO	0.70	0.73	0.60	0.56	0.68	0.68	0.48
Fe ₂ O ₃	12.30	12.25	12.16	11.31	12.04	12.02	12.02
K ₂ O	0.17	0.21	3.58	3.33	3.62	3.18	5.00
Li ₂ O	—	0.72	3.03	2.82	3.16	2.71	3.71
MgO	0.10	0.31	1.30	1.21	0.89	0.89	0.89
MnO	0.40	0.81	1.07	1.00	0.82	0.82	0.82
Na ₂ O	14.70	13.57	10.94	10.17	11.17	9.82	8.00
NiO	0.45	0.89	0.32	0.32	0.25	0.25	0.25
P ₂ O ₅	2.60	2.91	2.51	2.33	2.38	2.37	1.20
SO ₃	0.20	0.24	0.22	0.27	0.23	0.23	0.23
SiO ₂	44.59	46.05	44.90	44.90	40.93	40.93	40.98
ThO ₂	—	—	3.59	3.34	3.60	3.60	3.56
TiO ₂	0.03	0.15	0.98	0.91	0.77	0.80	0.80
UO ₃	—	—	0.59	0.55	0.58	0.58	0.63
ZrO ₃	1.65	2.70	0.29	0.27	0.32	0.32	1.32
Others	4.21	2.06	1.15	0.95	1.80	1.46	1.22

Figure 7-3. Target Glass Compositions Tested at the WVDP

Using these waste-form composition selection criteria, a series of reference glasses evolved,⁵³ (see figure 7-3). The Reference 6 glass formulation was ultimately selected as the final waste form using the criteria discussed previously. The measured processing characteristics of the Reference 6 composition are listed in figure 7-2. The major chemical additions needed to convert the blended HLW into the Reference 6 waste-form are listed in figure 7-1.

7.2 Vitrification Process Testing

The WVDP vitrification process testing has been performed at scales ranging from full-sized production equipment, to examine the interaction between the various unit operations; to bench-top procedures, for studying process chemistry and waste-form performance issues. This section summarizes several of the test programs that were used to develop the vitrification flowsheet or generate waste acceptance data required by the DOE.

The full-scale vitrification process was tested using nonradioactive, simulated wastes at the WVDP from 1984 to 1989. This testing developed the operating parameters and generated some of the waste-form qualification data required by the DOE Office of Civilian Radioactive Waste Management.⁵⁴ The full-scale test runs, summarized in figure 7-4, represent a significant step in the understanding of HLW vitrification processes. In fact, the quantity of glass melted during this testing represents approximately one-third of the total waste glass production planned during the radioactive campaign. The later stages of this testing sequence demonstrated that the vitrification system consistently produces canistered waste-forms with predictable chemistry and properties. This was a milestone toward establishing that the radioactive waste glass product will meet or exceed all of the DOE acceptance criteria and was key to enabling the WVDP to be the first site to obtain DOE acceptance of its WQR in August, 1995. As the WQR presents the data needed to demonstrate compliance with the DOE waste-form qualification requirements, its completion was one of the most important accomplishments in the progression toward authorization for the radioactive demonstration campaign.

The PCT testing was performed using the correct glass chemical formulation, generally with nonradioactive isotopes of the elements. To enable the Project to perform relevant glass performance studies with the actual WVDP waste-form, WVDP radioactive waste samples were combined with the appropriate glass-forming chemicals and melted to form the Reference 6 glass for PCT testing at the PNNL's Materials Characterization Center.

The testing has shown that the target glass composition, Reference 6, meets all the acceptance requirements for a deep geologic repository. Crystallization remains low in this formulation under very slow cooling conditions and this minor devitrification does not affect waste-form leachability. The PCT leaching data on the target glass are almost an order of magnitude lower than the DOE acceptance standard specified in the WAPS. Under all process conditions, the viscosity and electrical resistivity of the glass are within the processing range and have been shown to provide adequate melting and production rates in the full-scale production melter.

Run	Glass Composition	Slurry Fed l	Glass Produced kg	Canisters Filled
LIEF	WV-183A	---*	4,050	1.00
AT-1	WV-183A	---*	550	0.25
AT-2	WV-183A	---*	650	0.25
SPRVIL N	WV-183A	---*	250	0.25
TC PREP	WV-183A	---*	200	0.25
TC1AIRL	WV-183A	---*	250	0.25
TC-1	WV-192B	---*	1,450	1.00
TC-2	WV-192B	---*	1,550	1.00
TC-3	WV-192B	---*	3,650	2.00
OH	WV-192B	---*	500	0.25
SF-1	WV-192B	850	300	0.25
SF-2	WV-205	9,800	3,400	2.00
SF-3	WV-205	8,900	3,100	2.00
SF-3 OH	WV-205	1,200	400	0.25
EVAC	WV-205	---†	0	4.00
CIEF	WV-205	---*	1,600	0.00
SF-4	WV-205	5,800	1,900	1.00
SF-4 NO3	WV-205	1,600	500	0.25
SF-5	WV-205	4,400	1,400	1.00
SF-6	WV-205	8,600	2,600	2.00
TC-4	WV-205	---*	7,000	3.00
SF-7	WV-205	10,500	3,500	2.00
SF-8	WV-205	9,600	3,450	2.00
SF-9	ATM-10	23,300	7,600	4.00
SF-9A	ATM-10	6,800	2,100	1.00
TC-5	WV-183 & 205	---*	12,300	6.00
SF-9B	ATM-10	19,300	6,450	3.00
SF-9C	Water	---§	0	0.00
SF-9Ci	ATM-10	2,445	1,050	1.25
SF-10	ATM-10	28,500	10,500	6.25
SF-10A	Ref. 4	17,000	7,200	4.00
SF-10B	Ref. 4	11,500	5,300	3.00
SF-10Bi	Ref. 4	10,980	5,600	3.00
TC-6	Ref. 4	---*	8,200	4.00
SF-10C	Ref. 4	11,500	4,900	2.00
SF-11	Ref. 4	31,200	13,100	7.00
SF-12	Ref. 4	65,100	26,600	15.00
TOTALS		288,875	153,150	85.75

* Premelted frit added to melter, not simulated waste slurry

† Melter draining method demonstration

§ Water addition test

Figure 7-4. Full-scale Test Summary

7.3 Scale Vitrification System-III (SVS III) Testing

The SVS-III consisted of a 1/6-scale melter and associated tankage used for off-line testing of the vitrification process. The SVS-III test series⁵⁵ was designed to collect additional data regarding the use of the iron ratio ($\text{Fe}^{+2}/\text{Fe}^{+3}$) to forecast and monitor redox behavior of the molten glass. This test series successfully demonstrated the ability to ensure that the redox behavior of the glass will be acceptable. In addition, melter operation parameters; such as feed rate, cold cap coverage, glass melt and plenum temperatures, and melter power; were controlled successfully to provide steady-state operating conditions during the melter test runs.

The SVS-III runs also provided an opportunity for hands-on training of vitrification operators in melter operation, support system technology, and Conduct of Operations.

7.4 Waste Acceptance Process

The WVDP canistered waste-form must conform to the specifications put forth in the EM-WAPS. The plan for meeting these specifications was laid out in the compliance plan for the site, first published in 1988, and most recently published as Revision 9 in 1995.⁵⁶

The EM-WAPS is divided into five sections:

1. Waste Form Specifications
2. Canister Specifications
3. Canistered Waste Form Specifications
4. Quality Assurance Specification
5. Documentation and Other Requirements.

The Waste Compliance Plan (WCP), which generally described the approach to meeting the specifications, was reviewed and approved by a DOE Technical Review Group (TRG). This TRG also reviewed and approved the final description of how WVNS has met and will meet the EM-WAPS in the WQR. The WQR describes in detail the methods used, experimental results, and specific details of methods to comply with the EM-WAPS. It is this document, and the records required to be produced by this document, that form the basis of the final acceptability of the WVDP canisters of radioactive glass.

7.5 Radioactive Operations

The FACTS runs, particularly SF-12, demonstrated that process controls have been developed to control batch-to-batch variations during the production of radioactive glass.

After the cold chemical additions have been mixed with the radioactive waste slurry, samples are obtained. The chemical composition of these samples is tested to confirm both the attainment of the desired slurry formulation and mass balance closure (i.e., CFMT waste slurry sample analysis + cold chemical additions sample analysis = the analytical results from the slurry taken after the wastes and glass-former additions have been blended together). The test for verifying attainment of the desired slurry composition is two-fold. First, the batch mean values must be within the expected process region. Second, it must be shown that the predicted PCT result, based on the feed composition, is acceptable after accounting for applicable uncertainties. (Further details, including the definition of the expected process region and the particulars of the PCT prediction, are provided in WQR Section 1.3.) If the combined waste and glass-former slurry samples fail this test, additional sampling or

chemical addition operations will be performed and the acceptance test repeated. Only after the combined waste and glass-former slurry sample has successfully been shown to meet the requirement will the slurry batch be transferred to the MFHT for vitrification processing.

To determine the oxide composition of the waste form to be reported in the production records, chemical analysis of glass shards are made. Shards are taken from each canister. About 10 percent of the canisters will have their shards analyzed, the remaining shards will be archived. The reported composition must include all elements, excluding oxygen, present in concentrations greater than 0.5 percent by weight of the glass.

The chemical analysis will be done by inductively coupled plasma atomic emission spectroscopy (ICP-AES). Quality control standards will be run after every tenth elemental analysis and after every calibration. Corrections will be made for any analytical bias detected.

8.0 VITRIFICATION TEST PROGRAM

After completion of the functional and checkout testing of systems (FACTS) program in late 1989, the VF process components and subsystems were examined, modified, and prepared for conversion to radioactive service.

Functional and checkout tests were conducted both on site and at equipment vendors until activities were initiated to place the VF systems into service in early 1995. As the piping and instrumentation systems were installed, the construction contractor for each system flushed the system and performed leak checks, and hydrostatic, continuity, megger, and initial checkout tests. After the VF systems were placed into service, start-up tests were run to evaluate the equipment operation before the start of the integrated test runs. The start-up testing strategy was to begin elemental testing of components, progressing to subsystems testing, then system testing, and finally integrated testing of the entire facility.

8.1 Vendor Testing

One of the main objectives of the FACTS program was to demonstrate the ability to produce high-quality glass using prototypical components and subsystems. Some components, such as the CFMT, MFHT, and Cold Chemical Tanks, were retained from the FACTS program and refurbished for radioactive service. Others, such as the melter, canister turntable, and VF off-gas system (i.e., SBS and vessel vent condenser), were subject to design modification, fabrication, and checkout testing performed at equipment vendors and off-site test facilities.

The general philosophy was to perform testing of components and subsystems at the vendor, prior to delivery to the site, to confirm operability before being installed in the facility. All procured components were tested for basic performance, electrical continuity and insulation megger tests, hydrostatic and leak tests, and load tests. Other major components were tested more extensively to determine correct performance; these are discussed below:

After the FACTS program, the turntable was extensively redesigned. Bellows were used to improve the seal on the canister and alleviate air in-leakage problems. An Infrared Level Detection System (ILDS) was developed and a periscope was added to improve pour viewing. The drive mechanism also was improved.

