STARTUP AND INITIAL EXPERIMENTAL RESULTS FOR THE WEST VALLEY VITRIFICATION DEMONSTRATION PROJECT

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INTRODUCTION

The objective of the West Valley Demonstration Project (WVDP) is to solidify the wastes at the site and to clean up the facilities used in the solidification operations. The specifics of the Project scope are defined more completely in public law 93368 and as published previously.[1] The focus of this paper is to more fully describe the general process flow sheet, the process and equipment that will be used to vitrify the high-level wastes, summarize the testing completed to date, and present the plans for the remaining cold testing at West Valley.

PROCESS DESCRIPTION

There are two pairs of underground waste storage tanks at the WVDP site. Tank 8D-2 contains about 2.8 million L of neutralized PUREX wastes which are similar to the defense wastes found at the Savannah River Plant. The neutralized waste is composed of insoluble hydroxides that have precipitated to the bottom of the tank and their supernatant solution. Tank 8D-1 is the same size and construction as 8D-2 and serves as its backup. Approximately 31 thousand L of acidic THOREX wastes, generated during processing thorium containing fuel, is stored in Tank 8D-4. Tank 8D-3 is the spare for 8D-4.

The generalized flow sheet is represented schematically in Fig. 1. The preliminary waste treatment stages required before vitrification are outlined below.

The initial step is decanting the supernatant from Tank 8D-2 and passing it through zeolite ion exchange columns. When the zeolite ion exchange media becomes loaded with cesium and strontium radioisotopes, it will be discharged to the bottom of Tank 8D-1. After the supernatant has been processed, the sludge will be washed to remove its interstitial liquids (which are similar to the supernatant) and the sulphate salts. The washing process requires three to four cycles and the wash solutions will be treated by the zeolite system. The decontaminated effluent from the ion exchange system is routed to the concrete solidification system where it is solidified into concrete.

After the supernatant decontamination and the sludge wash cycles, the configuration of the tank farm will be cesium and strontium loaded zeolite in

