SOLIDIFICATION OF RADIOACTIVE INCINERATOR ASH

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ABSTRACT

The Ashcrete process will solidify ash generated by the Beta Gamma Incinerator (BGI) at the Savannah River Plant (SRP). The system remotely handles, adds material to, and tumbles drums of ash to produce ashcrete, a stabilized wasteform. Full-scale testing of the ashcrete unit began at Savannah River Laboratory (SRL) in January 1984, using nonradioactive ash. Tests determined product homogeneity, temperature distribution, compressive strength, and final product formulation. Product formulations that yielded good mix homogeneity and final product compressive strength were developed. Drum pressurization and temperature rise (resulting from the cement's heat of hydration) were also studied to verify safe storage and handling characteristics. In addition to these tests, an expert system was developed to assist process troubleshooting.

BACKGROUND

The BGI burns slightly contaminated solid and solvent wastes. The Ashcrete program was started to stabilize ash from the BGI and produce a wasteform that would resist subsidence or leaching in a burial ground facility. Portland (Type II) cement is used to stabilize (solidify) ash because of its low cost, shielding properties, and handling ease. A self-contained ash-solidification unit was built to remotely process both solid and solvent ash from the filter baghouse and incinerator chambers of the BGI.

The process equipment was purchased from Stock Equipment Company (Cleveland, Ohio) in January, 1984 and installed for complete nonradioactive testing. To limit personnel exposure to radioactivity, the unit is fully automatic and enclosed. It processes ash within the same drum received from the BGI. The unit can also process large agglomerates and tramp metallic objects that may be present in the ash. Finally, there is no contact between the equipment and radioactive ash.

PROCESS DESCRIPTION

Drums of BGI ash are solidified as follows:

- Ash is loaded into empty 55-gallon drums at the ash out ports of the BGI.
- Drums are loaded on the ashcrete unit transfer car.
- Water, cement, and sand are successively added and mixed with the ash to produce a concrete wasteform.

Figures 1a and 1b show the major system components (transfer cart, enclosure, water, cement, and sand addition stations, capper mechanism, and drum tumbler). Peripheral equipment includes wet and dry feed systems for remote material addition. The process sequences are controlled by an Allen-Bradley PLC/230 programmable controller.

