SAVANNAH RIVER WASTE VITRIFICATION PROGRAM

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INTRODUCTION

One of the alternatives for management of Savannah River high level liquid waste calls for conversion to a vitrified product followed by shipment to a Federal Repository. Solidification would begin in FY-1988, with plant authorization and initiation of plant construction anticipated for FY-1982.[1] The plant is being designed to process reconstituted waste from the Savannah River waste tanks at an average rate of approximately 9 gpm. The backlog of existing waste would be worked off in approximately 15 years. This paper describes the development program for processes and equipment to carry out the vitrification of Savannah River liquid waste.

BACKGROUND

The initial evaluation of waste forms and processes appropriate for conversion of Savannah River waste to a high integrity solid was made in 1973. The concept that was defined at that time (Fig. 1) included removal of the waste from tanks, followed by chemical tank cleaning, physical separation of the insoluble sludge from supernate, separation of soluble radionuclides from the supernate by ion exchange, incorporation of the sludge and radionuclides from ion exchange into a high integrity form, and evaporation of the decontaminated supernate to form a salt cake.[2] Subsequent laboratory studies during the period of 1973-1977 showed that the separation of nuclides from the soluble salts was feasible[3] and that glass was the preferred waste form.[4,5] Conceptual design studies and venture guidance cost studies of facilities for solidification were initiated in 1974.

The portion of the process involving vitrification (calcination of waste slurry, melting, and off-gas treatment) was considered to represent the largest remaining area of technical

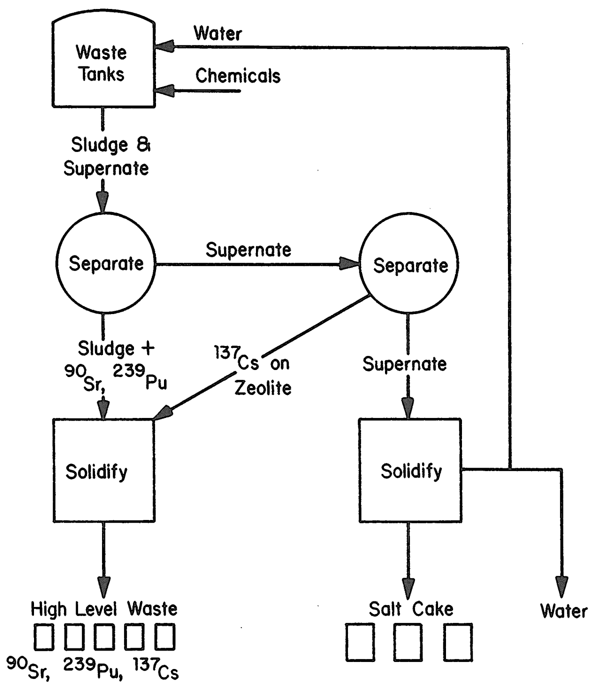

FIG. 1. Conceptual Waste Solidification Process

uncertainty in the process, and an accelerated development program was initiated in this area for Savannah River waste in 1977.

In the reference Savannah River process, up to 7,200 liters per day of sludge slurry are calcined and then melted to form ∿3 tons/day of glass (Fig. 2). The vitrification concept chosen was based on development work carried out previously at Battelle-Pacific Northwest Laboratories for commercial waste. The reference concept adapted from the PNL work includes heated wall spray calcination, melting in a continuous joule-heated ceramic heater (or

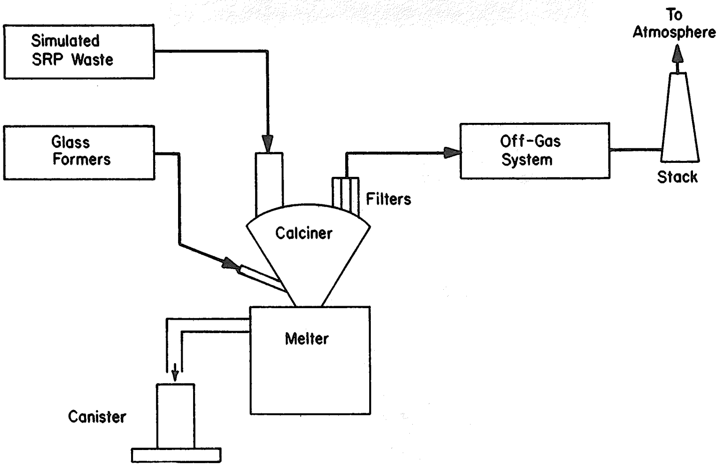

FIG. 2. Developmental Defense Waste Melter System

in an in-can melter as an alternative batch process), and removal of solids in the calciner off-gas by sintered metal filters. Milestones in the development program to date are summarized below:

