PRODUCTION-SCALE LLW & RMW SOLIDIFICATION SYSTEM OPERATIONAL TESTING AT ARGONNE NATIONAL LABORATORY-EAST (ANL-E)

James Wescott
ANL-E
Argonne, Illinois

Robert Nelson
Sargent & Lundy
Chicago, Illinois

Hyo No
H&P, Inc.
Vienna, Virginia

Arun Wagh
ANL-E
Argonne, Illinois

Dileep Singh
ANL-E
Argonne, Illinois

Abstract

Argonne National Laboratory-East (ANL-E) has begun production-scale testing of a low-level waste and radioactive mixed waste solidification system. This system will be used to treat low-level and mixed radioactive waste to meet land burial requirements. The system can use any of several types of solidification media, including a chemically bonded phosphate ceramic developed by ANL-E scientists. The final waste product will consist of a solidified mass in a standard 208-liter drum. The system uses commercial equipment and incorporates several unique process control features to ensure proper treatment. This paper will discuss the waste types requiring treatment, the system configuration, and operation results for these waste streams.

Introduction

Argonne National Laboratory-East (ANL-E) has installed and begun production-scale testing of a radioactive low-level and mixed waste solidification system. The system integrates equipment available in the commercial market. The main component of the treatment system is a double planetary change-can mixer. The mixing blades can be inserted into a 208-liter drum of waste and actuated while solidification media is added to the waste. After a pre-determined time, the mixer is retracted and the waste allowed to solidify in its original container. Characteristic mixed waste and aqueous low-level waste can then be disposed as a solid low-level waste.

ANL-E is a multi-program laboratory which focuses on basic and applied research that supports the development of energy-related technologies. The University of Chicago operates ANL-E for the Department of Energy (DOE). Research activities at ANL-E generate a multitude of waste streams consisting of hazardous, radioactive, and mixed wastes. These wastes are managed by the Waste Management Department of ANL-E Environmental Management Operations.

The Waste Management Department is composed of an on-site treatment, storage, and disposal operation and a technical support section. The facility handles approximately 215 m^3 of newly generated waste each year. In addition, a significant quantity of legacy waste remains to be processed. Hazardous and low-level radioactive waste are disposed off-site, while mixed waste are stored until appropriate treatment remedies can be implemented.

DISCLAIMER

The mixer system will be used to treat low-level waste requiring solidification, characteristic mixed waste such as sludge and soils requiring stabilization, and lead solids and debris requiring macroencapsulation. Approximately 40 m^3 of mixed waste will be treated in the system in the next 5 years. A smaller volume of low-level waste, primarily oils and non-hazardous scintillation fluids, will also be treated for disposal.

The Federal Facility Compliance Act of 1992 requires the DOE to develop treatment capacity for mixed waste and begin treating the waste to meet the Land Disposal Restriction requirements. ANL-E has worked closely with its stakeholders to develop a Site Treatment Plan to manage the ANL-E inventory of mixed waste. After consultation with its stakeholders, ANL-E determined on-site treatment options were the most effective solution. ANL-E has installed and tested six treatment units: a neutralization/precipitation unit for low-level corrosive waste with heavy metals, a neutralization/precipitation unit for corrosive transuranic waste, a photo-oxidation system for organics, a passivation unit for alkali metals, a CO_2 decontamination system for lead solids and other debris, and the solidification system. Lead solids and debris that can not be decontaminated will be macroencapsulated with the solidification system.

Solidification Mixer System Equipment

The solidification system is composed of three components: a double planetary mixer, a dry solidification media feed system, and building interfaces. The mixer is a ROSS 208-liter change can system (See Figure 1). The mixer is located in the basement of the Waste Management Operations facility. The mixer consists of a frame with a motor, gearbox, mixer, and hood mounted on a hydraulic lift. An air-over-oil lift system is used to raise and lower the mixer so that the 208-liter drum can be changed. The drum is loaded on a special dolly and held in place with a clamp. The control panel is mounted on the side of the mixer system and includes a power disconnect, start/stop buttons, speed control, and a timer.

The mixer drive consists of a 11 kW 480 VAC totally enclosed fan cooled motor and a gearbox. The motor speed is controlled from the mixer control panel speed controller which controls the output of the variable frequency drive which is located in the control cabinet. The speed can be controlled between approximately 12 rpm and 35 rpm. The speed and motor current are displayed on the speed indicator on the mixer control panel. The mixer has two blades. The mixer blades are rectangular frames, approximately 24 cm wide and 67 cm long, which are fabricated from 4 cm square stainless steel tube. The two mixer blades extend down from shafts in the gearbox and reach to approximately 6 cm above the bottom of the drum. When the mixer is operating, the individual blades rotate on the shafts from the gearbox and the two shafts rotate around the center of the gearbox. The mixer blades turn approximately 1 time for each rotation of the mixer unit. The minimum space between the edge of the mixer blade and the side of the drum is less than 2 cm. It is important to secure the drum in the drum clamp to prevent the mixer blades from hitting the side of the drum and to prevent the drum from turning. The mixer hood assembly is a stainless steel shroud over the drum and top of the mixer blades. It provides an enclosure over the drum to control splashing and to support the water addition, solidification media addition, spray nozzles, ventilation nozzle, and the sight glass. It also allows a slight negative pressure to be maintained in the drum during the mixing operations and controls dusting and splashing. Neither the ventilation air flow rate nor the negative pressure inside the mixer hood are monitored.

