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IMMOBILIZATION OF INCINERATOR ASH IN A CONCRETE MATRIX

by

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ABSTRACT

The ashcrete process will solidify ash generated by the Consolidated Incinerator Facility (CIF) at the Savannah River Plant (SRP). The ashcrete unit produces ashcrete, a stable cement-based wasteform, by remotely adding cement and water and tumbling drums of ash. Ashcrete product homogeneity, temperature rise during setting, and compressive strength were measured and product formulations were developed for several nonradioactive dry ash types. Saturation level and wet and dry ash densities for several ash types have been measured. Preliminary mixture formulations for the anticipated ash were tested. A proof-of-principle test was performed using a mockup of the CIF ash system. Finally, mechanical modifications to prepare the unit for use with the CIF and to ensure reliable operation are being implemented.

Introduction

The CIF will burn low-level radioactive and hazardous waste produced at SRP. Ashcrete's role in the facility will be to solidify the solid ash discharged from the rotary kiln incinerator. The ash will be expelled from the kiln into a water bath where it will cool to 100°F. A backhoe ash removal system will pull the ash from the bath, pause to allow excess water to drain, and drop the ash through an ash crusher (Figure 1). The ash crusher will discharge the ash into an ashcrete drum (up to the desired fill level) and the drum will traverse to the ashcrete processing unit.

The ashcrete processing unit was originally designed to solidify dry ash types (solid waste and spent solvent ash from an existing incinerator at SRP) in a cement-based wasteform that was resistant to subsidence and leaching.[1] Portland type II concrete was chosen as the solidifying agent because of its low cost, shielding properties, and handling ease. To limit personnel exposure to radioactivity, the processing unit is automatic and enclosed. Additionally, there is no contact between the processing equipment and the radioactive ash because all processing is accomplished within the CIF discharge drum.

To solidify drums of wet ash:

- Ash is removed from the CIF and moved to the processing unit. The drums traverse to the unit on the ashcrete unit transfer car.
- The proper amount of cement is added and mixed with the wet ash using several addition/mixing cycles.
- The mixed drum is removed from the processing unit and allowed to set before permanent disposal in a waste disposal facility.

Equipment /Process Description

The ashcrete unit consists of a process enclosure and three support units: a HEPA filter unit, a controller station, and an unbagger station (Figure 2).