- 1973 — Initial concept defined.
- 1974 — Began Engineering Department conceptual design studies.
- 1973-1977 — Feasibility of separations steps demonstrated and waste forms evaluated.
- 1977 — Initiated accelerated vitrification program.

SUMMARY

The principal objective of the Savannah River vitrification development program is to provide the technical data needed for design of the full-scale plant-configured system by the expected authorization date for the Savannah River Defense Waste Processing Facility, October 1981. The vitrification development program can be divided into three basic areas:

1. Small-scale melter and model studies at Savannah River Laboratory (SRL).

2. Large-scale tests in existing equipment at Battelle-Pacific Northwest Laboratories (PNL).

3. Full-scale developmental tests at SRL.

The first two areas of the development program will provide process development data (optimum glass-former compositions, etc.) and a firmer basic understanding of the vitrification process. (which includes spray calcination, melting, and off-gas treatment) in smaller-scale equipment and in existing larger-scale equipment at PNL. Most of this information will be provided during 1979 and 1980.

The third area of development, full-scale tests at SRL, will provide sufficient information for design of the plant equipment. These data will be available by the projected plant authorization date of October 1981.

PROGRAM

The Savannah River vitrification development program consists of three primary areas: 1) small-scale melters (using both simulated and actual waste) and model studies, 2) tests at Battelle-Pacific Northwest Laboratories (PNL) in large-scale developmental equipment using simulated Savannah River waste, and 3) construction and testing of full-scale equipment at Savannah River with simulated waste to demonstrate the process and the basic equipment features necessary for remote canyon operation.

Small-Scale Melters and Model Studies

Savannah River Laboratory is currently testing two similar small-scale rectangular melters with melt volumes of approximately 0.03 ft^3 and 0.5 ft^3, respectively (the full-scale melter will hold over 30 ft^3 of glass). Tests in these melters provide information on melting rate, foam formation, product quality, etc. for various glass-former (frit) and simulated waste compositions. Tests can also be carried out in these melters under more extreme conditions than would be possible in larger-scale melters. A small-scale cylindrical melter is also being constructed with a melt volume of approximately 1.5 ft^3 in order to provide data under conditions similar to those in the present reference design for the full-scale melter.

Mini-scale melting tests will be carried out with actual waste in shielded cells at SRL.

Both of the small-scale rectangular melters are in operation. Results to date in the 0.5 ft^3 melter indicate melting rates of at least 4 to 5 lb/hr in that melter. The rate was limited by the feeder device, and the system is being modified to allow determination of the maximum attainable rate in this size melter.

A cylindrical melter physical model with ∿one-fourth the volume of the full-scale melter is also being tested with a glycerine/LiCl mixture as the fluid. The model will provide velocity and temperature profiles and will allow convenient modification of electrode size and location. The physical model will be used in conjunction with mathematical modeling studies and the small-scale melters to develop a firmer basic understanding of the vitrification process. The physical model is currently in the start-up phase.

Tests at PNL

Large-scale vitrification tests are being carried out at PNL in 1) a spray calciner coupled directly to a 2-ft-diameter in-can melter, 2) a spray calciner directly coupled to a ∿9-ft^3 volume continuous joule-heated ceramic melter, and 3) a ∿19-ft^3 volume joule-heated ceramic melter using simulated calcine feed. Descriptions of this equipment have been published previously by PNL authors.

The principal goals of the tests at PNL are to evaluate process parameters such as melting rate, foaming, product quality, etc. in large-scale equipment for a variety of waste and frit compositions. The tests at PNL provide a large-scale comparison with the tests at SRL in the smaller-scale melters. A prime objective of both the small-scale melter tests at SRL and the large-scale melter tests at PNL is development and demonstration of a glass frit composition that will give good melting rate, produce no separate solid phases in the melt, and result in a high-quality glass product before initiation of full-scale testing at the SRL semiworks (late 1979).