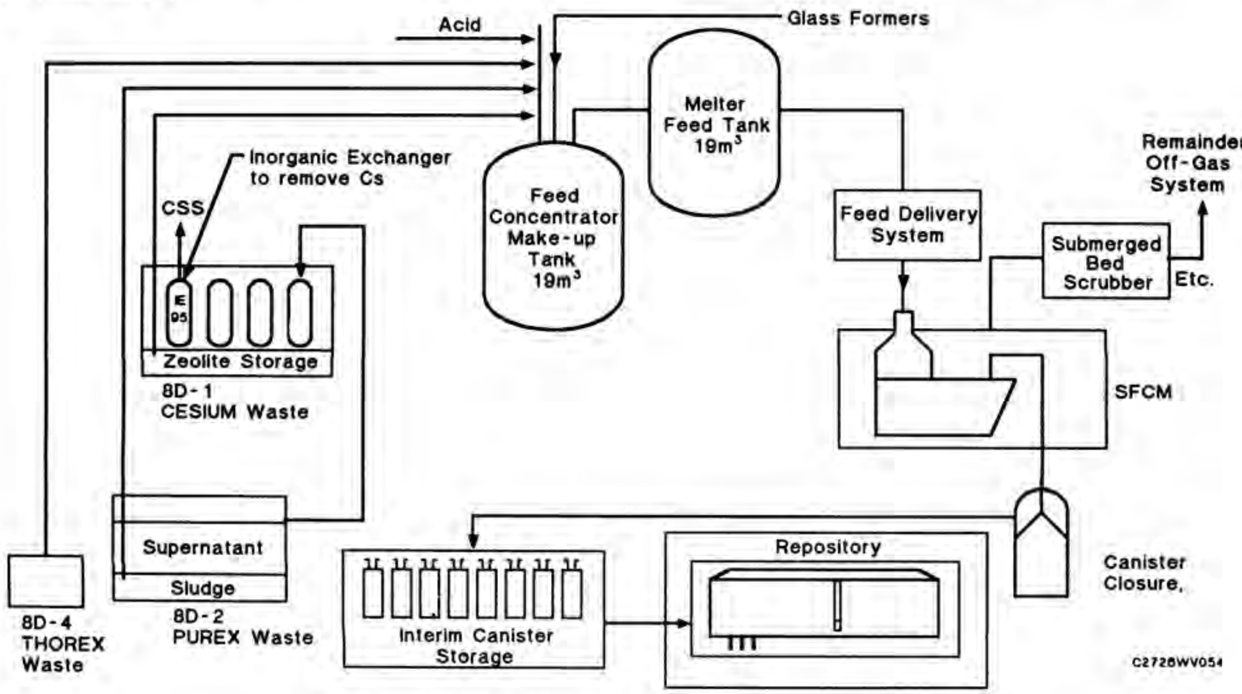

Fig. 1. West Valley high-level waste processing flow sheet.

Tank 8D-1, washed sludge in Tank 8D-2, and the THOREX wastes in Tank 8D-4. The current reference process is mobilization of the zeolite in 8D-1 and the sludge in 8D-2, and sequentially batching the desired volumes of these wastes, along with the THOREX wastes, into the waste concentrator in the vitrification facility.

An alternative approach is being pursued which would consolidate the zeolite, PUREX sludge and thorium wastes in a single tank, most likely Tank 8D-2. This approach is preferred because it is believed that the waste consolidation will minimize variations in the waste composition due to batch transfer errors to the process concentrator. The reduced number of potential glass compositions that would evolve from this strategy is felt to be an important consideration in minimizing the size of the compositional field that must be qualified for disposal.

After the wastes are transferred to the concentrator and feed make up tank, representative sample(s) will be obtained. As the sample is being analyzed, the waste slurry solution will be concentrated by a factor of two to three. When the analysis is complete, the chemical additions which are required to make the glass fall within the qualified compositional field are calculated. These chemical additions will be prepared in the cold chemical makeup system. These chemicals are then transferred into the concentrator system and thoroughly homogenized with the wastes. Concentrator samples will then be analyzed to confirm that the cold chemical additions to the waste bring the melter feed within the required compositional range.

Once a batch is homogenized and the desired composition, it is then transferred to the melter feed hold tank. The feed is then metered from the melter feed tank into the slurry fed melter in a nearly continuous manner for vitrification.

The melter off-gases are composed primarily of steam and nitrogen oxides with a minor amount of calcined feed slurry and glass carry-over. The majority of the carry-over is captured by the first element in the off-gas treatment system, the submerged bed scrubber. The carry-over particulates are recycled back to the feed concentrator. In addition to this scrubber recycle stream, evaporated overheads from the previous batch concentration operation will also be returned.

Glass that is generated during the vitrification processing is poured into canisters where it solidifies into the desired borosilicate waste form. After the canister cools, it is removed from the process and a temporary cap is installed prior to decontamination. The decontaminated canisters will be transferred to an interim storage facility on the West Valley site. When the repository receives authorization for acceptance of solidified, high-level West Valley waste, the glass canisters will be removed from the interim storage facility and the final closure performed. The canister will then be decontaminated to the level required by the repository's waste acceptance specifications. The canister is then to be loaded into a cask and shipped to the repository.

VITRIFICATION EQUIPMENT DESCRIPTION

The primary vitrification components designed for the WVDP process which are currently being tested are listed in Table I. The interconnections and placement of this equipment in the process are shown in Fig. 2. Their design features are described below.

Concentrator

The concentrator is a 19,000 L capacity vessel with internal steam coils and an external water cooling jacket. The vessel lid also provides space for installation of three steam chests if additional heat input is required. The tank diameter is 3 m and it is 3 m tall. The waste solids are kept in suspension by a 11 kW agitator. There are four internal baffles for vortex suppression.

The time required to prepare a batch of the waste slurry for vitrification is estimated to be approximately 100 h including sample analysis.

Because of the proximity of this vessel to the melter, it is envisioned that this will become the feed hold tank during hot operations, and the waste slurry will be prepared in a future concentrator.

ADS Pump

The feed slurry is metered to the melter by an air displacement style pump. The air displacement slurry (ADS) pump has a 2 L capacity fluid chamber equipped with inlet and outlet check valves. The check valves allow feed slurry to fill the chamber and then be forced out to the melter by a controlled flow of compressed air. The pumping chamber is installed near the floor of the concentrator. The ADS pump can provide slurry flow rates from 50 to 200 L/h.