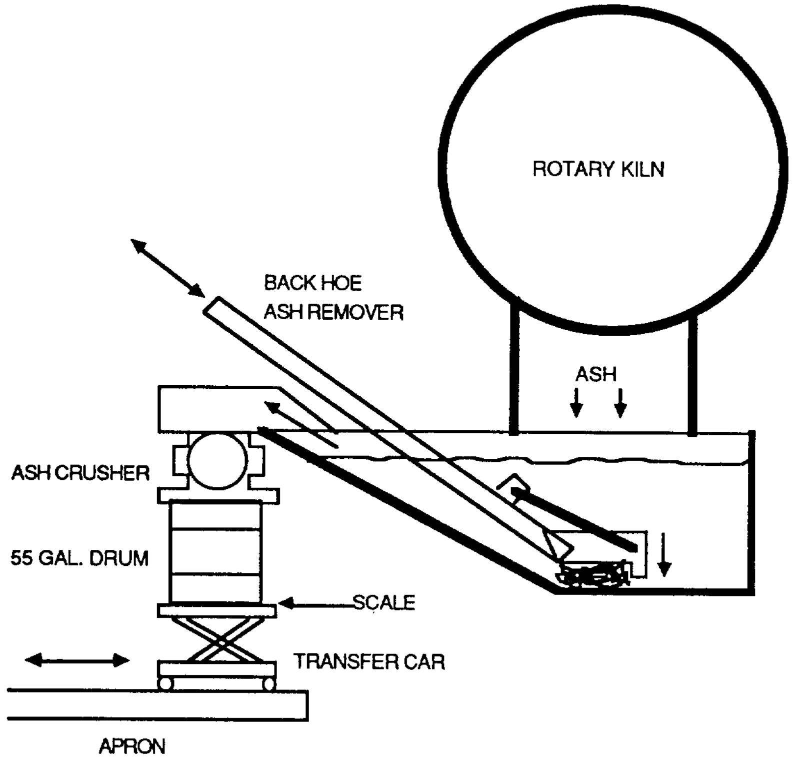

Figure 1. CIF Ashout System

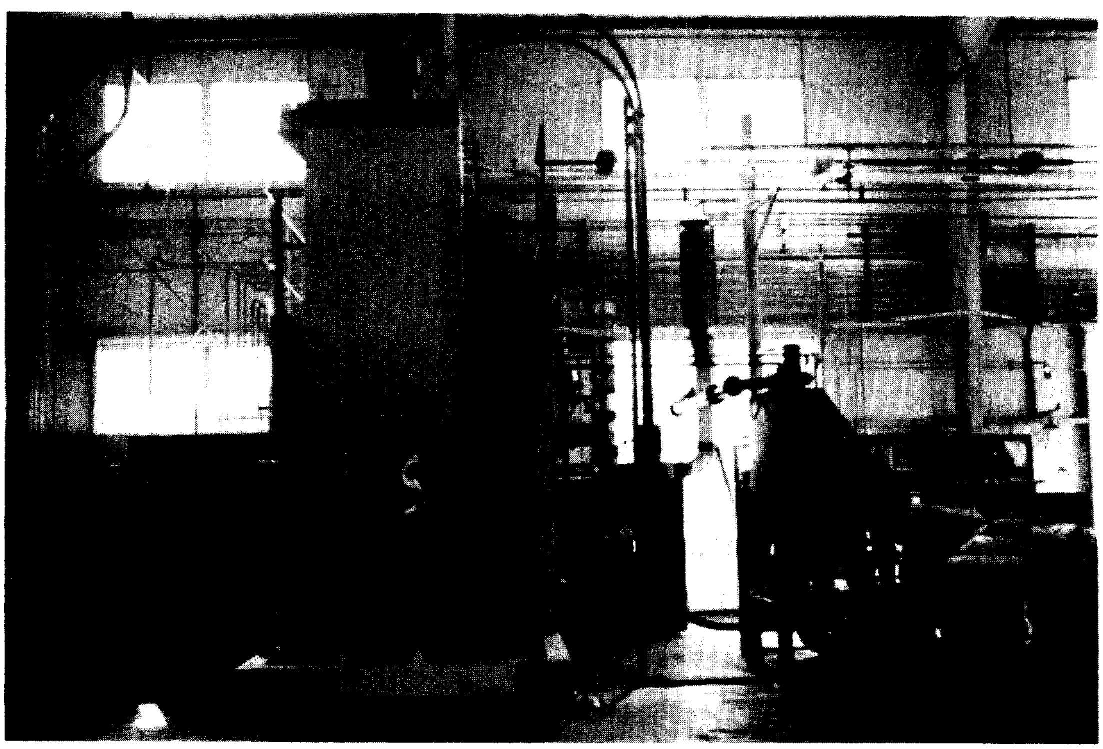
Figure 2. Ashcrete Process Unit

Process enclosure components are the car apron, the transfer cart, the enclosure door, the water addition station, the cement addition station, the capper mechanism, and the tumbler mechanism (Figures 3a and 3b). Support equipment includes cement hoppers, a dry feed system (screw conveyors), and a water reservoir. The process sequences are controlled by an Allen-Bradley PLC/230 programmable controller.

Processing begins at Station 1 where the wet ash-filled drum is prepared for entering the processing unit. The DOT-17C 55-gal drum is fixed with a lid that contains a 4-in. centered screw hole and the corresponding cap. Two iron mixing bars are added to the wet ash to ensure full mixing and product homogeneity.

The transfer car is self-propelled along two tracks that extend into the enclosure. The car lifts the drum at each station and weighs the drum throughout the process. The weight information is used to determine the amount of material remaining to be added. Car position and height are controlled using vane limit switches.