Although the feed to the solidification plant will be as well mixed as possible, there will still be some variation in composition of the waste fed to the hold tank at the front end of the process. A single frit composition is to be used for all feed compositions. However, even though the feed hold/mix tank at the head end of the process is over one million gallons in volume and provides a year or more of feed with well characterized, constant composition, it would be possible to change frit to accommodate marked changes in feed composition from batch to batch if necessary.

SR COMPOSITE SLUDGE COMPOSITION[a]

Composite	wt, %
Al_2O_3	46.9
Fe_2O_3	32.1
MnO_2	10.4
Zeolite	5.0
CaO	3.2
NiO	2.4
	100.0

SR FRIT COMPOSITION

Composite	wt, %
SiO_2	58.3
Na_2O	12.5
Li_2O	12.5
B_2O_3	11.1
CaO	5.6
	100.0

a. Simulated dried sludge from the calciner.

Results to date at PNL in small-scale in-can melters at ∿1050°C indicate melting rates equal to about half that attained for commercial waste at the same temperature. A continuous melting rate of ∿1.2 tons/day has been obtained in the 9 ft^3 continuous melter coupled with the calciner at a melter temperature of ∿1200°C.

Full-Scale Development

A new facility is under construction at Savannah River to complete the development of the Savannah River vitrification process and to provide sufficient information for design and procurement of full-scale plant equipment. The facility will include:

- Spray calciner.
- Continuous joule-heated ceramic melter.
- In-can melter furnace.*
- Off-gas system.

The overall objectives of this full-scale developmental facility are:

- Complete process development.
- Develop design basis data.
- Product characteristics as function of operating conditions.
- Define process control requirements.
- Facility for troubleshooting and scouting process improvements.
- Demonstrate Design Feature required for remote operation

The advanced developmental equipment being procured for this facility contains all of the basic features that are required to demonstrate feasibility of remote canyon operation. Location of equipment in the facility is shown in Fig. 3. Each major item is discussed below in more detail.

Spray Calciner

Extrapolation of calcination tests at PNL with simulated Savannah River waste in a 3-ft-diameter calciner operated at ∿800°C indicated that a single 4½-ft-diameter calciner chamber operated at 800-950°C could potentially process the expected 3.1 gpm (700 liters/hr) sludge slurry stream for the reference plant. The spray calciner chamber will be 4½-ft-diameter by

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* As an alternative to the continuous joule-heated ceramic melter.

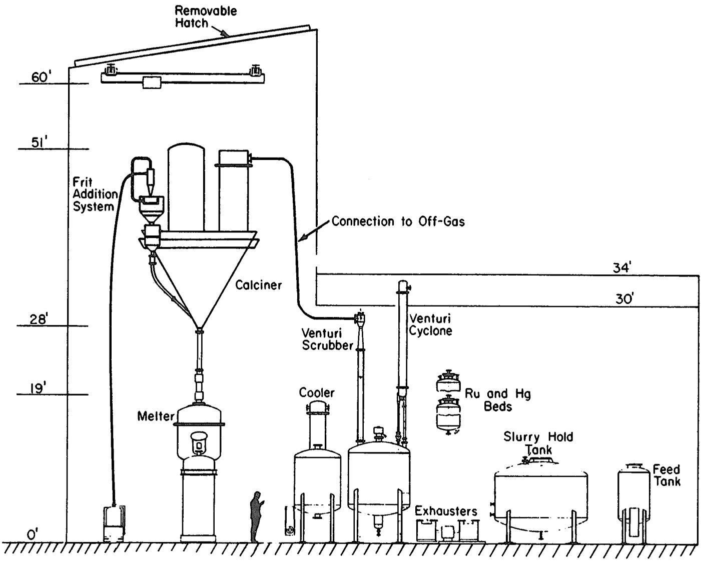

FIG. 3. Melter-Calciner - Off-Gas System

10-ft-high and is heated by a tapped single zone induction furnace that permits vertical profiling. Vibrators are located on the chamber to prevent solids accumulation. It rests on a collection cone with a minimum slope of 60° to avoid accumulation of calcine. The filter housing, containing 142 2-in.-OD by 6-ft-long sintered metal filters, also rests on the collection cone. Glass frit is added near the bottom of the cone. The collection cone has an ob-round shape to allow better vertical access to melter equipment located directly underneath the calciner (Fig. 4).