After fabrication, an extensive test program was conducted at the vendor's facility. Air leakage, drive mechanisms, load cells and calibration tests, canister insertion/removal, mechanism tests, drive control, and remote aspects were all tested prior to delivery of the component to the site.

As the first component for treating melter off-gases, the SBS is the only source for off-gas quenching and, therefore, is critical to process operation. Evaluations of the SBS made after FACTS revealed several inadequacies in this component's design, fabrication, and operation, including insufficient circulation velocity in the scrubber bed and receiver, poor cooling coil efficiency, and solids accumulation in the scrubber bed. A new concept was developed for suspending and removing solids from the scrubber.⁵⁷ Extensive testing was performed at the Westinghouse Science and Technology Center (WSTC) between September 1992 and March 1993. This concept is described in the Solids Suspension and Removal System Testing Procedure developed at the WSTC.⁵⁸ Developmental testing was done to determine how many nozzles were needed to suspend solids and how they should be positioned in order to establish the desired flow. These tests also determined the flow rate needed to suspend or mobilize solids, establish conditions for withdrawing solids from the bottom of the vessel, and demonstrate the motive force required for solids suspension.

Parametric testing was done to determine the flow rate and nozzle orientation needed to mobilize solids in the test vessel (both horizontal and vertical angle placement), as well as the most effective conditions for nozzle position, bore, and flow velocity. Parametric testing was also used to demonstrate solids withdrawal and suspension from the test scrubber, and to prove that the scrubber was capable of removing settled solids from both the scrubber and receiver so that no more than two gallons of liquid remained in either vessel.

Under test conditions defined in the Solids Suspension and Removal System Testing Procedure, the WSTC was able to demonstrate that the recommended design was capable of mobilizing, centering, and withdrawing solids while allowing for removal of solids and water at the conclusion of vitrification operations. Test results and recommendations for actual operations were incorporated into a final test report that was prepared and issued March 1993.⁵⁹ The new SBS was brought on site for performance testing September 1993.

Extensive development and performance testing was conducted at the vendor for the canister lid welder. Initial proof-of-principle testing of welds were made using a pulsed-arc, gas tungsten arc welding (GTAW) process. Further testing optimized amperage and voltage ranges, travel speed, and electrode configuration. A computer control system was developed that automated the weld process. Configuration of the testing was checked by helium leak tests at 1.1×10^{-9} atm cc/sec., metallographic, and fractographic techniques. Final proof-of-principle testing included simulated drop tests of the canister at heights of seven meters to ensure the integrity of the lid weld. The developmental testing, started at the vendor, continued on site during mock-up testing done at the Vitrification Test Facility (VTF).

A series of transfer cart component tests was performed at the Oak Ridge National Laboratories (ORNL) March 1994. Testing was then conducted at the vendor to confirm actual function. Based on the results obtained through vendor testing, additional modifications were made and components tests conducted at the ORNL May 1994.

A series of performance tests was conducted at the vendor for HVAC fans, as well as primary and secondary filter units. These tests included pressure-drop tests, flow distribution, dioctyl phthalate (DOP) injector nozzle tests, remotability, filter removal, and fan performance tests. In addition, the primary and secondary HEPA filters for the HVAC system were DOP aerosol mix- and leak-tested, and in-cell coolers were performance- and capacity-tested.

Seismic qualification tests for the HVAC control panel, individual components, and filter actuation mechanisms also were performed by the vendor.

When FACTS runs were completed, a series of modifications were made to expand the cold chemical feed preparation system for production use. In addition, several design changes were made to the venturi scrubber, which is the main component of the Cold Chemical System vessel ventilation subsystem, and the Vac-U-MaxTM, which is the pneumatic subsystem for dry chemical transfers. These changes were made to reduce unwanted material build-up and vapor migration in process equipment and piping. Performance tests for these subsystems were conducted at the vendor. The Vac-U-MaxTM tests included transfer efficiency and the procedures required to transfer powdered chemicals.

The back-up diesel generator was seismically tested at a selected vendor in accordance with engineering specifications. Tests included preliminary vibration checks run along the centerline of the diesel generator. These checks were used to establish a verification baseline prior to shake-testing the generator under an operating load.

Shake tests were performed at prescribed intervals with the diesel running at loads of 100 kW to 600 kW. No conditions of failure were found. Performance tests of the generator were conducted at the vendor prior to and after the seismic tests to verify correct performance.

8.2 Performance and Mock-up Testing

Various VF components, process methods, and subsystems required mock-up or full-scale testing before being placed into service; including the canister welder and welding process, slurry concentration and glass oxidation (Redox) control methods, canister decontamination subsystem, and DCS. In addition, several remote-handling techniques needed to be developed, including those used for Analytical Cell operations and slurry sampling.

8.2.1 Weld Testing

Background testing of the canister lid welder that began at the vendor was continued when the welding machine was delivered to the WVDP. The welder is an automated machine with a computerized ex-cell controller that operates the in-cell welding head. The controller monitors and controls eight separate weld parameters: arc current and voltage with a stationary electrode (two parameters); arc current and voltage with a moving electrode (two parameters); length of time an electrode is stationary or moving (two parameters); linear speed of a moving electrode; and gas flow rate. A set of target values for each parameter is preprogrammed into the controller as a "weld schedule." Part of the testing program involved developing a weld schedule (i.e., target values) that would produce a sound weld.

Initially, a series of six shakedown tests was performed to determine the reliability of the welder and to demonstrate the effects of selected weld parameters. Developmental testing was then performed to evaluate different set points for welder operating parameters. These set points were evaluated according to the quality of welds produced, as well as corresponding sensitivities to variable changes. Qualification tests also were run to confirm the set points determined during developmental testing.

Over 200 developmental and qualification tests were conducted that included hydrostatic burst-testing; macro-etch, micro-metallographic, and visual examinations; helium leak-testing; ferrite level measurements; and drop-testing. During performance of the first series of demonstrations tests, the automatic voltage controller (AVC) unit was observed to be "hunting" when the electrode changed from dwell to travel or vice versa. This observation was based on deviation from the desired square waves recorded on strip charts. After consultation with the vendor, a revision was made to the welder software to diminish hunting between intervals.

During performance of one of the final series of developmental tests, a canister flange fabrication weld was found to cause an arc blow, a weld aberration that makes visual inspections more difficult. Several canister fabricators suggested using ring-forged flanges, instead of a flange with a fabrication weld, to prevent an arc blow from occurring. Two ring forgings were purchased and a lid was welded onto one of these assemblies using a weld schedule formulated during developmental testing (Schedule 47). There was no arc blow and the weld had a good appearance. Based on this experience, the canister flange design was changed. In addition, the width of the land on which the lid sits in the flange counterbore was increased from 3.18 mm (1/8 in.) to 6.35 mm (1/4 in.). This made the welding process less sensitive to weld sag caused by accidental increases to heat input and arc blow due to other unforeseen circumstances.

Near the conclusion of developmental testing, six canisters were welded using the new weld schedule (Schedule 47). Five of these canisters were drop-tested at PNNL to demonstrate compliance with the drop-test specification defined in the WCP. Each canister met helium leak-tests before and after drop-testing. Canister lid welds were also evaluated by burst- and metallographic testing to determine compliance with the requirements.

Results of both demonstration and qualification testing showed that the canister lid weld process and the selected weld schedule produced a structurally sound weld that met leak-tightness requirements and did not induce microfissuring or sensitization. During the entire testing program, the remote aspects of the equipment were tested and subsequently improved upon.

8.2.2 Slurry Concentration and Glass Oxidation Control Testing

Operation control parameters and waste-form qualification data were developed during FACTS testing. This required several process simplifications to achieve test objectives. One major process simplification involved the use of a concentrated waste simulant to reduce the volume of aqueous effluents resultant from the process. This simplification was necessary to reduce waste disposal costs. In addition, the acidic quality of the concentrated waste simulant produced rheological properties required for process equipment.

Actual HLWs to be processed are basic (pH 11, approximately) and approximately 15 percent solids. Laboratory trials to concentrate wastes to around 40 percent solids using actual waste conditions resulted in high slurry viscosity. The addition of nitric acid would resolve rheology problems but cause a volume increase that required multiple transfers to obtain sufficient solids for slurry feed batch preparation. Such a strategy would extend the feed preparation cycle to an unacceptable length of time.

A program to obtain required fluid properties, without extending the feed preparation cycle, was initiated. After demonstrating that several commercially available fluidizing agents were ineffective in obtaining required fluid properties, laboratory research was conducted that showed that additions of sodium metasilicate could suspend waste slurry at high solids concentrations. Using the one-eighth scale mini-melter in the VTF, the proper sodium metasilicate concentration was determined. Use of sodium metasilicate also was demonstrated during full-scale Vitrification Facility start-up testing.

A method for controlling the oxidation state of glass was needed to prevent foaming or the precipitation of conductive materials in the melter, which could result in damage to the electrodes used for joule heating. During FACTS testing, glass oxidation was verified by melting a slurry sample then chemically analyzing it. This method was found to be unacceptable because of processing delays, increased radiation exposure, and mixed waste streams that would result from performing the chemical analysis. A predictive model that related the glass oxidation state to the concentration of nitrates and total organic carbon (sugar) was developed. Test runs were conducted during the SVS-III campaign to support this model.

Data from the SVS-III runs showed a greater glass reduction/oxidation (redox) response than had been anticipated when the model was developed. This increased responsiveness, combined with uncertainties concerning nitrate and carbon chemical analysis, indicated that the model was insufficient for predicting glass oxidation.

It was determined that the escalated redox response was caused by the presence of nitrites in the revised waste simulant composition. When the redox model was developed, it was assumed that nitrite salts would be washed from the wastes during pretreatment. Subsequent corrosion studies found that the presence of nitrite salts was necessary to passivate the steel vessels. This change invalidated the redox model and prompted the need for a revised methodology to control glass oxidation. A revised methodology was developed and tested during the SVS-III run and vitrification start-up testing.

8.2.3 Canister Decontamination Testing

Although extensive laboratory-scale testing, including radioactive tests of the canister decontamination process had been done at PNNL, full-scale testing of this system was needed to confirm the decontamination process. This testing was conducted in the VTF from 1992 to 1993.

Full-size, glass-filled oxidized canisters produced during FACTS were selected as test articles for full-scale testing of the canister decontamination system. A test method using coupons was developed and a test apparatus was built that paralleled the design of the proposed system. Three canisters were subjected to the decontamination process and test variations were conducted to evaluate different methods for achieving a more complete cleaning process. A final full-scale test run was conducted using modified concentrations of the selected chemical rinses (cerium +4 and nitric acid) to estimate effectiveness. Full-scale test results showed uneven cleaning of the canister surface on the bottom and sides. Analysis of the test coupons supported the speculation that the surface finish of the canister was a key factor in the variability of canister cleaning.

Full-scale testing confirmed that the proposed process could be used successfully by altering several aspects of the process, including adding a nitric acid rinse prior to the final water rinse, increasing the cerium concentration used in the decontamination process, and specifying a finer surface finish for the canister.