Melter

The melter vessel is fabricated primarily from Inconel 690.[a] Its dimensions are 3.3 m long x 3.2 m wide x 3 m tall and it weighs approximately 55 tonnes. The floor and roughly the lower 75 percent of the walls of the containment vessel are water cooled to reduce the heat load on the cell ventilation system and to minimize the overall weight and size of the melter.

The glass melting cavity dimensions are 1.7 m long, 1.3 m wide, and the depth ranges from 25 cm to 66 cm. The glass depth is not constant because the melter refractory walls slope inward, forming an inverted, prismoidal shaped glass pool. This shape was selected to improve the structural stability of the refractory lining and minimize the glass holdup volume. The estimated glass volume in the melter is 860 litres. The glass surface area is approximately 2.2 m^2 which yields an estimated maximum slurry processing rate of 130 - 160 L/h. The design glass production rate for the melter is 45 kg/h. This glass rate is achieved at a slurry concentration of approximately 350 g-oxide/L and at a processing rate of 130 L/h.

[a] Inconel is a registered trademark of the Huntington Alloys Corporation.

TABLE I

Vitrification Equipment Installation and Initial Testing Dates

Component	Delivered	Assembled and Installed	First Operated
Slurry Fed Ceramic Melter			December 24, 1984
- Melter Box	June 22, 1984		
- On Site Bricking		November 9, 1984	
Turntable	December 6, 1984	December 17, 1984	December 24, 1984
Submerged Bed Scrubber	May 16, 1985	May 24, 1985	June 19, 1985
Concentrator	July 23, 1985	August 2, 1985	August 13, 1985
ADS Pump	August 7, 1985	August 9, 1985	August 22, 1985
Test HEME	August 22, 1985	October 7, 1985	October 23, 1985
Test HEPA	September 16, 1985	October 10, 1985	October 23, 1985

The melter utilizes a three electrode design. Two electrodes are located near the glass surface and the third forms the melting cavity floor. These electrodes are air cooled to permit bulk glass temperatures up to 1,300°C. The electrodes extend from the melter, through the cell wall, into the service gallery to permit contact maintenance of the power connections. The electrode power is supplied by three independent, single phase, SCR controlled circuits. This power supply system is arranged such that all three electrode circuits can be simultaneously energized and controlled.

Two airlift controlled, overflow style glass discharges are provided for glass transfer to the canisters. This feature provides a backup canister fill assembly. Also, the backup discharge chamber is constructed entirely from refractory materials to prevent damage should high temperature melter operation be required. The active discharge chamber is maintained at temperature by a remotely replaceable array of silicon carbide heater elements.

Turntable

The canister turntable is 2.7 m dia x 3.3 m tall and holds four canisters in a carrousel assembly. The turntable is sealed to the melter vessel to eliminate the need to connect each individual canister to the melter. An air lock assembly is provided to permit insertion and removal of the canisters from the turntable without significantly