The calciner chamber, cone, and lower portion of the filter housing are to be constructed of *Incoloy 800H*.[a] The sintered metal filters and the upper portion of the filter housing will be constructed of *Inconel 600*.[a]

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a. Registered trademarks of Huntington Alloys, Inc.

Approximately one-half of the calcine is entrained in the off-gas passing up through the calciner. The calcine is collected on the sintered metal filters and periodically returned to the melter by air pulses that remove the solids from the filters.

Continuous Joule-Heated Ceramic Melter

The continuous melter is located directly beneath the calciner (Fig. 5). The melter was designed as conservatively as practical to give a maximum lifetime. The principal design features are summarized below.

Design Feature	Basis
Refractory contained in metal shell	Provides containment. Controls in-leakage. Keeps bricks in place during melter installation and operation.
Round shape	Maximum mechanical integrity during installation and operation. All forces act in compression and tend to keep bricks in place even with some cracking.
Maximum practical cooling of refractories (maximum thermal gradient)	Immobilizes glass that may get through cracks and does not permit further erosion or attack on the "cushion" layer between refractory and metal vessel.
K-3 (a fused cast chrome-alumina refractory with 27% Cr_2O_3) in contact with melt	Best resistance to SR defense waste.
Thin cushion layer between K-3 and shell	Allows for thermal expansion of refractory.
Joule heated by 2 pair of top-entering, cylindrical electrodes	Eliminates potential leak path as compared to side entering electrodes. May potentially be removable. Melter could probably run on only one pair. Rod electrodes give good mixing.