8.2.4 Distributed Control System (DCS) Testing

An off-line development laboratory was set up on site to develop and test system configurations before bringing the DCS on-line in the VF. The off-line lab used a small-scale mock-up of the system, as well as component simulations, to test various system components and configurations. Although smaller, the off-line lab included one of every component in the DCS system. Test activities included input and output testing, as well as 100 percent logic testing. The off-line lab was also used to test software changes that were required as the system was brought on line.

8.3 Start-up Testing

System preparation and performance testing was initiated after completion of construction turnover activities. Preliminary test activities included hydrostatic tests of system piping and continuity checks of the electrical circuits for valves and instrumentation to ensure proper signal transmission and response. After system piping, instrumentation, and associated equipment were functionally checked, tests were begun to evaluate equipment performance according to criteria given in test instruction procedures. These procedures were developed from specific testing requirements outlined in individual System Description Documents developed for each major system.

The test program was structured to allow for performance of the system and subsystem tests to be performed in parallel with each other so that integrated testing could begin once the required systems and subsystems had been placed into service. Early testing involved the performance of instrumentation and tank calibrations, as well as control logic and functional checks for primary process vessels and in-cell components, including the CFMT and MFHT, the melter, the off-gas and vessel ventilation system, and the turntable. Testing also was done to evaluate specific areas of in-cell component operation, including vessel heating, cooling, agitation, pressure control, bubbler probe operation (i.e, level, density, and pressure measurement), melter temperature and pressure control, melter viewing, off-gas and vessel ventilation function, and turntable function. A summary of in-cell vessel and component tests is given in figure 8-1.

Concentrator Feed Make-up Tank & Melter Feed Hold Tanks:

- Control Logic Checks for Agitators, Bubblers, and Heating and Cooling Coils
- Seal Pot Commissioning
- Miscellaneous Performance Tests with Water
- Transfers with Water
- Melter Testing

Pressure Control Valve Setting

- Main Melter & Overflow Heater Control Board Calibration
- Control Logic Checks for Periscope Steam and Air, Vent Valve, Film Cooler, Air Lift, Level, Density, Pressure, Glass Temperature Measure, Feed, and Ex-cell Off-gas Shutdown
- View System Power-up and Functional Check
- Calibration for Temperature Transmitters and Operating Instruments
- Pressure Control Commissioning
- Internal Thermocouple Operations Check
- Cooling Jacket Tests
- Discharge Lid Startup and Remote Test
- Thermocouple Operation and Electrode Cooling Check
- Cooling System Functional Test

Submerged Bed Scrubber and Off-gas Testing

- Cooling Instrument Calibration
- Cooling Commissioning
- Control Logic Checks for Cooling, Receiver Level, Density and Pump, Pressure Density and "C" Sampler, Bed and Off-gas Inlet Temperature, and Ex-cell Off-gas Blowers
- SBS Performance Test
- SBS to CFMT Transfer with Water
- "C" Sampler Performance Test

Figure 8-1. In-cell Vessel and Component Tests

After component evaluation and functional checks were completed, performance testing began. Performance tests were run in order to confirm component function and demonstrate actual operation before the start of integrated testing. Operational areas covered during performance testing included tank transfer and steam jet operation, utility operation, and HVAC performance testing.

8.4 Integrated Testing

Multiple systems and facilities are required to operate the VF. One of the primary goals of the vitrification test program was to demonstrate system operation, as well as to confirm component design, function, and operation. To meet this goal, a series of integrated operations (I. O.) test runs was developed. These test runs were structured to demonstrate system operation in a stepwise manner. Each integrated test run was developed according to specific operational task requirements, such as the ability to prepare slurry, feed the melter, or pouring glass in the canister. Six integrated operational runs were prepared that advanced through progressive stages of VF operation; from preparing slurry to operating the entire facility under full radiological control (i.e., simulating hot operations).

The purpose of the first integrated operations test run, I.O. #1, was to demonstrate the ability to prepare slurry using in-cell systems and components, including the CFMT, MFHT, melter (including melter viewing, pour viewing, film cooler, and canister infrared level detection systems), Control Room HVAC system, waste header, DCS, closed-loop cooling water system, SBS, and off-gas blowers and vessel ventilation system.

The purpose of the next integrated test runs, I.O. #2 and #3, was to demonstrate the ability to maintain melter feed operations using ex-cell off-gas, nitrogen oxide (NOx) abatement and HVAC systems, in addition to all the in-cell systems and components used during I.O. #1. These test runs also provided the opportunity to complete remaining performance tests, develop operator proficiency, and collect data regarding glass reduction/oxidation (redox) control and fluctuation.

The fourth integrated test run, I.O. #4, was used to operate the VF systems including the melter, off-gas, NOx abatement, ammonia monitoring, and VF support systems. It also was used to conduct operational repair testing of the melter and turntable. In addition, I.O. #4 was used to complete open Test Instruction Procedures (TIPs) and perform nonradiological transfer cart tests, sample transfer tests, ILD system retests, turntable checkout tests, and chemical addition tests for the CFMT and MFHT.

The purpose of the fifth integrated test run, I.O. #5, was to operate the Vitrification Facility as an integrated plant and complete two evolutions involving glass shard sampling, canister lid welding, and transfer of slurry from the CFMT to MFHT.

The purpose of the sixth and final integrated run, I.O. #6, was to operate the VF under full radiological controls, demonstrate the ability to safely perform operations, and conduct processing from canister load-in to interim storage in the CPC.

8.5 Test Observations and Lessons Learned

Performance and integrated operational test runs conducted during the vitrification test program provided a means for critical examination, observation, and evaluation of the vitrification system. Test data taken for each Test Instruction Procedure was used to evaluate component performance against system design and acceptance criteria, while test observations were used to correct, modify, or improve system operation. This process was critical in establishing operating conditions for the entire vitrification process.

8.5.1 Process Development

A major achievement of the FACTS program was the development of a strategy for producing high quality glass through knowledge of feed composition and process control. Integrated testing provided an opportunity to evaluate several process areas, including feed acceptance strategy, batch preparation, feed cycle timing, glass redox control, chemistry, and analytical methods.

The general strategy for feed acceptance developed during the FACTS program was validated during the integrated test runs. Experience and observations made during performance of SVS-III test runs were transferable to performance of the integrated test runs. The strategy developed for controlling glass redox during SVS-III operation proved valid during full-scale system operation.

Most of the chemistry and the analytical methods developed during the VTF mock-up testing performed as expected, although some differences were found in the length of time to perform these analyses when using the actual Analytical Cell. The time to prepare chemical analyses was determined to have a significant impact on the total duration of the vitrification process.

8.5.2 Primary Process Operation

Performance and integrated operational test runs were an essential means for evaluating key process areas and for determining the need to correct, modify, or improve system operations. Process areas evaluated during the test program included cold chemical system operation, in-cell component and system operation (i.e., off-gas and vessel ventilation systems), ex-cell off-gas and NO_x abatement system operation, and HVAC system operation.

8.5.2.1 Cold Chemical System

The basic order of chemical addition established during FACTS was confirmed during vitrification testing. This order follows general engineering principles for making chemical additions. Acid is added to water, liquids are added before dry chemicals to dissolve the chemicals better, and flush water is added after each liquid chemical. The volume of flush water is accounted for in the recipe. Dry chemicals that have an affinity for water (hygroscopic) are added before coarse materials that "scour" chemical addition lines. The mix tank and piping used for batch preparation are flushed at the end of a batch transfer.

8.5.2.2 Primary Process Vessels

Multiple aspects of the CFMT and MFHT operation were evaluated during the vitrification test program, including vessel heating and cooling, agitation, pressure control, bubbler operation (i.e., level measurement), seal pot operation, steam jet and transfer operation, and sampling.

Heating and cooling was evaluated for the CFMT both with water and with waste simulant (slurry). Performance tests showed that the CFMT could evaporate water at a target rate of 1,135.5 l (300 gal.) per hour. Tests done with waste simulant showed an evaporation rate of 378.5 l (100 gal.) per hour and 95 l (25 gal.) per hour. The slurry became too viscous near the concentration end point and heated more near the vessel jacket than the center. The target rate for CFMT concentration had been established according to estimated feed rate and production requirements. The need to meet this rate became less relevant since the actual concentration rate was found to be acceptable when combined with the actual melter production and lab analysis rates. The ability to modulate flow between the side and bottom coils to change evaporation rate for constant total heat input was demonstrated and the target cool-down rate was achieved during vessel cooling. In addition, testing showed that the tank level could be used to determine the end point for concentration. Changes in vessel concentration were used to modify the reference flow sheet.

Minor problems were experienced with control loops and water hammer during vessel heating and cooling. Potential for water hammer was corrected by changing piping to eliminate segments where water was collecting. The vessel control logic prevented reduced pressure from occurring in heating and cooling coils; no carryover (i.e., entrainment) was observed.

Testing showed that the agitators for the CFMT and MFHT could maintain slurry homogeneity within acceptable limits for feed qualification. Actual operation showed that a method to determine lubricant level and a method to add lubricant for agitator gears needed to be developed. Remote equipment was added that accomplished methods to monitor the lubricant level and add oil.

Vessel pressure is maintained below cell pressure by means of a pressure control valve between each vessel (CFMT and MFHT) and the vessel vent header. During integrated testing, vessel pressure ran at a higher vacuum than anticipated (i.e., excursions of minus 15 in. water instead of minus 5 in. water). Pressure control valves on each vessel were "stiff," and did not function well initially. Addition of a "volume booster" for each valve improved performance by doubling the volume of instrument air delivered to the valves' positioners.

Vessel level measurements are determined by three bubbler probe sets. Each set has an automatic blow-down cycle that purges the probes with instrument air at regular intervals. The blow-down cycle keeps the probes clear and maintains valid measurements. Each probe set consists of three individual probes; two of which are used to record level and density, the third is used for reference. Two of the probe sets are placed in a flow region. The third set is outside this region and is used to measure approximate static pressure. Bubbler probe sets for both the CFMT and MFHT functioned as expected during testing. The automatic blow-down cycle kept the probes clear and functional. Manual methods of clearing the probes with air and demineralized water also worked.

Vessel seal pots are used for pressure relief and overflow. Flow goes through a vessel seal pot to the waste header. Conditions were identified during testing that emptied seal pots. Administrative controls were set up to prevent seal pots from being emptied. A pressure break placed between the CFMT and SBS to prevent syphoning proved to be functional. The original jets used to transfer the seal pot contents to the waste header were too small to work well. Rust from steam and air utilities lodged in these jets and could not be removed. The original jets were replaced with larger ones and ran well.

The steam jets used to make vessel transfers worked well. Design and fabrication was sound and performance was predictable. Jets also tripped as designed (once flow stopped, some carried forward). Foam migration from the CFMT to the MFHT occurred when a jumper was removed. Jet utilities were redesigned to address this problem.

Transfer operations with water and slurry worked well. There was some difficulty with high-level interlocks. Set point reduction resolved alarm problems, though further correction was required. Some transfers from the Cold Chemical Facility to the CFMT resulted in a mass balance discrepancy. This problem was addressed by modifying the techniques used for tank level and density measurement.