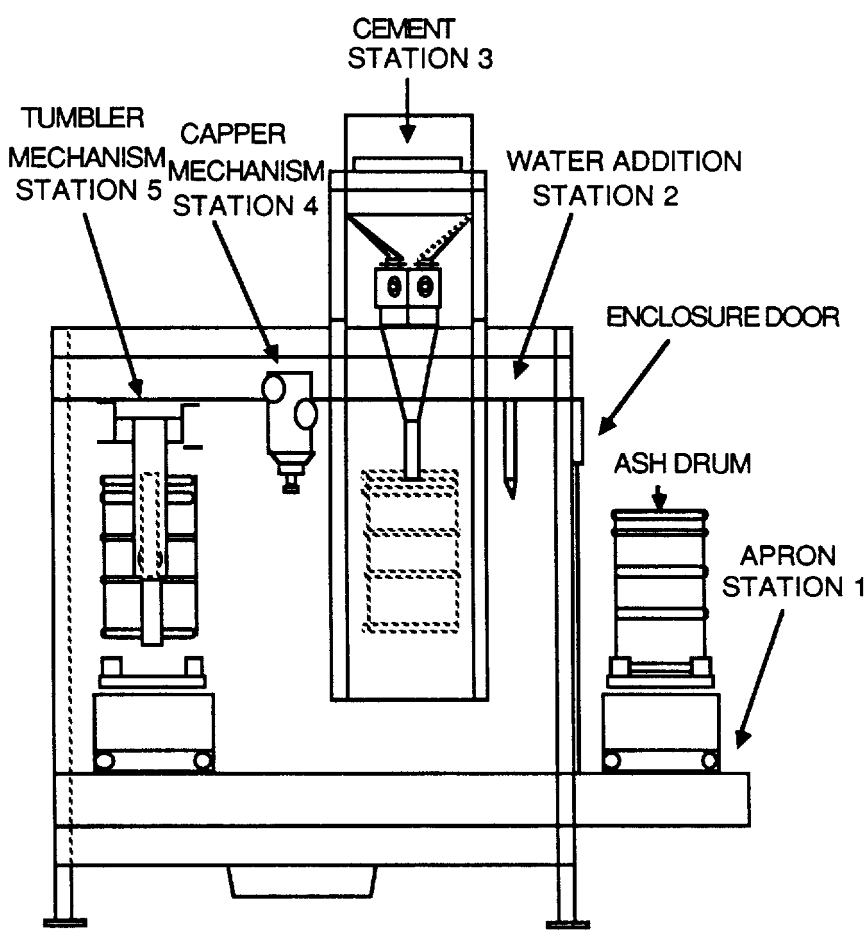

Figure 3a. Ashcrete Process Enclosure

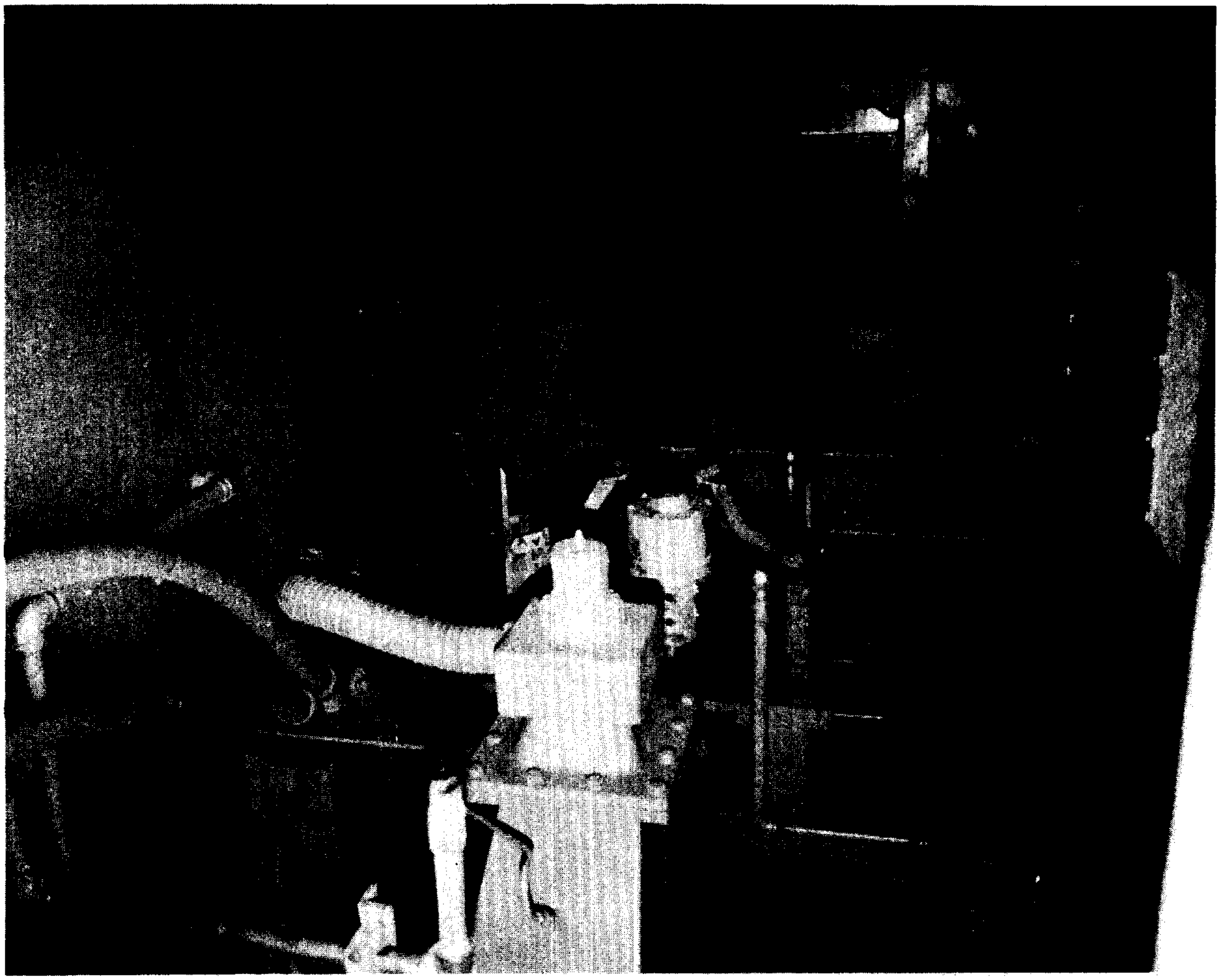

Figure 3b. Ashcrete Processing Stations

Cap removal and replacement occur at the capper mechanism (Station 4) before and after each material addition. Drums are raised to the capper level and positioned using four heavy guide fingers. A pneumatically actuated expanding collet grips the cap, unscrews it, and holds it while the drum is filled with material at another station (cement or water). After material fills, the drum returns to the cap replacement.

Cement addition is performed at Station 3. Cement can be fed from either of two 15-ft^3 hoppers. Cement is fed from the hoppers using the corresponding screw conveyor. The material travels from the conveyors through a feed nozzle into the drum.

Mixing of the drum contents is achieved by end-over-end tumbling at Station 5. The drum is raised to the tumbler height, the tumbler clamps grip the drum, the table lowers, and tumbling starts. Tumbling speed is 18 rpm, and tumbling time can be set at 5 minutes; 6 minutes, 40 seconds; or 10 minutes. The in-drum mixing method prevents equipment contact with the radioactive material.

The water fill station is used to add water to the ash mixture (although CIF wet ash may not need additional water). The unit also has a decontamination system that ties in with the water fill station. Water is used to spray down the enclosure interior, and the water is collected in the enclosure sump. This water can be pumped to the water reservoir and fed into a drum at the water fill station. Thus, any contamination is recontained in another drum.