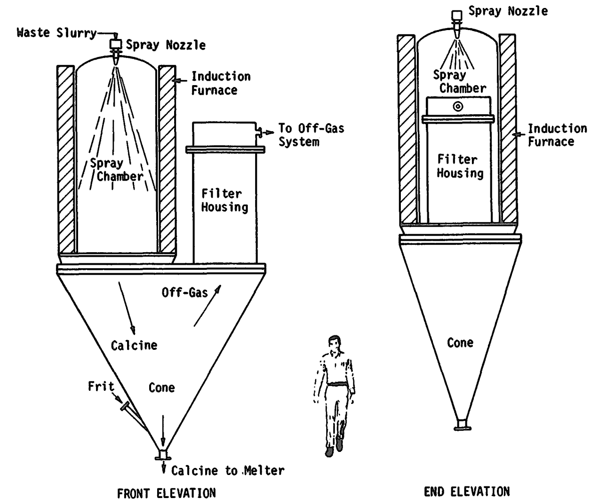

FIG. 4. Spray Calciner

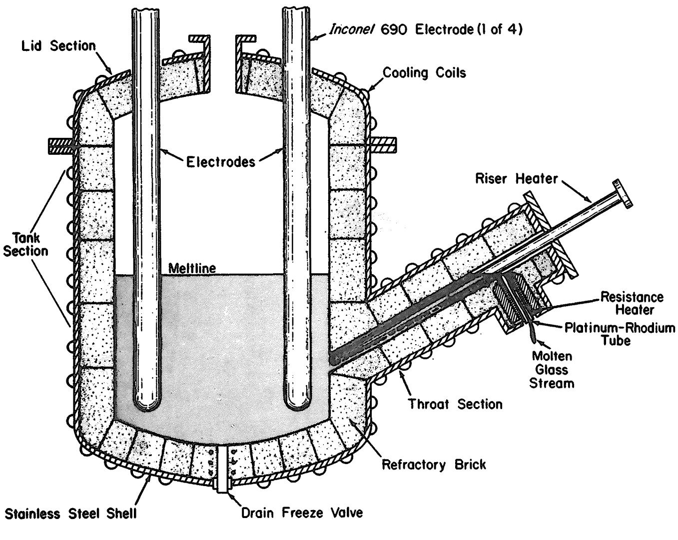

FIG. 5. Full-Scale SRL Continuous Melter

Design Feature	Basis
Electrodes 6-in.-diameter, air-cooled, and made of *Inconel*	Maximum lifetime. Flux is less than 2 amps/in^2. Material tests show *Inconel* best material. Air cooling extends lifetime.
Throat/riser for level control	Simplest concept. Self-regulating.
Tilt-pour	Considered more reliable than freeze valve.
Straight-through, slanted throat/riser	Minimizes "upward drilling" phenomenon.
Resistance-heated throat	Simplest heating technique. Adequate for lower temperatures in throat.
Hot air start-up/re-start	Simplest method for melter. Minimum thermal stress. Lid heaters will also be evaluated.
Bottom drain valve	Highly desirable for remote operation. Drain valve would always be connected to a container beneath the melter.

Specific goals for the full-scale melter are:

- Determine melting rates.
- Determine product quality.
- Demonstrate Start-up Method selected from Small-Scale tests such as
    - Sacrificial elements.
    - Liquid start-up.
    - Lid heater with frit.
    - Hot gas
- Demonstrate cylindrical melter/electrode system.
- Evaluate water-cooled refractories with no insulation.
- Evaluate *Inconel* and tin oxide electrodes.

- Determine effects of start-up and shut-down.
- Evaluate melter lifetime.
- Evaluate melt pour control.
- Evaluate melter drain.
- Determine interaction between calciner and off-gas.
- Determine long-term solids accumulation.
- Evaluate melter control.
- Evaluate cold cap behavior.
- Evaluate adaptability to canyon.

In-Can Melter

The reference concept for the Savannah River solidification plant is the continuous melter. The in-can melter concept may potentially provide a simpler system, however, more development work is needed to determine whether the system actually does provide the advantages postulated. To evaluate the quality of the product, the melting rate, dust containment, canyon space requirements, etc., a furnace is being procured for testing at the SRL semiworks that would allow testing of cans up to 30 inches in diameter by about 10 ft tall. Concepts for a remote operation are being developed concurrently by engineering studies and should be available by early 1979. Additional equipment may be procured pending the results of this study.

Comparisons have been made between continuous melting and in-can melting based on the postulated advantages of each. Sufficient information will be obtained in full-scale tests with both systems so that a choice can be made at the required time. The continuous melter is currently being assumed as the reference process for the Savannah River facility.

Off-Gas System

Gases from the melter are pulled up through the calciner and through the off-gas system by an exhauster. The melter, calciner, and off-gas equipment thus operate at a slight vacuum (10 to 15 in. of water). Relatively large quantities of calcine powder are entrained in the off-gas stream. The sintered metal filters remove 99.9% of the particulates. The function of the remaining portions of the off-gas system is to clean the gas stream to meet standards for discharge to the atmosphere. The primary functions of the steps in the system are shown below.

OFF-GAS SYSTEM

Operation	Primary Function
Quench/scrubber	Reduce off-gas temperature from ∿650 to ∿50°C. Remove additional particulates and non-particulates (HCl, HF, Hg, RuO_4).
Venturi cyclone	Additional particulate removal.
Mercury condenser	Reduce off-gas temperature to ∿5°C to condense out Hg.
Steam heater	Raise off-gas temperature ∿10°C above dew point to prevent condensation in downstream beds.
Ruthenium adsorber beds	Remove remaining volatile Ru on silica gel.
Hg adsorber bed	Remove remaining Hg on $AgNO_3$ exchanged zeolite.
HEPA filtration	Final particulate removal step.

Schedules

The basic goal of the SRL vitrification development program is to resolve remaining technical uncertainties and provide the technical data required for design of the plant equipment for vitrification by the planned date for plant authorization (beginning FY-1982). Development work would continue after that date; however, the emphasis would then shift to process optimization.

Development of frit should be sufficiently advanced by the end of 1979 that the frit composition would be defined. Although some additional minor modifications of frit would be made after that time, the main objective of the full-scale melter tests at SRL during 1980 and 1981 would emphasize the effects of changes in calciner feed composition for a relatively fixed frit composition. Testing of both the continuous melter and the in-can melter should be sufficiently advanced by April 1981 that a decision could be made at that time between the batch and continuous processes.

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