System logic and piping checks were performed for the slurry sample station, which samples both the CFMT and MFHT. Sample repeatability checks also were done to verify sampling operations.

8.5.2.3 Production Melter

Melter testing was accomplished in stages, beginning with performance testing and progressing to melter startup and integrated operation test runs.

Initial melter test activities involved setting pressure control valves for the melter, off-gas, and vessel ventilation systems. It also involved calibrating controllers and instrumentation, checking control logic, testing water jacket cooling, functionally testing the melter cooling system, and establishing melter pressure control.

After initial testing was completed, transfers, CFMT boiling, and vessel ventilation system performance testing was done while maintaining a vacuum on the melter. In addition, several activities were conducted before melter startup activities began. These activities included preparing the melter discharge lid for service. This activity required extensive troubleshooting to get heaters, wiring, and controls working properly. Other activities involved checking airlift, temperature, viewing system, and bubbler system control logic; checking electrode cooling operation; performing integrated phase-testing of the melter electrode drives; and testing the melter thermocouples. The melter cooling jacket was placed into service and the melter cooling system was functionally tested. Evacuated canister remotability testing also was done.

Melter startup operations began April 1995, with heat-up of the melter refractory brick until it was sufficiently dry to sustain glass making. This was accomplished with both startup and discharge lid heaters. During this period, temperatures were increased incrementally at regular 10-½ hour intervals. Minor overheating experi-

enced with the discharge lid was resolved by modifying the control logic. By late July 1995, temperatures were being raised to normal melter operating temperature. At the beginning of August, normal plenum temperature was established (approximately 1,150° C or 2,102° F).

Once the refractory had been dried (i.e., cured) and normal operating temperature established, heating was suspended to add frit (i.e., ground glass similar in chemical composition to the final waste glass product) to the melter. The addition of frit made it possible to establish a glass pool with radiant heat supplied by the startup heaters, while keeping the refractory in a dry condition. Radiant heating continued until the glass pool reached the temperature at which current can be conducted through glass (i.e., joule heating). The startup heaters remained in place until joule heating was fully established.

Startup Heater Failure:

Shortly after joule heating began, three of the five startup heaters failed due to a buildup of residue (i.e., frit dust) on the heating elements that caused them to short. The frit was ground prior to introduction into the melter and formed dust as it was dropped into the melter. The problem was later solved by not grinding the frit and introducing the frit prior to heat-up.

Nozzle Liner Failure:

During removal of the failed heaters, broken pieces of alumina nozzle liner were discovered in the melter glass pool. The melter off-gas jumper was removed and melter temperature reduced to simplify removal of liner pieces from the melter glass pool. A series of analyses were done to determine the cause of fractures in the nozzle liners and to make repairs.

Both the melter lid and the nozzles on the original FACTS melter had severely corroded due to sodium and sulfur vapors from the melter slurry. One design change made after FACTS involved the addition of replaceable alumina liners to the melter nozzles to protect the melter nozzles and lid from corrosion. Alumina was selected as the liner material because it is highly resistant to corrosion. Although it is resistant to corrosion, it is prone to crack from thermal stress. It was hypothesized that the alumina may have cracked during the initial phases of melter heat-up. In addition, cracking may have occurred during melter configuration and jumper placement. Based on evaluation of the alumina liners' inability to withstand thermal or material stress, the decision was made to replace it with a much tougher material, Inconel 690. However, with Inconel it was necessary to ensure that the conditions necessary for sulfidation corrosion were not present.

Nozzle liners provide protection between the nozzle walls and the melter inserts (i.e., plugs, thermowells, film cooler, and periscope). If the liners corrode, vapors can pass through to the melter lid and condense (see figure 8-2). In this case, sulfidation corrosion of the lid over time could occur if melter lid or nozzle temperatures were between 600° C and 900° C (1,112° F and 1,652° F). The nozzle liners are replaceable, but the nozzles and melter lid are not. It was necessary to decide if design modifications were needed to supply forced cooling to the melter lid to prevent temperatures from reaching 600° C (1,112° F).

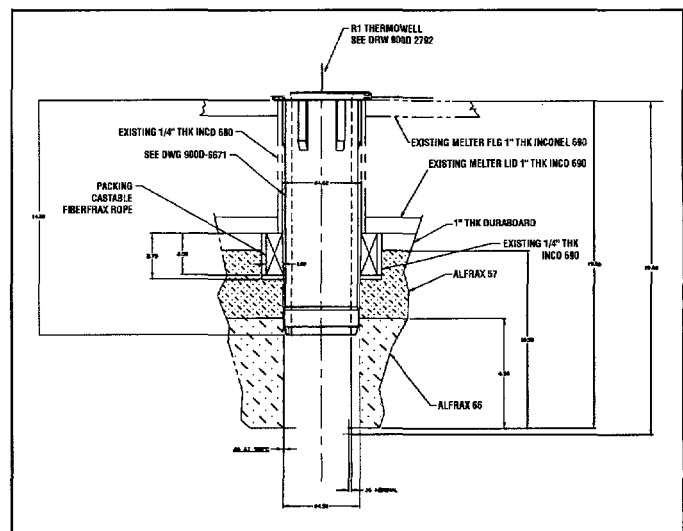


Figure 8-2. Melter Nozzle Liner

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Since normal, steady-state operating temperature of the melter plenum is approximately 1,150° C (2,101° F), it is feasible for heat transferred from the plenum through radiation and conduction to raise the lid temperature to nearly 600° C (1,112° F). A heat transfer analysis was done for the melter nozzles and liners to obtain predicted temperatures for the lid. This analysis showed that predicted lid temperatures ranged between 170° C and 420° C (338° F and 788° F). To verify the analysis, thermocouple measurements were taken at several points on the melter. The measurements taken were well below those predicted by the analysis. These results showed that forced cooling of the melter lid was not necessary; however, the new Inconel liner design incorporated a purge of air between the liner and the nozzle to sweep corrosive gases away from the space between them.

Nozzle repair was completed in late August 1995. Shortly afterwards, melter heat-up resumed. Joule heating was established and the startup heaters were removed. In mid-September, the first glass pour was performed. Actual feeding of the melter from the MFHT began in late September.

West Discharge Chamber Glass Buildup:

Melter feeding and glass production was conducted throughout the month of October. During this period a number of irregularities were noted with glass pours, including erratic flow and glass buildup at the bottom of the discharge cavity. Problems also were experienced with melter pressure fluctuation.

The melter has two discharge chambers: the west chamber, which is used for production; and the east chamber, which is used for backup. In mid-November, a large glass buildup was noticed in the west discharge chamber. Shortly after, glass was found around the west discharge trough. Test activities were suspended to examine the condition of both discharge chambers and assemble an independent review team to help in melter evaluation and repair. Team members represented the areas of metallurgy, welding fabrication, refractory installation, melter design, and commercial glass making.

Initial examination of the west discharge chamber showed that the trough was displaced from its original position. Subsequent examination, involving removal of some refractory in the west discharge chamber, showed that the discharge trough was displaced outward slightly and rotated downward approximately two degrees. It also showed that seal welds, which joined the trough to the dam, had failed. Further removal of refractory showed that the dam had bowed out 19.05 mm (3/4 in.) at the top, and 9.53 mm (3/8 in.) immediately above the trough, leaving a gap between the dam and the melter chamber. Inspection of the east discharge chamber showed no trough displacement, weld failure, or dam distortion, though it did show that the east trough, unlike the west trough, was secured to the dam by a gusset.

Molten glass flows from the melter to the canister through the discharge trough. The trough in the west chamber is a large, solid metal spout made of Inconel 690. It is seal-welded on three sides (north, south, and bottom) to the discharge dam, which is a 6.35 mm (1/4 in.) Inconel 690 plate that prevents migration of unwanted molten glass from the melter (see figure 8-3).

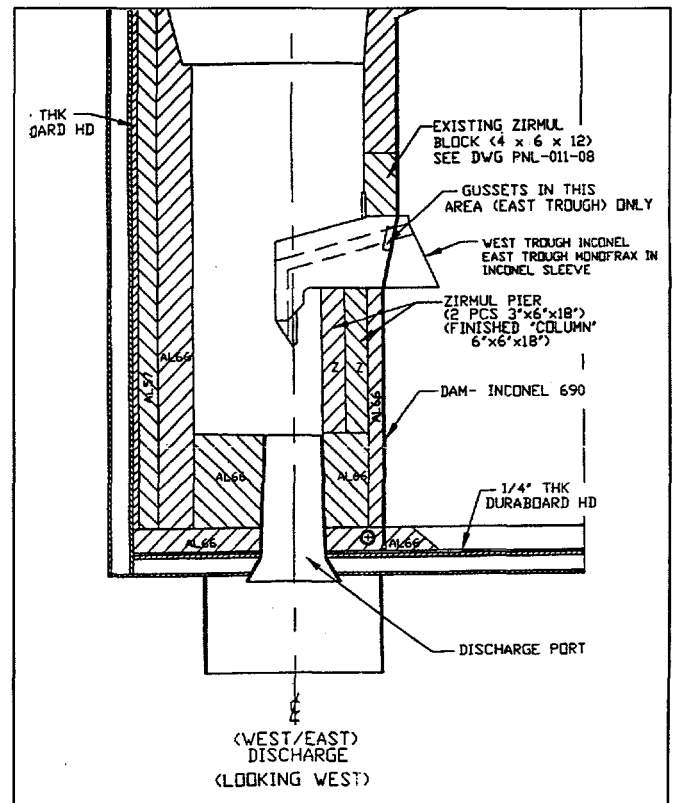


Figure 8-3. Melter Discharge Trough/Dam
(Original Configuration)

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The trough is positioned so that the distance from the trough to the floor of the melter is longer than the distance from the trough to the top of the dam. As designed, the dam is surrounded by refractory on both sides, with expansion board on two edges. A pipe that uses cooling air traverses the sides and bottom of the dam. It cools the outside of the dam and freezes any glass that may migrate to the outer edges. Heaters are installed inside the discharge chamber that maintain chamber operating temperature at 1,050° C (1,922° F).

At normal operating temperature, heat radiates outward from the trough. Temperature decreases as distance from the trough increases. Since the edges of the dam are cooled, a large temperature differential exists between the trough and the edges of the dam. This thermal differential results in expansion of the dam. When refractory was removed from the discharge chamber, refractory (Alfrax 66™) was cast above the top edge of the dam that restrained the dam from moving vertically (upward). This restraint, combined with plastic deformation, created enough stress to fail the seal welds. After the seal welds failed, glass could migrate into refractory materials under the trough (see figure 8-3). The deterioration caused by this migration was sufficient to cause the refractory materials to tilt forward and prevent them from supporting the trough after it cooled down. This was observable from the downward rotation of the trough during inspection. In addition, the intense heat at the trough, combined with the temperature gradient across the dam, produced enough force to deform the area of the dam nearest the trough and move the trough. Expansion of melter refractory also contributed to motive force.

Analyses of all critical data confirmed that trough displacement, weld failure, and dam distortion in the west discharge chamber had been caused by a combination of factors: high temperature, thermal expansion at large temperature differentials, restraint that prevented expansion, lack of proper trough reinforcement, and the presence of residual weld stresses due to the melter heatup rate.