The process can be operated in automatic or manual mode using the programmable controller and control panel (Figures 4a and 4b). In automatic mode, the controller determines material additions, operates all mechanical functions, and monitors all system interlocks. The manual mode limits the controller's function to monitoring the system interlocks and allows the operator to choose the processing steps. An Allen-Bradley T-3 CRT monitor displays the ladder logic programming, and a printer provides process status and fault information.

Figure 4a. Ashcrete Control Panel

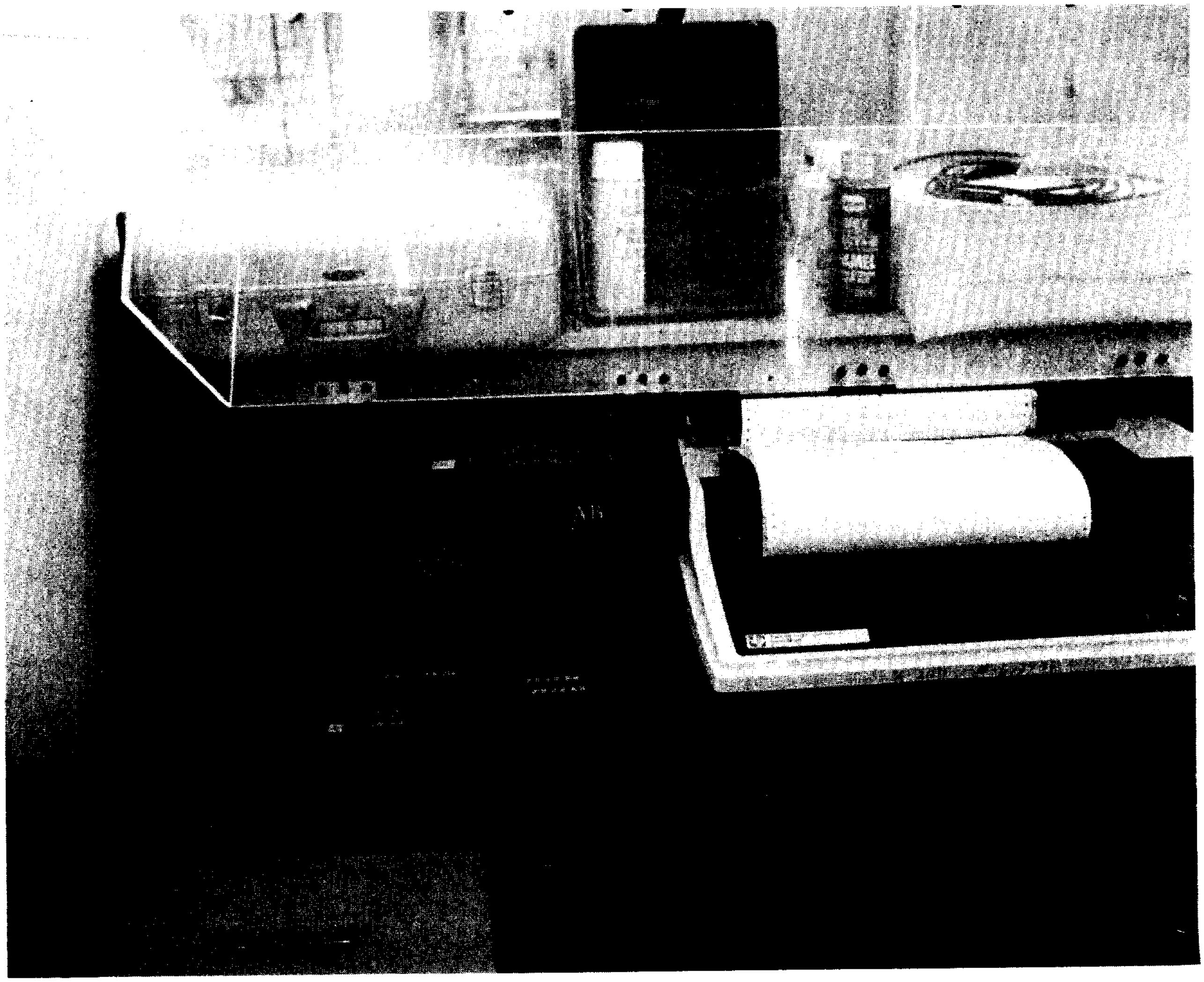

Figure 4b. Programmable Controller Station

Testing

1. Dry Ash Testing: Tests were run to verify ashcrete product integrity and mixture formulations, to determine temperature profiles during setting, and to measure product homogeneity and compressive strength.[1] Results of these tests are now being used to establish mixture formulations and material fill levels for the anticipated wet ash output from the CIF.