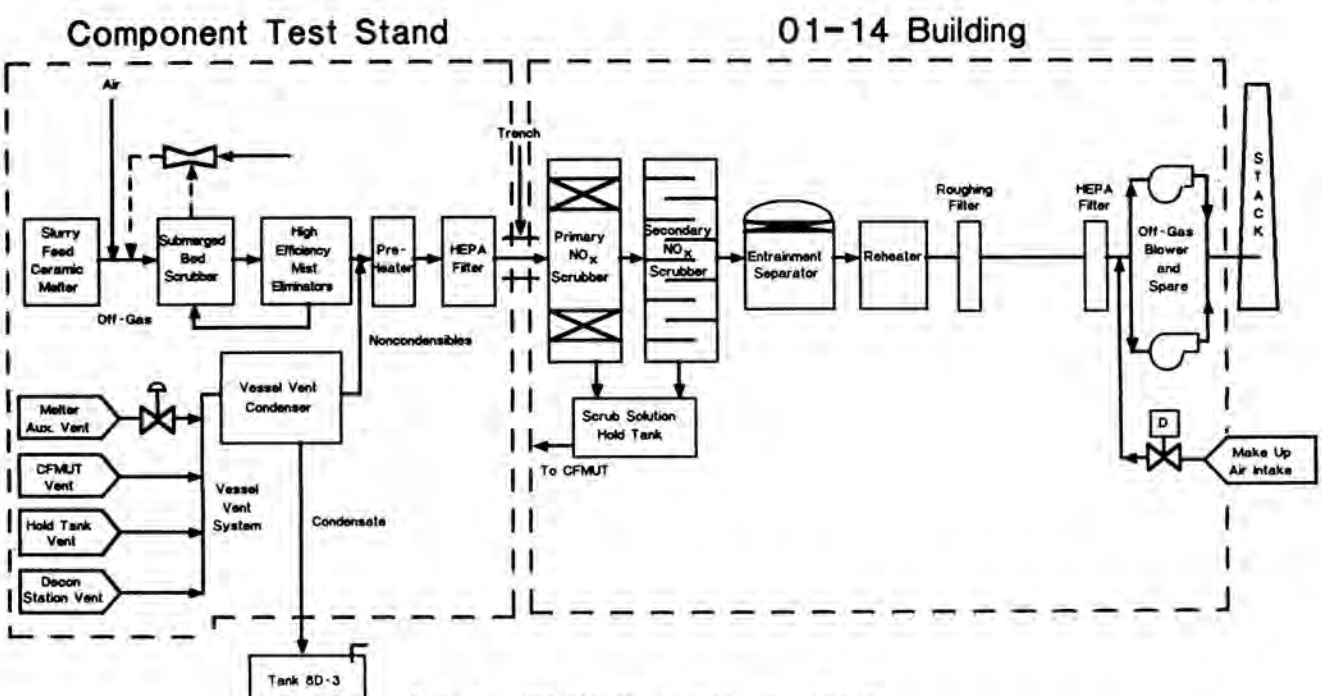

Fig. 2. Off-Gas and Vessel Vent System.

increasing the air inleakage to the process. The canisters are installed within removable liners in the turntable carrousel, enabling recovery from a canister overfill or accommodation of canister design changes.

The turntable is cooled by external water jackets to remove the latent heat from the glass canisters and control the canister cool down rates.

Submerged Bed Scrubber

The Submerged Bed Scrubber (SBS) is the first component of the process off-gas system and is 2.4 m dia and 3.4 m tall. The SBS is actually two vessels in one as it is composed of a 3,000 L scrub tank with a 5,500 L condensate collection tank beneath. Each of these tanks has an independent set of water cooling coils.

The SBS is a packed bed style scrubber which utilizes the process off-gases to circulate the scrubbing solution, no recirculation pump is required. The packing is 1 cm diameter ceramic spheres.

The primary purpose of this scrubber is to condense the steam from the melter and to remove particulates larger than 1 μm.

Test HEME

The process high-efficiency mist eliminator (HEME) is a 76 cm diameter by 3 m tall vessel which contains a washable, deep bed, fiber filter element. This style of filter is designed for submicron particulate removal. The HEME was sized to process the off-gas at flows up to 28 m^3/min with a pressure drop of less than 5 cm-w.c. An internal set of spray nozzles are installed to provide back flush capabilities to keep differential pressure to less than 13 cm-w.c. The flush solution is recycled to the SBS.

The current HEME vessel is not designed for remote use and will be replaced prior to hot operations. Test information will be incorporated into the final, radioactive design.

Test HEPA

A HEPA filter assembly and preheater are the final off-gas treatment systems inside the vitrification facility. This filter element is also designed for 28 m^3/min gas flow. Similar to the HEME, the HEPA filter assembly was not designed for remote operations, only for cold testing purposes. This unit will be replaced prior to hot operations. The remote HEPA will use two filter elements installed in parallel, but for cold testing a single HEPA filter is used.

01-14 Off-Gas Equipment

After the process HEPA filter, the off-gases will be routed to a NO_x removal system installed by Nuclear Fuel Services (NFS) in the 01-14 Building at the West Valley site. This equipment is shown in Fig. 2, and is composed of packed and bubble cap NO_x scrubbing columns arranged in series, a reheater, roughing and HEPA filters, and parallel positive displacement blowers. The treated process off-gases are then released to the stack.