Results of all melter evaluations performed were used to develop a repair plan that both corrected and improved the design of the discharge chambers. Three basic areas were covered by the repair plan: welding, reinforcement, and refractory modification. Weld repairs included three changes: increasing weld size to provide additional reinforcement; adding a weld to the bottom of each trough; and using a weld procedure specifically developed to reduce distortion and stress while making welds. Reinforcement repair involved adding two gussets (outer and inner) to both the west and east discharge troughs. It also included adding an expansion joint made of fiberboard layers to the top of the dam to allow expansion of the dam and hence reduce stress. Refractory modification involved using a stack of six keystone-shaped bricks placed on top of a rectangular shaped brick to provide greater structural support for the trough and make the chamber floor more resistant to glass contact (see figure 8-4). In addition, the gap created behind the dam in the west discharge chamber was filled with a pumpable mixture of fiberboard to eliminate the air gap and reduce the potential for a hot spot developing in that location. Several minor modifications were also made, including the addition of a splash plate and a retaining clip to the area surrounding the trough.

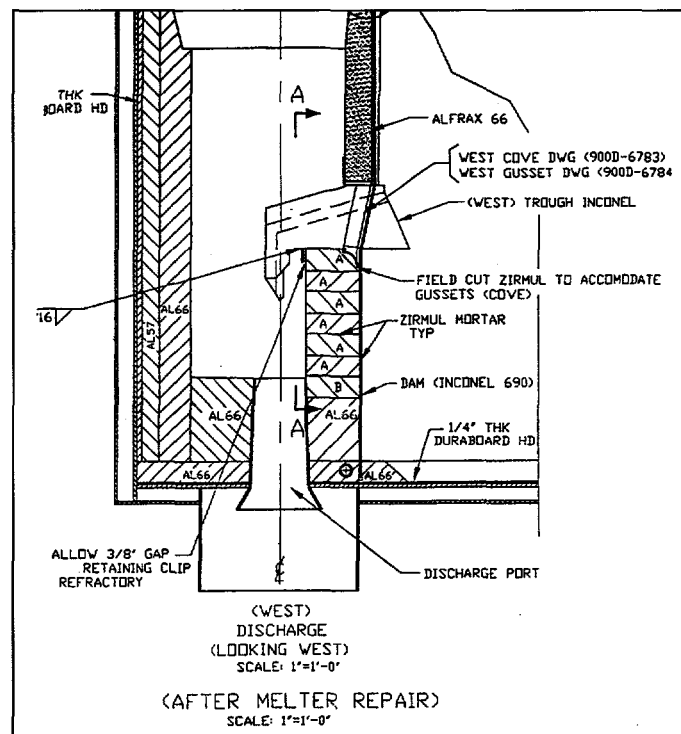


Figure 8-4. Trough/Dam Modifications

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A series of computer thermal and stress analyses was done at the Westinghouse Science and Technology Center in Pittsburgh, PA to confirm the repair plan. The use of expansion materials and reinforcements was assessed to confirm that these modifications adequately distributed thermal stresses and minimized concentrated stresses. Determinations also were made to confirm that sufficient expansion space was given and that time was allowed for thermal stress relief during melter heatup.

Once analytical acceptance criteria were established, evaluations were made at separate intervals using a projected heatup curve. The first evaluation, made at 50 hours, showed that stress values remained in the elastic range of material behavior and did not exhibit creep. A second evaluation, made at 70 hours, showed that stress values were reaching the plastic range of deformation. The third evaluation, made at 80 hours, showed that stress values had advanced well into the plastic range of deformation. Plotting done on a time-to-failure curve also showed an unacceptable trend at this interval.

Based on these evaluations, adjustments were made to the heatup curve to allow time for creep and stress relief to occur. A series of runs was then done using the new curve. All data plotted for these runs fell below established acceptance criteria and showed that stress relief continued after a steady state temperature was reached.

The original curve used for melter heatup was based on refractory concerns. Evaluations done with the new curve clearly showed that a slower heatup rate was needed for the discharge dam than for the refractory. They also showed that the discharge dam needed the ability to expand both vertically and horizontally. These conclusions confirmed modifications proposed in the repair plan, but also showed that they needed to be used with the revised melter heatup rate to withstand thermal stresses imposed during melter operation. Melter repairs were started and a heatup plan prepared based on these recommendations.

Melter Restart:

Actual melter heatup activities began in mid-February 1996. Shortly after, a small pinhole-size leak in the melter cooling jacket was discovered. The leak was found along a weld point. The melter water jacket was drained and a through inspection of all jacket welds was performed. These inspections showed no other weaknesses in the weld points. A method for repairing the leak was developed and used to repair the weld. After repairs were completed, melter heatup resumed. After joule heating was fully established, integrated operations began again. This heatup proved that a melter filled with cold, solid glass could be successfully restarted and the glass melted using the startup heaters.

Various aspects of melter function were evaluated during integrated test runs. Both before and after melter repairs, the startup heaters were used to raise the glass pool temperature to the point where joule heating could be established.

Melter pour viewing was good during glass-making operations. Plenum viewing was much improved from the viewing that was experienced during the FACTS program. Several adjustments were made to improve flow controls. Melter level and density probes were functional.

Testing to realign the electrical power to the melter electrodes after a simulated loss of normal, off-site power was successful. Backup power was brought online 55 minutes after a loss of power. During this period, the melter stayed at a reasonable temperature, 1,150° C to 1,050° C (2,101° F to 1,922° F). After normal off-site power was restored, the temperature dropped 30° C (179° F), with the off-gas system both off and on, after power was restored. This was well within acceptable limits.

Melter Pressure Fluctuations:

The melter emergency vent valve periodically lifted while integrated test runs were underway. This happened because of spikes in the melter pressure that sent a signal to open the valve. As the valve slowly opened, a connection was made between the melter and the vessel vent header, which has a greater vacuum than the melter. Melter pressure lowered as a result.

During initial melter feed operations, melter pressure stayed at desired levels (i.e., 5 in. negative, plus or minus 0.5 in.). Shortly after feeding was established, melter pressure spiked when glass was transferred to the discharge chamber using the airlift. A number of adjustments were made to the melter airlift operations during integrated test runs.

Melter pressure fluctuations were experienced during the initial integrated tests. Melter pressure is maintained by off-gas control and air injection to the melter. Since all major in-cell components are tied to the vessel vent header, pressure varies at different in-cell locations because of variable pipe lengths, pressure drops, etc. It also varies as more or less liquid is carried into the off-gas stream or as condensing surfaces get clogged. For most integrated test runs, the main off-gas pressure control valve, which is downstream of the vessel vent condenser, could not adequately control system pressure. Addition of a "volume booster" to position this valve more rapidly reduced some pressure control problems.

Air injection is achieved by two inlet pressure control valves on the melter: one that supplies air expressly for pressure control, the other that supplies air as a secondary function to supplying the film cooler. Air streams from both of these valves must be drawn out of the melter by the off-gas blowers. When the off-gas blowers were originally put into service, they drew too much air. This forced the inlet valves to be open 100 percent of the time and resulted in too much vacuum being drawn on the melter. A number of modifications were made to reduce this vacuum.

Both of the melter inlet pressure control valves need to operate smoothly and with good responsiveness. A digital "filter" was added to the control software to improve valve performance. Adjustments were made to the air inlet controls to make the valves more responsive. The extent of these adjustments was limited by the fact that air injection occurs as slurry is being pumped into the melter, in pulses, by the air displacement slurry (ADS) pump. Since this pump runs rapidly, having the inlet valves respond at the same rate would not improve pressure fluctuations.

As designed, the off-gas system allows for a certain amount of air in-leakage. During integrated testing, the system had too much in-leakage from the turntable. The air leakage from the turntable flows into the discharge chamber and this was restricted to reduce flow. Later, a system-wide protocol was developed to tune pressure control loops and achieve more stable system pressures.

Another factor that influenced melter pressure was operation of the automatic blow-down cycle for the CFMT and MFHT bubbler probe sets. This cycle influenced melter pressure in two ways: first, it produced an airflow that caused transient pressure; second, because the automatic cycles for both vessels were able to function simultaneously, the transient effect was doubled when simultaneous operation occurred. A software interlock was installed to prevent this from happening and actions were taken to determine the minimum acceptable airflow rate that can be used to keep the bubblers clear and operational.

Other operational areas were also reviewed to determine the effects on melter pressure including SBS operation, melter feed pump operation, component-to-component air flow variation, and the relationship between system in-leakage and performance variation.

8.5.2.4 Canister Turntable

Canister turntable testing was accomplished in stages and covered several basic operational areas: canister loading and turntable rotation, glass pour viewing, and level determination (i.e, infrared level detection, load cell operation, and mass balance calculation). After motor function was established, a number of tests were done involving the remote installation and removal of test canisters. Specific tests were run to determine if canisters could be loaded or unloaded from the turntable without disturbing pouring operations. Testing also was done to see if the turntable could be rotated without exceeding the allowable air in-leakage limits.

Certain limits to adequate formation of canister seals are imposed by the difficulties inherent in sealing rotational pieces of equipment to stationary parts. Initial testing showed that several design changes were needed to mitigate in-leakage caused by seal problems. To improve seal performance, a softer material was selected for actual seals. Additional weight also was added to improve latching and unlatching functions.

During actual glass-making operations, air flow from the turntable into the melter discharge chamber was great enough to cause irregularities with the melter pour. An orifice was installed in the equalization jumper between the overflow section of the melter and the melter cavity to minimize the effects of turntable in-leakage during glass pours. Before addition of this orifice, several design limitations were imposed on the canister seal mechanism to prevent dramatic fluctuations in air flow when engaging or disengaging the canister from the seal mechanism. The addition of the orifice significantly reduced the amount of air that could flow through the discharge chamber and made a number of design changes possible. These changes involved simplification of the turntable "top hat" seal and guide assemblies. Like the canister seal mechanism, some modification of the ILD system was needed before the system became fully operational. After modifications were made, the system proved itself to be functional.

When glass-making operations began, a number of variations occurred in load cell readings. Canisters that were in contact with the turntable seal expanded as they were filled with molten glass. When this expansion occurred, the load cells indicated a weight that was greater than the actual amount of glass in the canister. Allowing the canister to cool down between pours minimized this effect and resulted in a more accurate reading.

8.5.3 Ex-cell Off-gas and NO_x Abatement Systems

The control valve used to maintain system off-gas pressure is located in the 01-14 Building, which is remote from the off-gas source (i.e., melter). Several basic difficulties related to maintaining proper off-gas pressure control are attributable to the distance imposed by this layout.

During one test period, the control valve was operating in the fully open position. This made it difficult to maintain the desired pressure of minus 75 in. water. In addition, the off-gas blowers were running at 50 Hz, providing minus 90 in. of water at the air inlet. (At this time, melter plenum pressure remained relatively stable at the desired pressure of minus 5 in. water.) The screen to the outside air inlet was found to be plugged with insects, and an instrument failed (instrumentation pressure [I/P] transducer). A temporary modification was made to allow air to flow through one of the filter housing access ports. The I/P transducer was replaced and the primary and secondary off-gas blower motor frequencies were synchronized so that there was a smooth transition when it was required to switch over to the back-up blower. Blower speed was also adjusted so that the air in-bleed control valve could run at approximately 50 percent open, giving greater control over inlet pressure.