Dry ash testing utilized solid waste ash and spent solvent incinerator ash produced during the cold run-in of the Beta Gamma Incinerator (BGI) at SRP.[2] Flyash from the powerhouse supplemented the small supply of BGI baghouse ash. The chemical composition and physical makeup of the flyash are representative of the baghouse ash. Mixture formulations were developed for each type of ash (Table 1). Limits on product homogeneity and the minimum compressive strength (100 psi for 67-day cure) were established to ensure the processed drums would withstand disposal handling.

Table 1. Full-Scale Test Formulations

Ash Type	Water/Ash	Cement/Ash
Solid	1.00	1.50
Solvent	0.75	1.00
Baghouse	0.50	1.00

Sand was initially used to increase product strength, but was later eliminated from the formulations. Sand caused unmixed pockets to form and added unnecessary material addition and tumbling cycles. Compressive strength was above the 100-psi limit after a 7-day cure, and final strengths were above 1,000 psi (Table 2).

Table 2. Compressive Strength Data

Ash Type	Cure (days)	psi	Cure (days)	psi
Solid	7	610	69	1,300
Solvent	7	600	69	2,100
Baghouse	7	1,600	69	1,630

Homogeneity was assessed with varied tumble times, the amount of material added per cycle, and mixture formulations. Cement addition was limited to 100-lb increments to increase homogeneity and prevent material overflow. Mixing bars were added to increase mixing by breaking up material pockets and any agglomerates. For the dry ash, all of the water was added first to aid homogeneity and inhibit concrete from setting prematurely.

Temperature rise of the setting product was recorded to examine drum heating. The temperatures were recorded at three radial positions from the drum center for several days. The maximum recorded temperature for any interior sample was 65°C and below 40°C at the drum surface. Therefore, pressurization of the drum is unlikely, and the processed drums can be easily handled.

2. Wet Ash Testing: The objectives of this series of tests were to:

- Verify that the ashcrete unit is compatible with the CIF wet ash.
- Verify mixture formulations.
- Determine how much wet ash can be solidified per drum.
- Determine the expected ashcrete processing rate per drum.

Saturation levels for several ash types were established, a mixture formulation was demonstrated for wet ash, and a proof-of-principle test was performed using a mockup of the CIF ashout system.

Ash saturation tests were performed to specify preliminary mixture formulations for wet ash solidification. Solid ash, solvent ash, and flyash were contained in twenty-eight, 55-gal drums. Three samples were taken from each drum to determine the saturation level for the ash by volume and weight, the density of the ash, and the density of the wet ash. The averaged results are presented in Table 3.

Table 3. Ash Saturation Data

Ash Type		Water: Ash Ratio (volume)	Water: Ash Ratio (weight)	Ash Density (lb/ft^3) Dry	Ash Density (lb/ft^3) Wet
Solid Inc.:	(n=24)				
	x	0.55	1.00	37.95	79.20
		0.13	0.35	7.72	6.29
Solvent:	(n=15				
	x	0.50	1.12	27.26	79.60
		0.13	0.42	6.09	5.99
Flyash:	(n=15)				
	x	0.37	0.59	41.96	74.80
		0.11	0.27	7.09	16.75

Using these results and the dry ash formulations (by weight), wet ash formulations were derived and material fill levels were estimated (Goal: 90% drum fill). The 90% level will ensure uniform drum integrity and minimize the number processed without overfilling them.