VITRIFICATION TEST SUMMARY

The vitrification tests completed to date, the glass compositions processed, and the amount glass produced are listed in Table II.

The following section describes selected tests, emphasizing the slurry fed runs (SF-1 through 6) and the suction canister melter draining test. The future test plans, logic sequence, and principle objectives for the future runs are also presented.

LIEF

The glass log-in-eight-four (LIEF) was the startup operation for the WVDP melter and canister turntable. Startup was accomplished by preheating the melter with removable silicon carbide elements. After the melter was at temperature, glass frit was added to fill the melting cavity. The startup heaters were removed after conduction between the electrodes was established. The startup process was accomplished over an 11 day period.

PROCAN Tests

The process canister (PROCAN) tests were performed to characterize the deformation of thin walled glass canisters during the filling process. These tests filled canisters of 6 mm, 5 mm, and 3 mm wall thicknesses with simulated waste glass. Glass frit was used to permit well controlled glass melting rates.

In all cases, canister deformation observed was well within the +1.5 cm, -1.0 cm band proposed by the draft repository waste acceptance criteria.

SF-1

This test was the first slurry-fed operation of the vitrification equipment. Slurried WV-192 frit was used for the test. The run was designed to checkout the auxiliary equipment required to feed and ventilate the melter. The run duration and slurry processing rates were limited by air inleakage into the melter/turntable system.

SF-2

Run SF-2 was the first demonstration of the concentrator as a feed tank and also was the first time that the reference WV-205 glass was processed. This test was intended to verify that the system upgrades following SF-1 were effective and to evaluate the melter and turntable performance at the flow sheet glass production rate. A total of 9,800 L of slurry feed was processed yielding 3,400 kg of glass. The average feed rate was 95 L/h and a rate of 150 L/h was achieved for a 26 hour period.

SF-3

This experiment included the first test of the concentrator as a feed evaporator, use of the ADS pump, and the processing of hydroxide based, simulated WV-205 waste slurry. A WV-205 frit slurry was concentrated at an average evaporation rate of 570 L/h.

TABLE II

WVDP Vitrification Test Summary

Date	Run Description	Feed Type	Glass Feed Composition	Fed (kg)	Litres Slurry Fed (L)	Concentration of Oxides in Feed (g/L)	Amount of Glass Collected (kg)
12/20-26/84	LIEF	FRIT	WV-183 - A	4,050	-	-	1,800
01/31/85	AIRLIFTING TEST	FRIT	WV-183 - A	550	-	-	550
02/14/85	AIRLIFTING TEST	FRIT	WV-183 - A	650	-	-	650
02/18/85	SPRINGVILLE NIGHT	FRIT	WV-183 - A	250	-	-	-
03/29/85	PREPROCAN TEST	FRIT	WV-183 - A	200	-	-	300
04/26/85	AIRLIFT CALIBRATION	FRIT	WV-183 - 1	250	-	-	300
05/02-03/85	PROCAN TEST TC-1	FRIT	WV-192 - B	1,450	-	-	1,500
05/15-17/85	PROCAN TEST TC-2	FRIT	WV-192 - B	1,550	-	-	1,600
05/28-31/85	PROCAN TEST TC-3	FRIT	WV-192 - B	3,650	-	-	3,850
06/16/85	OPEN HOUSE	FRIT	WV-192 - B	500	-	-	700
06/19-21/85	SF-1	FRIT SLURRY	WV-192 - B	-	850	350	200
07/17-22/85	SF-2	FRIT SLURRY	WV-205 - C	-	9,800	350	3,400
08/13-23/85	SF-3	FRIT SLURRY	WV-205 - C	-	8,900	350	3,500
		HYDROXIDE SLURRY	WV-205 - D	-	1,200	300	
08/28/85	MELTER DRAINING BY SUCTION CANISTER, ETC. 1,2,3,4						2,050
10/20-21/85	CIEF MELTER RESTART	FRIT	WV-205 - C	-			1,600
10/31-11/03/85	SF-4	HYDROXIDE SLURRY	WV-205 - 0	-	5,800	325	1,900
		NITRATE SLURRY	WV-205 - E	-	1,600	325	500
12/17-12/23/85	SF-5	NITRATE SLURRY	WV-205 - E	-	4,400	320	1,400
01/18-28/86	SF-6	NITRATE SLURRY	WV-205 - E	-	8,600	300	2,600
	TOTALS				41,150		28,400

In total, 8,800 L of the frit slurry was processed by the melter at an average of 80 L/h. The slurry throughput rate was limited by a viscous, foamy layer formed at the glass surface.