During commissioning testing activities, the Train A preheaters of the NO_x Abatement System developed over-temperature-related distortion and insulation damage due to a temperature control problem. Since operation of the NO_x Abatement and melter off-gas systems were on the critical path to integrated vitrification operations, this could have developed into a significant setback. A team was assembled to evaluate the causes of the damage and perform a material analysis. This resulted in a redesign of the preheater components including the addition of thermocouples to the preheater shells, a change in insulation materials, and additional instrumentation. New preheaters were fabricated while the failed components and piping were removed from the Cell.

Inspection and conductivity tests were also performed on redundant Train B of the NO_x Abatement System to ensure system integrity. Piping was analyzed as an independent system. Since Train A and Train B are redundant systems and the potential existed for Train B to be heat damaged in the same manner as Train A, temperature detectors were procured and installed on Train B. Additionally, thermocouples and their associated wiring were installed on the reheaters in both trains prior to the commencement of integrated testing to prevent recurrence of the failure.

These activities resulted in a slight delay in the testing schedule but were of no impact on the overall vitrification schedule.

8.5.4 Ventilation Testing

Ventilation testing included four basic activities: air balancing, fan reliability testing, interlock checking, and differential pressure/alarm checking. Tests also were run to demonstrate the ability to start fans after a power loss, adjust dampers when control logic failed, and replace filters. Air balancing to meet reduced in-cell pressures was done in stages as cell closures occurred. Testing demonstrated that the HVAC system was able to maintain in-cell pressures without excessive in-leakage. Final air balancing was completed when the pathway was opened to the EDR. Fan reliability was tested, as well as the ability to switch fans. Fan bearings were subject to overheating during fan testing. The alignment of bearings and stiffening the fan structure resolved this problem. Problems were also experienced with dampers that had difficulty keeping up with the supply fan. Differential pressure and alarm checks revealed some defects with differential pressure sensors; defective sensors were replaced. Filter replacement testing also showed that changes were needed for the secondary filter unit bag-in and bag-out procedure.

9.0 VITRIFICATION OPERATIONAL READINESS

As a United States DOE nuclear facility, the WVDP is subject to policies used to establish and operate facilities at U.S. DOE nuclear sites. Specifically, the VF at the WVDP is subject to criteria given in DOE Order 5480.23, DOE Order 5480.31 (DOE Order 425.1), and DOE Standard 3006.93.⁶⁰ These documents define how safe operating conditions are to be established and confirmed at U.S. DOE nuclear facilities.

9.1 Development of Readiness Criteria

The first step in meeting the criteria used to establish safe operating conditions at the VF was the release of a Safety Analysis Report (SAR). This document provided a detailed description of the VF, its function, and the limits (i.e., "safety envelope") that must be observed to operate the facility according to safe, approved standards. The SAR prepared for the WVDP VF operations and HLW interim storage, received final DOE approval in June 1995.

While this approval was underway, a method for confirming safe operating conditions was developed. This method, which is described in the Vitrification Operational Readiness Review (ORR) Plan of Action (POA), was structured according to DOE requirements as they apply to the VF and its scope of operation.⁶¹ The primary function of the POA was to define the VF operational readiness review process and serve as a guidance document for it. Key areas discussed in the POA included DOE core requirements, readiness prerequisites, and release point criteria (i.e., conditions that must be proved).

The vitrification ORR POA was submitted to the DOE for formal approval in September 1994. Approval to develop an internal vitrification ORR according to the guidelines given in the POA was received in January 1995. Development of an internal readiness assessment process also began as part of readiness activities. This process, known as Line Management Self-assessment (LMSA), was used to define specific actions that required completion before the formal ORR could begin. These actions were directly related to release-point criteria identified in the POA and could be used to confirm specific DOE core requirements for safe operation.

The release-point criteria used to confirm vitrification operational readiness reflected both the completion of vitrification test objectives and the validation of DOE core requirements. The actual release points developed from these criteria covered nine separate areas or events: shielding verification; hazardous chemical use; melter startup; WTF isolation and simulation; off-gas verification; Analytical and Process Chemistry Lab startup; integrated cold operations; issue of a Declaration of Readiness; and confirmation of completion. A summary of vitrification readiness release points is given in figure 9-1. The LMSA actions derived from these readiness release-points were used to develop self-assessment checklists. These checklists addressed three basic areas of readiness determination: plant facilities and hardware, personnel, and procedures. Using this approach, specific line managers developed criteria and compliance actions for their areas of responsibility. Using the approved compliance actions, documentation was prepared and presented by the line managers to verify their readiness for each release-point. All items were maintained in a database used to manage the LMSA process and evaluated regularly by designated members of a line management self-assessment team. This team was responsible for evaluating release-point status and confirming that all checklist activities had been properly addressed before determining release-point completion.

Vitrification Readiness Release-points

Release #1: *Shielding Verification*

Shielding meets ANSI/ANS 6.4-1985 guidelines. Adequate to maintain ALARA radiation exposure. Sufficient to sustain allowable operating limits.

Release #2: *Use of Hazardous Chemicals*

Hazardous chemical preparations and permits in place, including recycling, waste minimization, and disposal plans. Chemical storage and delivery adequate for production.

Release #3: *Melter Startup*

Support utilities ready. Startup heaters functional. Dry-out complete. Vacuum can be maintained. Exterior can be cooled. Cooling air can be injected into off-gas line. Melter can be run in idle. Continuous processing can take place.

Release #4: *Waste Tank Farm*

HLW header and condensate collection areas isolated. Equipment and procedures in place for simulated operations.

Release #5: *Off-gas Verification*

Conditions met to begin off-gas testing, including NO_x. Remote corrective and preventive maintenance possible.

Release #6: *Analytical and Process Chemistry Laboratory*

Ready to take representative samples and analyze for chemical constituents and homogeneity of materials in process vessels. Ready to conduct remote sampling operations between Analytical Lab and Supernatant Treatment System. Approval obtained for hot simulation and waste handling.

Release #7: *Integrated Cold Operations*

Preparations for integrated cold operations completed. All systems able to support continuous operations using simulated waste, including chemical hazards and effluents.

Release #8: *Declaration of Readiness*

All systems in place and requirements met for transition to radioactive operations.

Release #9: *Confirmation of Completion*

Radioactive tie-ins, equipment checkout, and relevant action items completed.

Figure 9-1. Vitrification Readiness Release-points

9.2 Operational Readiness Review

To confirm VF safe operating conditions, the ORR process used a uniform, systematic approach to evaluate facilities, equipment, personnel, procedures, and management control systems. Evaluations were done on two levels: contractor level and DOE level. The ORR served to ensure that the VF is operated within approved safety limits (i.e., "safety envelope").

The contractor ORR for the VF was conducted by an independent review team made up of qualified, technically knowledgeable personnel who had no line management responsibility for the areas or activities being reviewed as part of the ORR process. The main responsibility of the ORR Team was to review and evaluate readiness release-points after the LMSA Team evaluations and determinations had been completed.

Once the ORR Team agreed that a specific release point had been completed, a final verification was issued for that specific release-point. After final verification was received, testing progressed to the next level, or release-point. This process was used for each of the release-points.

As the Project milestone that was used to demonstrate the ability to support continuous VF operations, the contractor Declaration of Readiness (Release #8), marked the transition point between internal readiness evaluations and external review. Once approval for the start of radioactive tie-ins was received, internal evaluation of all systems, equipment, and requirements needed for the start of radioactive processing began in parallel with actual operation of the VF itself. A summary of areas evaluated for the start of integrated cold operations is provided in figure 9-2. A summary of areas requiring evaluation for the Declaration of Readiness (Release #8) is provided in figure 9-3.

A primary goal of the external review process was to determine readiness to proceed with 1) radioactive tie-ins and 2) radioactive operation and conversion of HLW into glass. As with contractor readiness assessments, DOE readiness evaluations were made for all areas pertinent to VF operation. Emphasis was given to areas defined by the internal review process as a means to ensure operational readiness: technical adequacy of systems, components, and hardware; staffing and training of personnel; procedures (i.e., standard operating procedures); and facility readiness. A rigorous, review of these areas and activities began in November 1995.

Integrated Cold Operations (Release #7) Readiness Release-point Summary

Procedure in place and hazard analysis reviewed for safety limits.

Existing training and qualification programs updated to include new requirements.

Vitrification Operations personnel level of knowledge verified by demonstration and examination.

Test plans conducted within hazard analysis.

Each readiness release point evaluated for incorporation of safety class equipment into procedures and Open Items Tracking System for preventive maintenance and instrument calibration.

Open Items Tracking System effective.

DOE Orders incorporated into policies, procedures, plans, and operating documents.

Sufficient qualified personnel are available to support process.

Startup test program covers operation of equipment, procedures, and operator training.

Responsibilities, lines of communication, and safety controls implemented.

Conduct of Operations and maintenance programs in place.

Adequate Operations personnel available.

Changes incorporated into drawings, training, and operating procedures.

Operations, technical, and management qualifications are adequate.

Figure 9-2. Integrated Cold Operations Readiness Release-point Summary

Declaration of Readiness (Release #8) Release-point Summary

Process system safety limits correct.

Training and qualification verified by demonstration, examination, and drills.

Able to maintain operations within limits defined by SAR.

Safety systems defined by SAR operable.

Program function verified by audit.

Program functional.

Sufficient qualified personnel indoctrinated.

Emergency plan in place and training exercises complete.

Startup plan completed for nonradioactive testing.

Responsibilities, lines of communication, and safety controls implemented and competency demonstrated.

Conduct of Operations and maintenance programs in place and working.

Adequate Operations personnel available.

Activities consistent with Environmental, Safety, and Health requirements.

Changes incorporated into drawings and training.

Training and procedures in place and working, including modifications.

Operations, technical, and management personnel qualifications adequate, functional, and on-going.

Figure 9-3. Declaration of Readiness Release-point Summary

The external DOE ORR was conducted by a 17-member independent, technical review team made up of experts from various scientific and technical disciplines both within and outside the DOE. The team evaluated all activities addressed in the POA against stringent requirements for radioactive tie-ins and waste processing operations (i.e., vitrification operations). Their evaluations formed the basis for a detailed ORR Report issued at the conclusion of the review process. This report summarized the DOE ORR Team's findings and provided recommendations to the DOE approval authority on the VF's readiness to begin safe operations.

Central among the recommendations made by the DOE ORR Team was the determination that radioactive tie-in activities could continue after the resolution of four specific findings: verification of VF staff qualification requirements; definition of VF supervisor qualifications; full implementation of process safety requirements; and improvement of the lock and tag program (i.e., the program to secure components properly before and after servicing equipment). Approval to proceed with radioactive tie-ins also was contingent on the establishment of corrective action plans for the findings. A summary of these findings is given in figure 9-4. In addition, the Team suggested that several improvements be made to the startup test plan.