The preliminary formulations were tested by adding the proper ratio of water and dry ash (for saturation), mixing the water and ash, and then processing the wet ash-filled drum. The formulation's product appeared to have the proper consistency, but filled the drum only 70%, as there was a product volume reduction associated with tumbling and absorption. Additional testing established the weight of wet ash (420 lb) and cement (325 lb) that obtained 90% full product drums (Table 4).

Table 4. Wet Solid-Ash Formulations

Test	Cement/Wet Ash	Wet Ash (lb)	Cement (lb)
Preliminary	0.75	326	246
Full 90% fill	0.77	420	325

The preceding tests used the process unit to mix the ash and water inside the drum at saturation levels. However, the actual CIF ashout system will add the ash, already saturated, to the process drum. Additionally, it was determined that the ash expelled from the CIF would have a slightly different physical and chemical makeup that the solid ash (BGI ash) used during the preceding tests.

A proof-of-principle test was conducted to ensure that the ashcrete system would be compatible with the CIF ashout system and that formulations could be determined for the slightly differing solid ash expected. Solid ash that was representative of the CIF output was obtained from cold testing of the Plutonium Waste Incinerator (PWI) located at SRP.[3] The ash has a higher carbon content and higher unburned material content than the previously used solid ash. A mockup of the CIF ashout system was built using a 250-gal ash saturation tub (filled with 150 gal of water), operators using shovels (to represent the backhoe system), and the PWI ash (Figure 5).

The PWI ash was loaded into the saturation tub and allowed to sit until saturated. Operators then scooped the wet ash into process drums (as the backhoe system would). The drums were then processed using the 0.77 cement/wet ash weight ratio determined in the previous formulation tests.

The initial tests showed that there was insufficient cement in the mixture. The mixture contained excess water, which indicates additional water (above the saturation level) was added during shoveling and that absorption levels could be lower for this solid ash type. Testing, using the mockup, was continued to establish proper cement addition levels (Table 5). The 1.0-to-1.0 mixture ratio produced a product that appeared to be of the proper consistency and began setting up quickly. Dip samples were taken from two of the drums to be tested for leaching characteristics and compressive strength (after complete setting).