A hydroxide simulation of the reference glass was processed after completion of the frit slurry objectives. In all, 900 L of the hydroxides were fed to the melter at an average rate of 70 L/h, and a maximum sustained rate of 100 L/h was achieved. The combined frit and hydroxide slurry glass production was 3,300 kg.

Suction Canister Test

Forming and casting the concrete wall of the cell behind the melter was one of the initial stages of the continuing vitrification facility construction.[1] These activities required that the electrode power supplies to the melter be turned off for about a two month period. Rather than allowing the glass in the melter to freeze, it was removed using the suction canister technique.

The startup heaters were reinstalled in the melter. A total of four suction canisters were used and 815 L of glass was removed. This represents removal of more than 94 percent of the glass capacity of the melter. The glass heel remaining in the melter was approximately 50 L. The time required to fill the suction canisters averaged about 10 minutes.

SF-4

Following the restarting of the melter, the first nitrated slurry feed was processed in SF-4. Nitrate feed testing was deferred to this point while the NO_x scrubbing equipment was upgraded for this application. This run was also the initial test for several off-gas components: film cooler, HEME, HEPA, and NO_x scrub columns.

The first part of the run was completed with the simulated hydroxide slurry. The hydroxide based feed stream processed well and melter feed rates up to 180 L/h were sustainable. The average feed rate was 150 L/h.

The feed composition was changed to include the process flow sheet level of nitrates for the last day of the test. The nitrated feed did not process as readily as its hydroxide analog and the average slurry feed rate fell to 100 L/h. During SF-4, 5,800 L of hydroxide and 1,600 L of nitrated simulated waste slurry was processed which produced 2,400 kg of glass.

SF-5

The initial data for the WVDP process/product correlation was gathered during Test SF-5 following the installation of the C-sampler in the concentrator. The process/product correlation will utilize the data base generated during the vitrification equipment cold testing phase, and assure that the desired feed formulation and melter operating conditions will produce a glass product which meets the waste acceptance criteria for the future federal HLW repository. This correlation requires both an accurate feed slurry sample and analysis. The C-sampler is a candidate method for obtaining the sample. This test was also the first time the vitrification distributed control system (DCS) was used to operate process components.

Maximum slurry processing rates were limited by glass foaming events to between 50 to 60 L/h. The foaming was a combination of glass reboil and feed slurry chemical composition variations. The slurry feed was found to be enriched in Si and low in B and the alkalies. These compositional variances are believed to be caused, at least in part, by feed segregation in the concentrator. This and other potential causes of the feed composition discrepancies are currently being analyzed.

Approximately 4,400 L of slurry was vitrified in this test, generating 1,400 kg of glass.

SF-6

The SF-6 test marked the first use of the data collection/logging capabilities of the DCS. The process/product correlation data base accumulation was continued from SF-5, emphasizing the ADS pump as a possible feed sample source. The process off-gas sampling abilities were also improved to upgrade the vitrification mass balance, especially for semivolatile radionuclides.

One of the major objectives of SF-6 was to modify the SF-5 feed remaining in the concentrator to the desired WV-205 formulation, and assess the effect of this change on the slurry processability. Therefore, the appropriate amounts of B, K, Li, and Na were added to the slurry. This change resulted in an increased maximum feed rate from 50 - 60 L/h to roughly 100 L/h. The higher slurry processing rate was limited by bulk glass reboiling rather than melting behavior. As discussed in the next section, glass reboil control will be the focus of the near term runs.

Another lesson from the SF-6 run was that the off-gas line film cooler air flow should not be interrupted. The air was turned off during the later stages of SF-5 and this apparently allowed off-gas particulates to obstruct portions of the film cooler air injection slots. These obstructions disturbed the flow patterns in the film cooler leading to significant off-gas line fouling during SF-6.