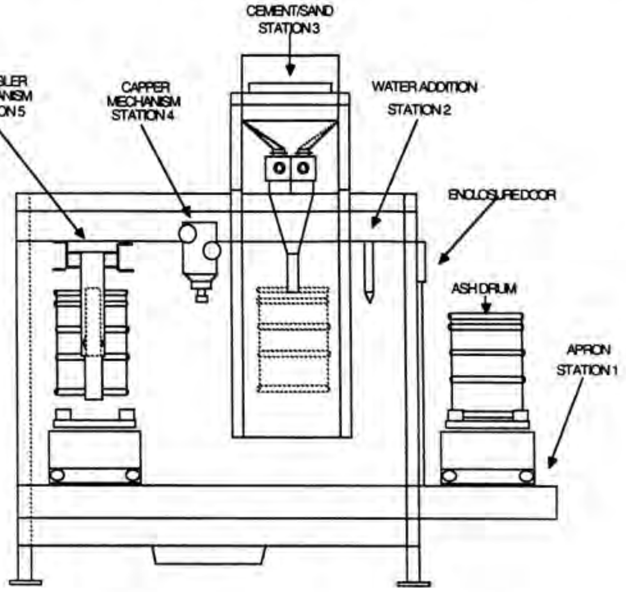

Fig. 1a. Ashcrete Process Enclosure

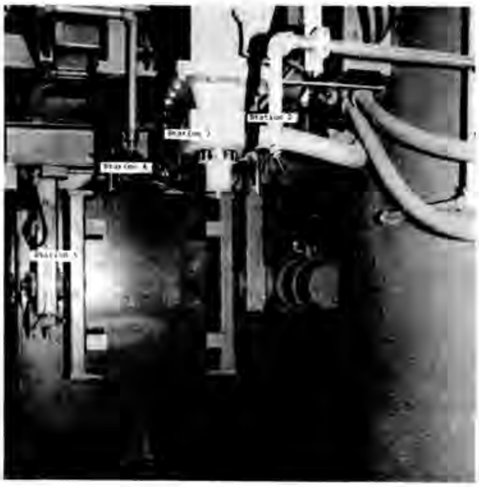

Fig. 1b. Ashcrete Process System Stations 2-5

EQUIPMENT DESCRIPTION

Processing begins at Station 1 where the ash-filled drum is placed onto the transfer cart. Each DOT-17H 55-gallon drum is equipped with a special top containing a 4" bung hole and cap. Two iron mixing bars are placed in the drums to ensure product homogeneity. The transfer cart rests on two tracks that lead into the process envelope. The self-propelled cart lifts and weighs each drum. Cart and track limit switches provide position information. Weight information is used to quantify material additions.

The ash drum is moved from Station 1 into the enclosure and stops at Station 2, the water fill position. Water is fed from a 25-gallon process water reservoir. Any water used to flush the inside of the enclosure is collected in a sump and recirculated into the process water.

Cement and sand additions are performed at Station 3. The sand and cement are fed from individual 15 cubic ft hoppers and are selectively discharged through the feed nozzle.

Cap removal and replacement occurs at Station 4. A drum is raised to the capper level, where guide fingers position the drum onto a pneumatically expanded collet. The collet expands and rotates to remove the cap for material addition. After material is added at Station 2 or 3, the drum returns to Station 4, where the cap is replaced and tightened.

The end-over-end tumbler mechanism at Station 5 clamps the drum and rotates it at 18 rpm. This mixes the ashcrete without any physical contact between the process equipment and the contaminated ash.

PROCESS CONTROL

Figures 2a and 2b show the programmable controller and control panel. The process can be operated in automatic or manual modes. The controller monitors all limit switches and motor controls to provide process information. A printer provides process status and fault information. A remote Allen-Bradley T-3 CRT monitor displays the unit's ladder logic.