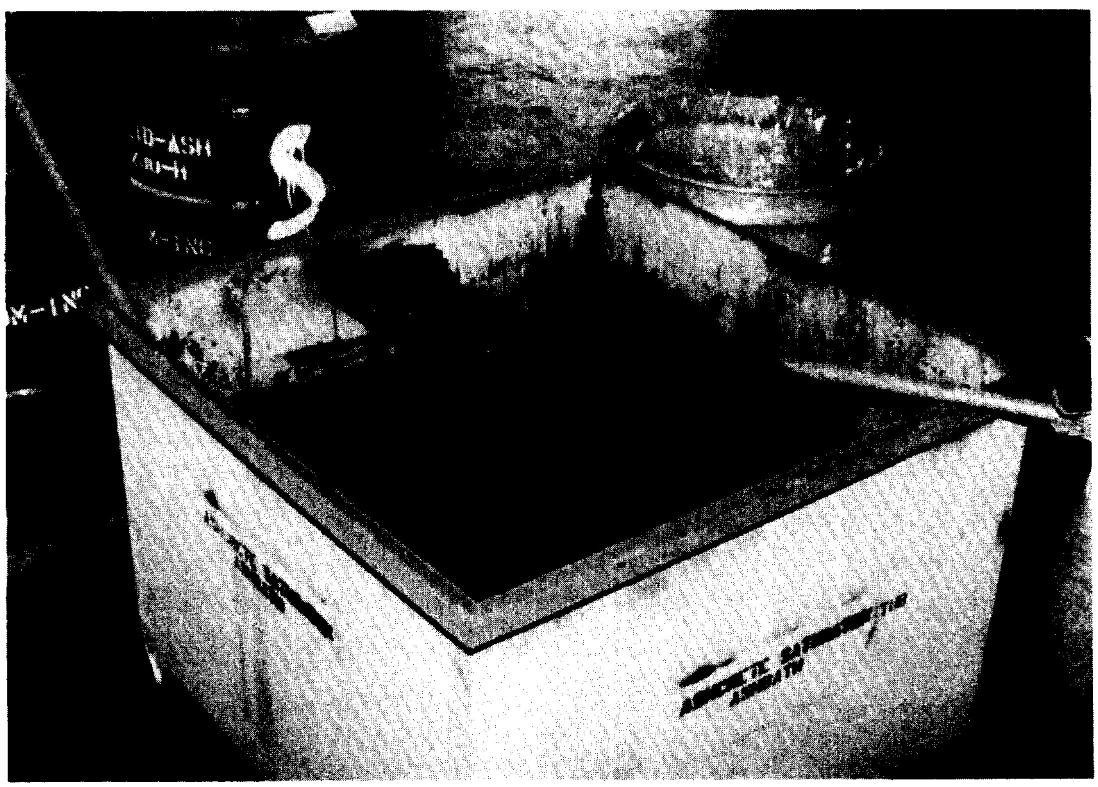

Figure 5. Proof-of-Principle Testing Mockup

Table 5. Proof-of-Principle Final Formulations

Test	Cement/Wet Ash	Wet Ash (lb)	Cement (lb)
90% Fill	1.00	370	370
Cement Addition Steps		1) 150, 10:00 tumble 2) 120, 10:00 tumble 3) 100, 10:00 tumble	

From these tests it was determined that:

- The ashcrete system is compatible with the CIF ashout system.
- Processing times for each drum should be under 40 minutes.
- Mixture formulations can be easily established (once the ash is characterized).
- Material additions can be established for a 90% drum fill level.

The final product should be nonleaching and have sufficient strength for disposal due to its similarity to the dry ash product.

Reliability and Functionality Modifications

Based on material balance calculations for the CIF and the proof-of-principle tests, the ashcrete unit will be required to process between 2 and 19 drums per day (185 lb of dry ash per drum). The unit must meet these demands with minimal downtime and maximum dependability. Several mechanical modifications are being made to enhance operational reliability.

1. Hopper Design: The unit utilizes two, 15-ft^3 hoppers with live bottoms (vibrating) and screwfeed conveyors to feed the cement. These hoppers will be replaced with two, 25,000-lb capacity (266-ft^3) hoppers. The new hoppers will have a baghouse, loading connections, cement vibrating units, and new screwfeed conveyors. The filled hoppers will supply the unit for up to 2 months, depending on usage.

2. Transfer Car Apron Extension: The apron (outside of the enclosure) will be extended 12 ft. The extension will allow the car to traverse from the ashout point into the enclosure on one set of tracks.

3. Tumble Stop Mechanism: Process faults occasionally occurred because the tumbler motor brake did not stop the drum upright at the intended stop point. A mechanical latching device has been fabricated to provide a positive stop in addition to the motor brake.

4. Decontamination System: The present system consists of three rotating spray nozzles rated at 12.56 gpm at 20 psig. Four additional spray nozzles will be added along with a 2-in. process water supply line. The new system will give complete enclosure decontamination using higher water pressure.

5. Enclosure Rewiring/Sealing: Several process faults have resulted from wet wiring after the decontamination system was activated. The interior wiring and transfer car will be rewired and sealed.

6. Transfer Car Scale: The scale previously used to weigh the drums utilized a poor designed and was subject to up to 40-lb inaccuracies. It was replaced with a four-load cell scale that is accurate to 0.2 lb.

7. Camera System: A borescope camera system has been added to allow internal viewing during all operations. Process air is passed over the camera lens to keep it clean and clear at all times.

8. Ladder Logic: The ladder logic program will be rewritten as needed for operation with the CIF. The portion of the program used for automatic processing of dry ash types will be replaced for processing with wet ash.

Future Testing

The remainder of the program will focus on making and testing the mechanical modifications and refining formulations for the CIF wet ash. Formulation refinement will be accomplished using ash generated by a scale mockup of the actual CIF rotary kiln.

Acknowledgments

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