A total of 8,600 L of simulated waste slurry was fed to the melter and 2,600 kg of glass was collected during this run.

Future Test Plans

The plans for full scale integrated testing between now and hot operations are displayed in Fig. 3. The strategy in the early slurry feeding runs has been to establish reliable processing equipment, instrumentation, and control systems. The development and upgrading of these systems for high process reliability is required to obtain proven, stable, extended run information. This mode of testing will continue until most of the system equipment problems have been resolved.

The early tests will also be used to confirm the results of laboratory experiments designed to eliminate the reboil problem experienced in runs SF-5 and SF-6.

After achieving stable process operation, the integrated process testing plan progresses towards qualification of the process and the resulting product. This is envisioned to occur in four general stages: 1) performance characterization of the equipment that is planned for hot operations; 2) finalization of process chemical specifications; 3) development of draft standard operating procedures; and 4) implementation of long term process testing (30 to 60 days).

After a reliable processing data base is accumulated from which bulk glass reboil control can be achieved, the procedures and the equipment will be made to closely simulate the actual plant operation. One or more preliminary operational tests will be implemented before beginning a qualification test which would be fully documented in accordance with ANSI/ASME NQA-1,[2] the required quality assurance plan at the project and the repositories.

Following this qualification run, the simulated waste composition received by the concentrator will be varied and the operating staff will not be informed of the actual chemical composition. These variations will assess the process equipment integration, sampling, analytical practices, and the cold chemical preparations required to make a qualified glass. These blind experiments will also provide the assurance needed for actual operations.

Before completion of the full-scale equipment testing, the duration of runs will be extended up to 30 - 60 days. Each of these tests will also include waste variations unknown to the operations crew and will provide supplemental data to confirm that a quality product can be produced by appropriate process chemical specifications and constraints, and through process control parameters.

Once these objectives have been achieved and approved, the equipment will be torn down and evaluated for corrosion and other possible failure modes. The melter will be rebricked and reinstalled in position. For cold operations, the remote operating systems, including the process crane and the jumpers, will be installed. Cold operations will involve integration of all operational facets including the remote handling. The cold testing will include a run of approximately four months in duration. An extended test of this length is needed for confirmation of the procedures and operability of the remote systems prior to radioactive service.

A minimum of nine full scale integrated tests are planned between now and beginning of cold operations. These full scale integrated tests will follow the generalized pattern as indicated in Fig. 4. This figure represents the generic FACTS (Functional And Checkout Testing of Systems) run logic. The general pattern of these runs will be to establish run objectives, implement the run objectives through the completion of the run, and evaluate the results of the test through debriefings of the operating staff and analysis of samples obtained from the experiment. This leads to preparation of run summary reports and formulation of the run objectives for the next FACTS run.