One principal finding was to modify the Integrated Operations Run Plan (IRP) to include prototypical, full-scale integrated operations. These operations involved five activities that had not been fully addressed during earlier integrated test runs: equipment demonstration; use of all procedures in final form; use of production methods for sample collection, waste form data collection, handling, and storage; demonstration of canister tracking; and Operations staff training. By modifying the IRP to include such activities, the VF Operations staff would be given ample opportunity to develop the degree of proficiency needed to operate the VF safely and produce an acceptable waste product.

In response to the DOE ORR Team findings and recommendations, modifications were made both to the IRP and the readiness evaluation process. Both the run plan and evaluation process were expanded to emphasize performance-based assessments of identified areas of concern. In addition, a series of intermediate decision points (IDPs) was added to the line management review process to provide for the progressive completion of all tasks needed before receiving authorization to continue with radioactive tie-ins.

A particular focus was given to the development of operator proficiency and training. A revised operator proficiency performance matrix was incorporated into the run plan and a series of field evaluations was conducted to assess operator performance of procedures. A summary of the performance matrix is given in figures 9-5 and 9-6.

DOE ORR Findings

Satisfactory basis needed for VF start-up.

Completion needed for integrated operations run plan.

Confirmation needed that communications among Operations personnel ensures accurate information exchange.

Confirmation needed that alarms or indications result in appropriate actions (i.e., erroneous alarms or indications).

Confirmation needed that operating procedures support safe processing of HLW.

Confirmation needed that procedures are clearly understood by all operators.

Confirmation needed that minimum staffing requirements for radioactive operations have been established.

Confirmation needed that monthly surveillances will not exceed allowable limits.

Confirmation needed that operators and supervisors have performed control manipulations prior to certification.

Confirmation needed that training program evaluations are complete and fully implemented.

Confirmation needed that continuing training programs have been implemented for VF operations.

Confirmation needed that all operations required to process HLW have been demonstrated.

Confirmation needed that all qualification programs reflect changes to the VF and procedures.

Confirmation needed that the canister tracking system is adequate.

Confirmation needed that the production records data package contains the information necessary to demonstrate compliance.

Confirmation needed that procedures are in place that demonstrate or record compliance with waste form qualification requirements.

Figure 9-4. DOE ORR Findings

Cold Chemical Facility

- Receive bulk liquid chemicals (nitric acid or sodium hydroxide)
- Prepare batch of glass formers or waste simulant
- Calibrate weigh scale
- Transfer contents of a mix tank to the CFMT or MFHT

Vitrification Facility - In-cell Operations

- Remove & replace a jumper remotely
- Jet SBS to CFMT
- Jet SBS to waste header
- Concentrate simulated waste in CFMT
- Sample CFMT
- Perform steam blow-down of the CFMT and the MFHT bubbler probe sets
- Transfer CFMT to MFHT and verify volume transfer (mass balance)
- Establish melter cold cap
- Airlift molten glass to canister and complete mass balance calculations
- Jet in-cell sump
- Restore lost seal loop on HEME
- Restore lost seal loop on condenser
- Start-up Off-gas and vessel vent system
- Change off-gas trains (HEPA prefilter and HEME)
- Weld a canister lid
- Take shard samples and transfer them remotely
- Operate the sample transfer drawer
- Decontaminate a canister at the decontamination station
- Operate the shield door between the Crane Maintenance Room and the Vitrification Cell (63-M-002)

Canister Transfer and Transfer Cart Operation

- Transfer canister from Load-in Facility to Equipment Decontamination Room (EDR)
- Load canister onto transfer cart in EDR
- Operate cranes for canister movement
- Change canister in turntable
- Move canister from the weld station to the decontamination station
- Operate transfer cart and shield door between the Vitrification Cell and the transfer tunnel (63-M-001)

Figure 9-5. Operator Proficiency Requirements: Primary Process Operations

Ex-cell HVAC

- Switch to backup fan and restore to normal operation, as in a power outage
- Routine diesel testing
- Change ex-cell filters
- Change exhaust blowers during weekly test
- Changeout air bottles and recover from loss of emergency instrument air supply system
- DOP-test HEPA filter
- Demonstrate 01-14 Building HVAC operation

NO_x Abatement System

- Switch re-heater or pre-filter trains
- Change NO_x filter
- Change lead off-gas blower
- Change calibration gas supply bottle and reset analyzers
- Sample and transfer condensate from off-gas trench pipe
- Receive bulk ammonia
- Bypass reactors for melter idling, or return from bypass to normal

Miscellaneous Ex-cell Operations

- Isolate chiller for maintenance and restore for operation
- Switch in-cell coolers
- Provide alternative means of melter cooling (utility water)
- Demonstrate uninterruptible power supply (UPS) operation
- Operate VF Control Room HVAC

Remote Operations

- Remove a mechanical jumper
- Remove an electrical jumper
- Remove and replace a dust cover

Abnormal Event Drills

- Melter power drill
- HVAC system drill
- Continuous air monitor (CAM) alarm drill
- Walkthrough of alarm responses according to alarm response procedure
- Perform 10 additional drills per crew

Figure 9-6. Operator Proficiency Requirements: Ex-cell Operations

At the conclusion of the additional integrated operations and Release-Point 9, a contractor Declaration of Readiness was issued. This document indicated completion of all action items and activities identified during the readiness evaluation process. Specifically, it represented completion of more than 80 abnormal response drills, 670 Control Processing Findings manipulations (i.e., individual operator proficiency demonstrations), and 270 performance evaluations of VF activities designated in the startup test plan. It also represented completion of a series of management verifications, interviews, and field observations used to complete the remaining items that required closure before readiness could be declared.

After the line management Declaration of Readiness was issued, an external DOE readiness validation process began to ensure successful closure of all remaining items and activities. Once this validation was completed, a final DOE ORR recommendation was made to the DOE approval authority on June 19, 1996, that the VF was ready to begin processing radioactive waste.

10.0 CONCLUSION AND FUTURE ACTIVITIES

From the inception of the WVDP Act in 1980 through the demonstrated readiness for radioactive operations in June 1996, the WVDP has completed significant efforts to modify, construct, test, and qualify components, systems, processes, and facilities for the vitrification of HLW (see figure 10-1 for a current photo of the site). The anticipated vitrification campaign and the production of glass-filled radioactive canisters to acceptable requirements for federal disposal has evolved from the initial FACTS testing to determine the glass recipe and component performance, to the full qualification of the waste form by demonstration of successful facility operation.

The WVDP achieved readiness for radioactive operations through the use of extensive testing programs, proven designs, existing facilities, and numerous independent evaluations. Five years of FACTS testing were used as a means to demonstrate full-scale production and qualification of nonradioactive vitrification operations. Nonradioactive testing also identified deficiencies in some full-scale components resulting in their redesign and in increased operational efficiency. Later startup and final integrated testing of subsystems and systems also demonstrated the ability and accuracy of the process to meet system parameters.

Component and facility designs adapted from existing technologies used at DOE operations in: Savannah River, SC; Hanford, WA; and Oak Ridge, TN. In turn, designs for various in-cell components were transferred from the WVDP to the DOE's Savannah River, Hanford, and additionally, Fernald, OH sites.



Figure 10-1. WVDP Site Photo

5030.pcx

The focus of construction on converting existing facilities allowed for construction to proceed in phases that paralleled testing activities. Construction to build new facilities and join these facilities to existing facilities also progressed in phases parallel to annual budget allocations. The maintenance of a high level of construction safety during all phases also contributed to the Project's Total Recordable Case Rate below industry and DOE averages. Independent evaluations utilized for waste qualification, equipment designs, and the ORR enhanced the overall reliability of the vitrification process.

Authorization to initiate radioactive tie-ins between the WTF and existing contaminated facilities and between the WTF and the VF was received on April 29, 1996 from Richard J. Guimond, DOE Principal Deputy Assistant Secretary for Environmental Management. The tie-ins were completed in May 1996 in preparation for the transfer of radioactive waste for vitrification and solidification (see figure 10-2 for a current photo of the Vitrification Cell).

Integrated operations testing of all vitrification facilities and systems were completed in June 1996, by the remote filling, capping, decontamination, and transfer of four nonradioactive canisters into the CPC or HLWIS. DOE approval to initiate vitrification of high-level radioactive waste was granted on June 19, 1996 by Alvin L. Alm, DOE Assistant Secretary for Environmental Management.

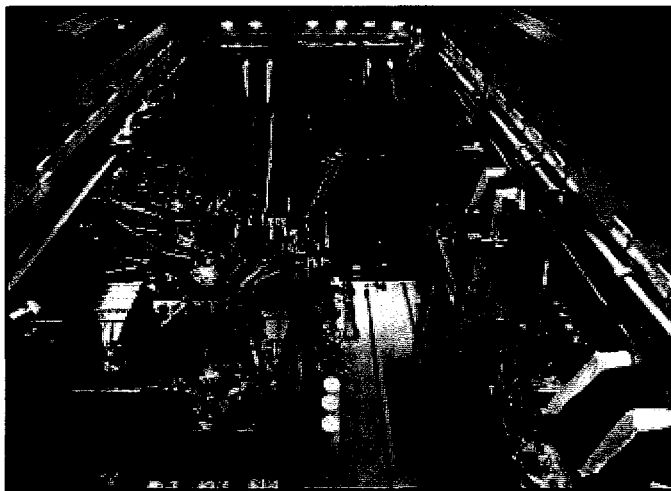


Figure 10-2. Vitrification Cell Photo

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High-level radioactive waste solidification by vitrification is scheduled to begin in July 1996. Detailed operations of all radioactive vitrification systems and activities will be accomplished using Standard Operating Procedures (SOPs) and a Vitrification Radioactive Run Plan.⁶² The run plan provides the sequence of operations in which the SOPs are performed.

Special radiological controls, in addition to normal actions established in WVDP radiological procedures, have been instituted. These controls govern liquid high-level waste transfers, canister lifting and transfer, sampling, transfer drawer use, Analytical Cell use, and a re-evaluation of special requirements to adjust radiological postings of work areas.

The length of the overall vitrification campaign with the current inventory of high-level waste is projected to be completed in two years, with the production and subsequent interim storage of approximately 300 radioactive glass-filled canisters. These canisters will remain at the site in shielded storage until either shipped to a different interim storage location or to a federal repository for permanent storage.