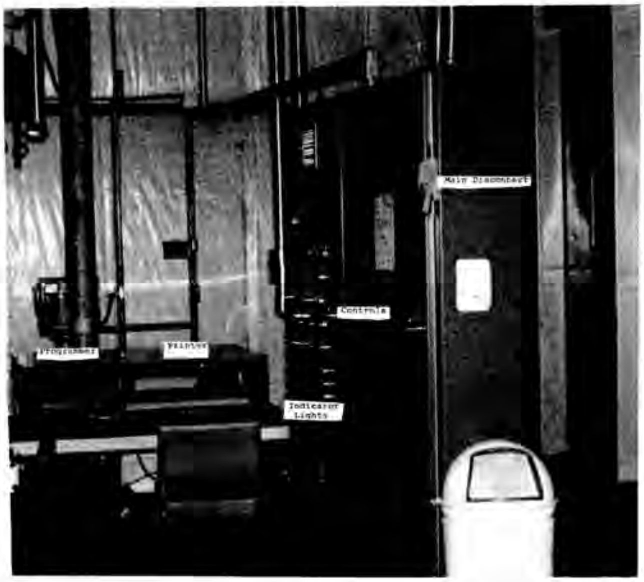

Fig. 2a. Ashcrete Control Panel and Programmer

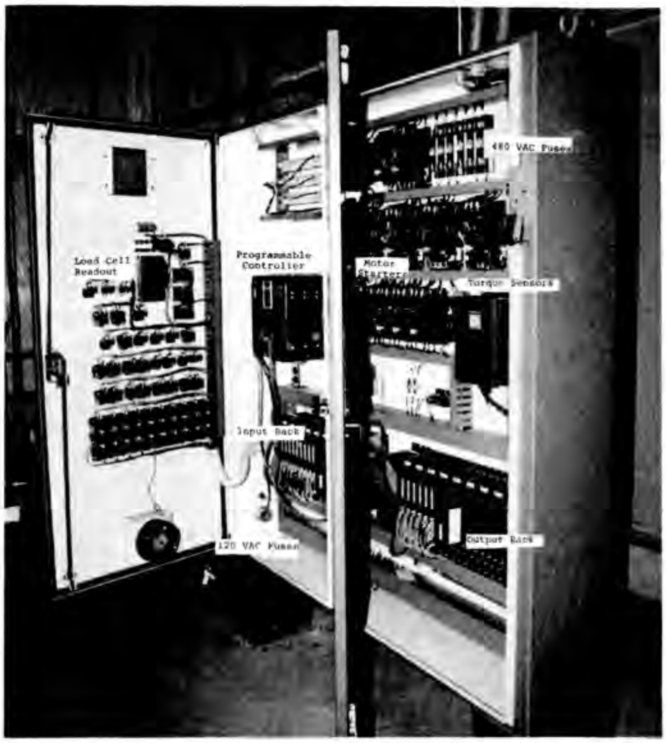

Fig. 2b. Ashcrete Control Panel, Interior

TESTING

Tests were run to establish product integrity and process reliability. Ash formulations were developed to create a strong, durable product that could survive process and storage handling. Equipment was modified to increase process efficiency and reliability.

Ash Formulations

Slightly contaminated solid and solvent waste are burned in the BGI. Solid waste consists of job control waste that is slightly contaminated. Purex solvent is burned with tetrabutyltitanate (TBT) to form solvent ash. Ash is collected from both the incinerator and baghouse compartments. Baghouse ash has higher carbon content and smaller particulate size than incinerator ash. Each ash form was obtained (or approximated) with a substance of similar chemical and physical makeup for testing in the Ashcrete. SRL developed separate formulas for the solid and solvent incinerator ashes and one formula for baghouse ashes.

To accurately simulate the chemical and physical makeup of each type of ash, drums of BGI solid and solvent incinerator ash were obtained from the BGI cold run-in. Sufficient quantities of baghouse ash were not available for testing because it is only 10% of all BGI ash produced. Powerhouse fly ash was used in place of the BGI fly ash because it is close chemically and physically to the actual baghouse ashes. Parametric tests on solvent incinerator ash and baghouse fly ash indicated the effects of chemical components as ash mix. The effect of calcium and phosphate present in solvent ash was tested by processing eight drums of tricalcium phosphate. Six drums of carbon black were processed to determine the effect of carbon content and particulate size on the homogeneity of baghouse ashcrete.

Product homogeneity and compressive strength determined preliminary product formulations. Small-scale testing was performed by Stock Equipment Co. These formulas were modified following full-scale testing at SRL. Table I lists the small and large-scale test formulations for three different ash types.

A minimum acceptable compressive strength of 100 psi (7-day cure) was established. This limit enables processed drums to withstand all necessary burial ground storage handling. The limit was established assuming that the drums would be stored in columns of 4 drums.

Initially, sand was added to the formula to improve compressive strength. Dip samples taken from drums showed a higher strength, but pockets of unprocessed and decreased overall drum strength. Steel mixing bars placed in the drums improve homogeneity, but were ineffective in eliminating sand pockets. The relatively quick setting time demonstrated by the ashcrete product inhibited the proper mixing of the sand.

Additional water and cement mixing steps were added to ensure proper ash/cement mixing. Tests determined that sand would be used solely as a loose filler. Its contribution to compressive strength was insignificant compared to the decreased homogeneity resulting from its addition.

Dip samples taken from processed drums were placed in 1 cubic ft brass molds and tested for maximum compressive strength (Table II). Solid, solvent, and fly ash strengths were above the 100 psi limit after a 7-day cure. The final ashcrete compressive strengths were over 1000 psi for all wasteforms. Additional solid waste from the BGI cold run-in was processed on a limited scale. The results of these tests are included in Table II.