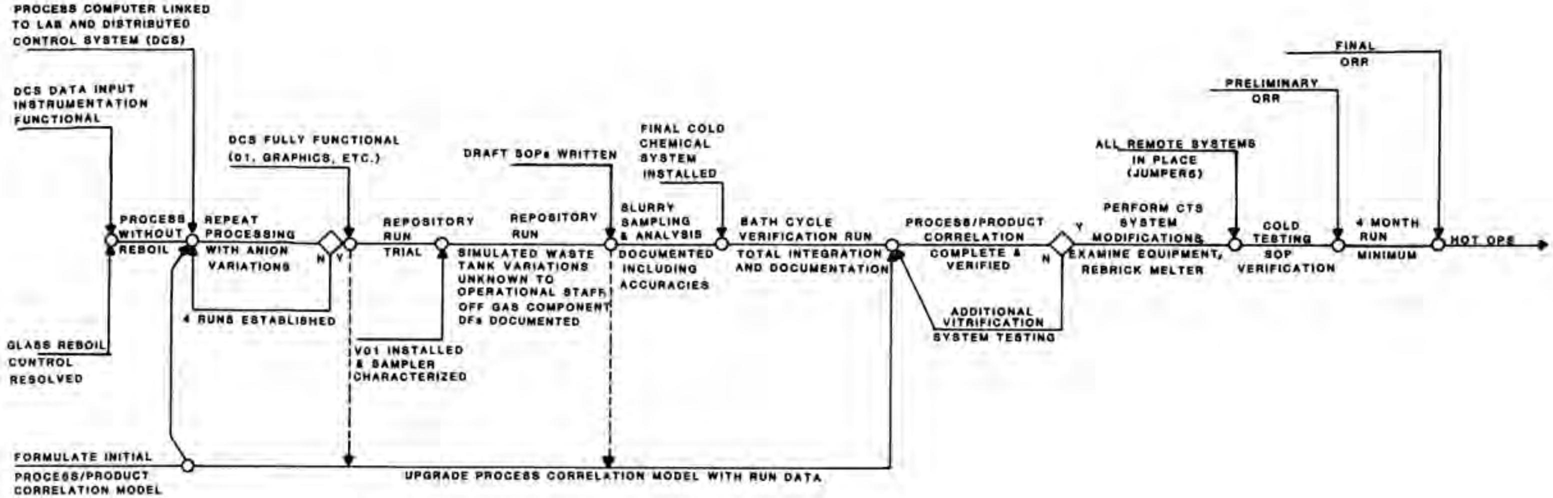

Fig. 3. West Valley Full Scale, Integrated Process Testing Plan.

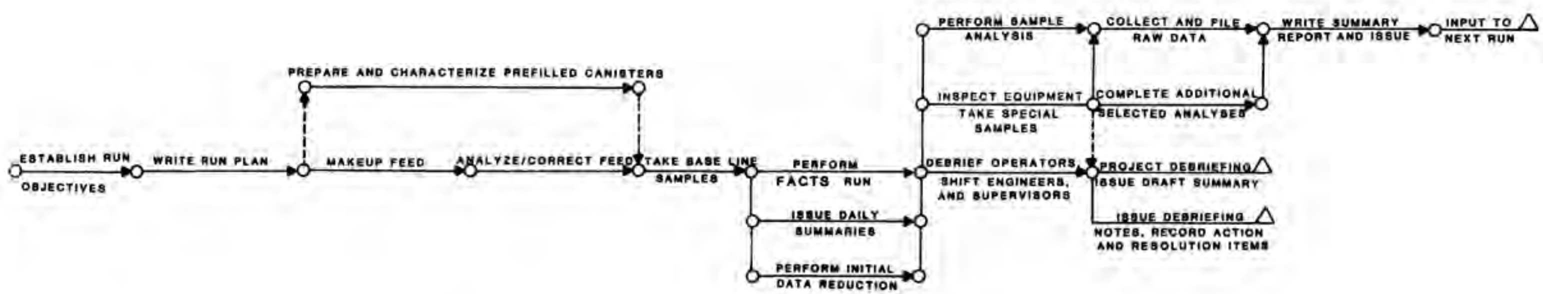

Fig. 4. Generic FACTS Run Logic.

Some of the key objectives required of these FACTS runs are:

- 0 Statistically demonstrate that the concentrator feed makeup tank and melter feed tank are well agitated.
- 0 Statistically verify that a representative sample of the concentrator and feed tanks can be obtained.
- 0 Verify that accurate chemical analysis of the slurry samples can be obtained routinely.
- 0 Measure and document off-gas effluent decontamination factors for the purpose of determining and defining radioactive constituent releases.
- 0 Define and verify processing logic through the distributed control system.
- 0 Demonstrate that a quality product can be obtained by process sampling and process control with variations in the waste stream and the key processing variables.
- 0 Test to assure appropriate operability of the remote systems.

SUMMARY

Nearly all of the full-scale process equipment designed for vitrification of the high-level radioactive wastes at the West Valley Nuclear Services site are installed and undergoing verification testing. To date, 41,150 L of simulated waste has been vitrified and 28,400 kg of waste glass has been produced during 17 process tests.

The requirements for waste qualification and process verification have been analyzed. Objectives for completion of the remaining qualification requirements have been identified, and this analysis indicated that a minimum of nine test runs are required prior to the start of cold operations. The preparations for these verification tests have begun and the glass qualification testing is in progress.

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