NOTES

1. United States Congress, West Valley Demonstration Project Act, Public Law 96-368, October 1, 1980.
2. Waste acceptance criteria for the WVDP are in the following documents: Waste Acceptance Product Specification for Vitrified High Level Waste Form (WAPS), February, 1993; West Valley Demonstration Project Document WVDP-185, Waste Form Compliance Plan (WCP), Revision 9, January 13, 1994; and West Valley Demonstration Project Document WVDP-186, Waste Form Qualification Report (WQR), latest revisions for all chapters.
3. D. Carl et al., West Valley Demonstration Project Vitrification Process Equipment Functional and Checkout Testing of Systems (FACTS), Topical Report, DE-AC07-81NE44139-64, September 30, 1990.
4. Specifications for the Vitrification Cell wall modules are in Vitrification Cell Wall Modules, WVNS-EQ-265, Revision 7, June 3, 1993.
5. A list of Vitrification Cell penetrations and their respective drawings are in Wall Penetration Index, WVNS-WPI-001, Revision 8, December 28, 1995.
6. Specifications for Vitrification Facility shield windows are in Vitrification Facility Equipment Specification for Oil-Filled Shielded Viewing Windows, WVNS-EQ-308, Revision 4, September 14, 1993.
7. Vitrification Facility shield door specifications are outlined in Special Doors for the Vitrification Facility, WVNS-EQ-264, Revision 6, September 11, 1989.
8. Fire detection and protection systems for the Vitrification Facility are in accordance with: National Fire Protection Agency (NFPA) Codes; United States DOE Order 6430.1A, General Design Criteria, April 6, 1989; United States DOE-ID-12044, Operational Safety Design Criteria Manual, Revision 4, April 1995; United States DOE Order 5480.7A, Fire Protection, February 17, 1993. Specific application of codes and compliance issues are detailed in Fire Hazard Analysis for the Vitrification Facility, WVNS-FHA-001, Revision 3, June 12, 1996, and Fire Detection and Protection System Description, WVNS-SD-63FP, Revision 2, January 4, 1996.
9. More information on the Chemical Process Cell (High-Level Waste Interim Storage) can be found in Design Criteria, High-level Waste Interim Storage System, WVNS-DC-048, Revision 2, August 25, 1993, and High-level Waste Interim Storage System Description, WVNS-SD-68, Revision 2, April 14, 1996.
10. More information on the Cold Chemical Building and cold chemical system can be found in Design Criteria Cold Chemical System, WVNS-DC-045, Revision 1, May 13, 1987, and Cold Chemical System Description, WVNS-SD-65, Revision 2, January 5, 1996.
11. More information on the Load-in Facility can be found in Design Criteria Vitrification Load-In Facility, WVNS-DC-066, Revision 0, April 6, 1995, and Load-in Facility System Description, WVNS-SD-63M, Revision 4, March 20, 1996.
12. More information on the Sludge Mobilization System can be found in Design Criteria Sludge Mobilization Waste System Removal, WVNS-DC-046, Revision 0, July 24, 1992, and Sludge Mobilization and Transfer System Description, WVNS-SD-55, Revision 0, January 17, 1995.
13. C. M. Jantzen et al., Nuclear Waste Glass Product Consistency Test (PCT), Version 5.0 (U), WSRC-TR-90-539, Revision 2, Westinghouse Savannah River Company, Aiken, SC, 1992.

14. More information on the vitrification process chemistry can be found in Vitrification Process Chemistry System Description, WVNS-SD-63P, Revision 0, May 12, 1995.
15. More information on the process of vitrification, including waste transfers, residence time of waste in process vessels, and process components can be found in Vitrification Main Process System Description, WVNS-SD-63I, Revision 3, May 16, 1996.
16. More information on sampling equipment and the system for transferring samples to the Vitrification Analytical Lab can be found in Vitrification Facility Sampling System Description, WVNS-SD-69A, Revision 2, December 2, 1995, and Vitrification Facility Sample Transfer System Description, WVNS-SD-69B, Revision 1, January 6, 1995.
17. More information on the canister lid welding process and equipment can be found in Canister Welding System Description, WVNS-SD-63L, Revision 4, November 7, 1995.
18. More information on the canister decontamination process and equipment can be found in Canister Decontamination System Description, WVNS-SD-63J, Revision 3, December 27, 1995.
19. United States DOE-ID Order 12044, Operational Safety Design Criteria Manual, Revision 4, April 1985.
20. United States DOE Order 6430.1A, General Design Criteria, April 6, 1989.
21. C. G. Skillern et al., Vitrification of High Level Wastes, WVNS-DC-022, Revision 3, January 20, 1992.
22. West Valley Demonstration Project, Safety Analysis Report for Vitrification Operations and High-Level Waste Interim Storage, WVNS-SAR-003, June, 1995.
23. The initial basis for the West Valley Demonstration Project safety classification and quality levels was established in Technical and Administrative Approach for the West Valley Demonstration Project Safety Program, WD:84:0471, S. Marchetti to W. H. Hannum, April 1985.
24. United States DOE Order 5481.1A, Safety Analysis and Review System, August 13, 1981, and DOE Order 5481.1, Safety Analysis and Review System for DOE Managed Activities, August 21, 1981.
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26. West Valley Demonstration Project, Safety Review Program, WVNS-906, Revision 15, February 10, 1995.
27. West Valley Demonstration Project, WVNS Quality Manual, QM-2, Quality Assurance Program, Revision 7, February 11, 1994.
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31. United States DOE Order 5480.11, Radiation Protection for Occupational Workers, June 17, 1992.
32. American National Standards Institute (ANSI), N101.6, Concrete Radiation Shielding, 1972.
33. American National Standards Institute (ANSI)/American Society of Mechanical Engineers (ASME) N510, Standard for Testing of Nuclear Air-Cleaning Systems, 1980.
34. West Valley Demonstration Project, Safety Analysis Report Project Overview and General Information, Safety and Environmental Assessment, WVNS-SAR-001, Revision 1, August 19, 1993.
35. University of California Research Laboratories (UCRL), 15910, Design and Evaluation Guidelines for DOE Facilities Subjected to Natural Phenomena Hazards, 1988.
36. New York State, New York State Code Manual for the State Building Construction Code, 1980.
37. United States Nuclear Regulatory Commission, Regulatory Guide 1.60, Design Response Spectra for Seismic Design of Nuclear Power Plants, 1973.
38. United States DOE Order 5480.28, Natural Phenomena Hazards Mitigation, January, 1993.
39. Hazard assessment guidelines followed for the Design Basis Earthquake are per DOE Standard 1024, Guidelines for Use of Probabilistic Seismic Hazard Curves at Department of Energy Sites, December, 1992, as stated by DOE Order 5480.28, Natural Phenomena Hazards Mitigation, January 1993.
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41. G. W. Nicholas and R. C. Egan, Meteorological Program for West Valley Demonstration Project, Dames and Moore, January, 1983.
42. Lawrence Livermore Laboratory, Natural Phenomenon Hazard Studies and Recommended Design Criteria for the West Valley Site, West Valley, New York, October 1, 1981.
43. American National Standards Institute (ANSI), A58.1, Minimum Design Loads for Buildings and Other Structures, 1982.
44. The application of National Fire Protection Agency (NFPA) codes and National Electric Codes (NEC) are described in detail in Fire Hazard Analysis for the Vitrification Facility, WVNS-FHA-001, Revision 3, June 12, 1996, and Fire Detection and Protection System Description, WVNS-SD-63FP, Revision 2, January 4, 1996.
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LIST OF ACRONYMS

AVC	Automatic Voltage Controller
CAM	Continuous Air Monitors
CCR	Chemical Crane Room
CCTV	Closed-Circuit Television
CFMT	Concentrator Feed Makeup Tank
CMOA	Crane Maintenance Operating Aisle
CMR	Crane Maintenance Room
CMROA	Crane Maintenance Room Operating Aisle
CPC	Chemical Process Cell
CSS	Cement Solidification System
CTS	Component Test Stand
DBA	Design Basis Accident
DBE	Design Basis Earthquake
DBT	Design Basis Tornado
DCS	Distributed Control System
DF	Decontamination Factor
DGR	Diesel Generator Room
DOE	Department of Energy
DOP	Dioctyl Phthalate
DWPF	Defense Waste Processing Facility
EA	Environmental Assessment
EDR	Equipment Decontamination Room
EDS	Electrical Power Distribution System
EM-WAPS	DOE Office of Environmental Management - Waste Acceptance Product Specifications
EPA	Environmental Protection Agency
FACTS	Functional and Checkout Testing of Systems
FSAR	Final Safety Analysis Report
GTAW	Gas Tungsten Arc Welding
HEME	High-Efficiency Mist Eliminator
HEPA	High-Efficiency Particulate Air Filter
HLW	High-Level Waste
HLWIS	High-Level Waste Interim Storage
HVAC	Heating, Ventilation, and Air Conditioning
HVOS	Heating Ventilating Operating System
ICP - AES	Inductively Coupled Plasma - Atomic Emission Spectroscopy
ILDS	Infrared Level Detection System
INEL	Idaho National Engineering Laboratory
IRP	Integrated Operations Run Plan
I&C	Instrumentation and Control
I.O.	Integrated Operations

LIST OF ACRONYMS (cont.)

I/P	Instrumentation Pressure
LMSA	Line Management Self-Assessment
MCC	Motor Control Centers
MFHT	Melter Feed Hold Tank
NEC	National Electric Codes
NFS	Nuclear Fuel Services Company, Inc.
NH ₃	Anhydrous Ammonia
NMPC	Niagara Mohawk Power Corporation
NO _x	Oxides of Nitrogen
NPH	Natural Phenomena Hazard
NRC	Nuclear Regulatory Commission
NYARDA	New York Atomic Research and Development Authority
NYSERDA	New York State Energy Research and Development Authority
OAD	Office of Atomic Development
ORNL	Oak Ridge National Laboratory
ORR	Operational Readiness Review
OSHA	Occupational Safety and Health Administration
PaR	Power
PCT	Product Consistency Test
PGA	Peak Ground Acceleration
PLC	Programmable Logic Controller
PNNL	Pacific Northwest National Labs
POA	Plan of Action
PSAR	Preliminary Safety Analysis Report
PUREX	Plutonium Uranium Extraction Process
PVS	Permanent Ventilation System
P&IDs	Piping and Instrumentation Drawing
QA	Quality Assurance
REBAR	Reinforcing Bar
REDOX	Oxidation Reduction
SAR	Safety Analysis Report
SBS	Submerged Bed Scrubber
SDG	Stand-by Diesel Generators
SF	Slurry Fed
SFR	Secondary Filter Room
SGN	Societe Generale Pour Les Techniques Nouvelles
SMS	Sludge Mobilization System
SOP	Standard Operating Procedure
STS	Supernatant Treatment System
SVS	Scale Vitrification System

LIST OF ACRONYMS (cont.)

THOREX	Thorium Extraction Process
TIP	Test Instruction Procedures
TRC	Total Recordable Case Rate
TRG	Technical Review Group
UBC	Uniform Building Code
UCRL	University of California Research Laboratories
UPS	Uninterruptible Power Supply
VF	Vitrification Facility
VF Control Room	Vitrification Facility Main Control Room
VTF	Vitrification Test Facility
WAPS	Waste Acceptance Preliminary Specification
WCP	Waste Compliance Plan
WIPP	Waste Isolation Pilot Plant
WNYNSC	Western New York Nuclear Service Center
WQR	Waste Qualification Report
WSEG	Westinghouse Scientific and Ecology Group
WSTC	Westinghouse Science and Technology Center
WTF	Waste Tank Farm
WTFVS	Waste Tank Farm Ventilation System
WVDP	West Valley Demonstration Project
WVNS	West Valley Nuclear Services Company Incorporated

DOE/NE/44139-77

WEST VALLEY DEMONSTRATION PROJECT

DOE

Vitrification Facility at the
West Valley Demonstration Project