TABLE I

Preliminary Ash Formulations

Ash Type	Small-Scale Test Formulations Water/Ash	Cement/Ash	Sand/Ash
Solid	1.00	1.00	0.33
Solvent	1.00	0.80	0.25
Baghouse	1.00	1.00	1.00

Ash Type	Full-Scale Test Formulations Water/Ash	Cement/Ash	Sand/Ash
Solid	1.00	1.50	(to fill)
Solvent	0.75	1.00	(to fill)
Baghouse	0.50	1.00	(to fill)

TABLE II

Compressive Strength Data

Ash Type	Cure (days)	PSI	Cure (days)	PSI
Solid	7	610	69	1300
Solvent	7	600	69	2100
Baghouse	7	1600	69	1630
Rubber	6	2000	-	-
Paper	6	980	-	-
Waste Mix	4	1770	-	-

Homogeneity Studies

Drums were processed using various ash formulas, mixing periods, and material additions. Each drum was sectioned after setting to evaluate mix homogeneity. Mixture homogeneity was best when all process water was added at the beginning of each process cycle. Early water addition also improved product consistency by inhibiting initial concrete set. Dry material was subsequently added in 100 lb intervals. Smaller material additions also eliminated drum overflows. The solid ash drum in Fig. 3a was processed with sand in the mixture. The drum in Fig. 3b, however, was processed using sand as a filler. Backfilled sand absorbed standing water in the drum following processing.

Fig. 3a. Solid Ash Drum with Sand in Mixture

Fig. 3b. Solid Ash Drum with Sand Backfill

Maximum Drum Fill

The target fill level for ashcrete drums is 90%. This level ensures drum integrity for subsequent burial ground handling. Initial ash weight is limited to 235 lb to avoid overfill.

An ultrasonic level detector mounted in a protective housing with a Polaroid transducer (developed for Polaroid's self-focusing cameras) was installed. The detector was used following the final tumbler cycle and allowed the controller to calculate the sand backfill addition. The hostile environment and uneven product surfaces have limited the reliability of the detector. A new, more rugged detector is being designed for more reliable service.

Temperature Data

To determine the maximum drum temperatures following processing, three thermocouples were placed at 4" intervals (8" deep) from the center of the drum. Figures 4a and 4b illustrate the temperature profiles for solid and baghouse ashes. The cement's heat of hydration raised the drum temperature during setting. The maximum temperature recorded was 65°C at Position 1, therefore, drum pressurization due to boiling water is unlikely.

Drum skin temperatures (Position 3 in Figs. 4a and 4b) were well below the maximum burn limit temperature of 60°C. If necessary, drums can be handled with leather gloves.

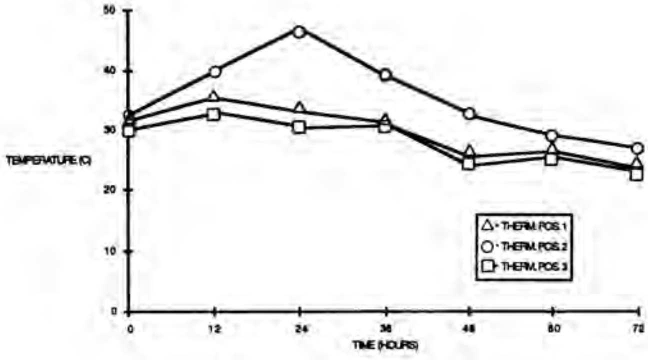

Fig. 4a. Solid Ash Temperature Profile

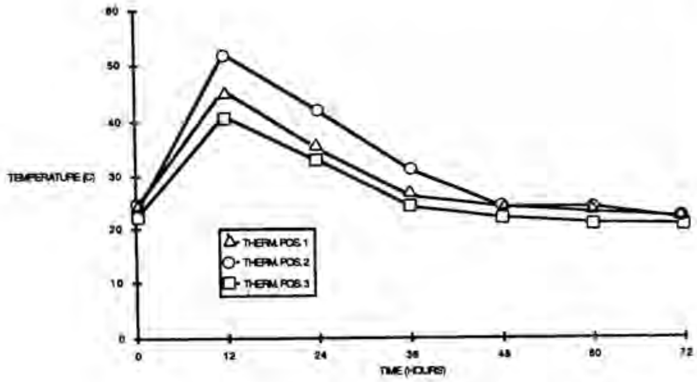

Fig. 4b. Baghouse Ash Temperature Profile

Reliability Studies

Reliability tests were designed to establish the equipment's mechanical dependability. Process modifications were made after mechanical failures during formulation and temperature testing.

a. CAPPER MECHANISM - As the capper mechanism operates 12 times during each Ashcrete cycle, its dependable operation is vital. Over the past 2 years, 22.5% (18 of 80) of all drums processed experienced capper malfunctions.

   As more cement is added to the ashcrete mixture during processing, the concrete begins to set. The final slow tumbler rotation causes the thickening concrete to settle at an angle within the drum. The uneven weight distribution causes the transfer cart table to tilt and misalign the drum. The cart then proceeds to the capper mechanism to prepare for the next material addition.

   Three capper guide fingers were unable to properly seat the 4" collet in these slightly misaligned drums (over 1/4"). We added an additional guide finger and reduced the size of the unexpanded collet to strengthen the mechanism and provide increased reliability. No capper malfunctions occurred following this modification.

b. TUMBLER MECHANISM - Mechanical and software problems caused several tumbler clamp malfunctions. The tumbler mechanism slows from 18 to 6 rpm before righting itself above the transfer cart. When the vertical position limit switch is activated, the locator arm holds the idler clamp, the transfer cart raises, and the tumbler clamps release the drum.

   There were seven recorded cases in which the brake was unable to stop the clamps. As a result, the transfer cart table rose, jamming the drum as it passed its vertical position. The emergency stop was activated and the clamps were separated to remove the drum and right the clamps. When power was returned to the unit, the clamp motor starter drew the clamps out beyond their limit switches, breaking the supporting pillow blocks.

   To eliminate these problems, modifications were made to the tumbler motor brake and controller ladder logic. Brake torque was increased to stop the drum in a vertical position. Additional tests will indicate the exact torque setting required for reliable operation.

   Basic controller logic will be reformulated to eliminate tumbler malfunctions. Major functional sections of ladder logic will be moved from subroutines into the main program to permit easier operator access. All ladder logic bits will be reset to recognize only those parameters which are activated when the machine is restarted. The unit will begin manual operation from the beginning of the program after each process fault. This change will prohibit the program from starting in the middle of a process step (as it did with the tumbler mechanism). Additional program modifications will adjust timer bits to ensure reliable process operation.

Expert System

SRL has developed an expert system on an IBM PC to identify process faults and suggest problem solutions. An EXSYS expert system development package provided the skeleton for the Ashcrete system. The EXSYS system asks the operator position and process status questions and recommends corrective action. Process enclosure graphics were added to simplify program operation. Each Ashcrete operation and related control panel element is visually identified. When the expert system specifies corrective action within the control panel, program graphics can specify the location of the suspicious indicator light or motor starter.

PROGRAM — RELIABILITY TESTING

Additional reliability testing will be conducted to verify mechanical reliability of the process equipment. Future modifications include:

1. Installation of a more powerful decontamination system in the process enclosure. The present system will be augmented with a new 2" process water supply line and four new spray nozzles (seven total) for complete enclosure decontamination capability. The new system will deliver 12 gpm at 20 psig.

2. Installation of a Borescope camera system will allow operators to visually monitor the entire process. Air passing over the lens will allow the camera to operate under dusty conditions. At present, three windows provide the only monitoring ports.

3. Developing an expert system to monitor the Allen-Bradley Programmable Controller. The system will either prompt the operator for position and status confirmation, or provide an immediate solution without operator interaction.

This work will be completed and a final report written by the end of FY 1986.

Acknowledgments

The information contained in this article was developed during the course of work under Contract No. DE-AC09-76SR00001 with the U.S. Department of Energy.

Walter A. Roberson for work on Ashcrete run-in, formulation and homogeneity studies, and system modification.

R. B. McCampbell for work in ash formulation and system modification.

P. D. Soper and F. G. Smith for development of Ashcrete expert system.