A nozzle to add water to the drum is provided on the mixer hood. The water addition is controlled by a manual valve on the side of the mixer drive frame over the hood. This water is supplied from the lab cold water system at system pressure. Spray nozzles are provided to clean the mixer blades, clean the sight glass, and increase the water content in the waste. The mixer wash-down spray nozzles are located at two different levels on opposite sides of the mixer hood and are controlled by separate valves. The mixer must have a drum of rinse water under it and should be turning when the blades are being washed. Steel mixer dollies that are specifically designed for use with 208-liter drums and this mixer are provided. They have locking casters.

There are several interfaces between the solidification system and treatment facility The interfaces are: lab cold water, high-efficiency particulate air filtered ventilation system, and electrical power. A flexible vent line, with an isolation valve at the mixer is provided on the mixer hood. The vent line maintains a slight negative pressure inside the waste drum when the hood is down. A 480 VAC electrical power is provided to the mixer. The solidification media feeder and controller are supplied 120 VAC power from a transformer mounted on the mixer control panel; power to this transformer is from the disconnect on the mixer control panel. The controller is located on top of the mixer control panel.

The solidification media feeder has a hopper and vibrating feeder suspended on three load cells. It is mounted on the steel deck over the mixer room at the grade level. It includes a weight indicator and control panel (mounted on top of the mixer control panel) and has provisions to stop feeding after a pre-determined weight of solidification media has been discharged. The discharge of the solidification media feed system is connected to the inlet of the mixer by a clear flexible hose. The flexible hose is used to allow the mixer to be raised and lowered. The solidification media feed system has a 0.3 m^3 conical hopper with a hinged cover and 10 cm vent with a bag cover on the top. The vent discharges to a 10 cm pipe; the flexible hose to the mixer is connected to this pipe. It is supported by a frame that surrounds the hopper. The bottom of the hopper extends below the floor and into the mixer room.

A electromagnet driven vibratory feeder is mounted on the bottom of the hopper. The feeder uses a vibrating plate type mechanism to control the flow of solids; the feed rate is dependent upon the magnitude of the displacement of the vibrating plate; the frequency is 60 Hz. The magnitude of the displacement of the vibrating plate is controlled by a batch controller and can be set for a high rate for most of the batch and a slow rate to finish the batch.

Process

The solidification process can be used for low-level and mixed radioactive waste. The waste should be relatively homogenous to assure uniform mixing. Solid waste consisting of various size fractions can be processed through an on-site shredder or a series of mechanical screens to facilitate treatment.

The mixer is started and allowed the mix the waste to form a uniform slurry, then the speed is varied to develop a motor current vs. speed profile (See Figure 2). The motor current indicator is a digital ammeter. It uses a small coil to measure the current through one leg of the 480 VAC feed lines to the variable frequency drive unit; measuring the supply current eliminates the variations in response of the coil due to the changes in frequency on the motor controller output. The speed controller (a potentiometer calibrated from 0 to 100) and digital speed indicator interface with the variable frequency drive unit. The operative range of the potentiometer is approximately 35 to 100 and the corresponding speed range is 12 to 35.2 RPM; for potentiometer settings below 35, the speed remains at 12 RPM. This motor current vs speed profile provides a basis for estimating the water content of the waste and is part of the waste characterization portion of the process control program. If necessary, additional water may be added to bring the waste to the optimum moisture content level.

Based upon the weight of the waste, the water content, and the type of waste, the amount of solidification media that is required is calculated and entered into the weight loss batch controller. With the mixer running at the speed specified for the specific formulation, the feeder is started and the dry solidification media is added to the waste slurry at a controlled rate until the specified weight for that drum has been added. The feeder stops automatically. The mixer is allowed to run for a specified length of time. The mixer motor current is monitored and recorded by the operator throughout the process as part of the process control program and to detect indications of early setting. Once mixing is complete, the blades are raised and residual material on the blades is scrapped into the drum. A sample may be taken for analysis. The drum of waste is removed from the mixer, covered, and allowed to set for a pre-determined duration before the surface of the solidified waste form is checked for hardness.

A rinse drum is placed under the mixer and the blades lowered into the water. The speed control is set for 100% and the blades are washed. Additional rinse water can be applied from two spray nozzles in the mixer hood. Once the blades are clean, the mixer is raised and the blades wiped with paper towels. The paper is disposed in the drum of solidified waste.

Treatment Results

The system was initially tested using soil from a construction project on the site. The soil was a silty clay interspersed with cobbles. No attempt was made to screen the material. There were some problems attributed to the high clay content of the soil. These included the formation of a layer of clay on the side of the drum and a large piece of clay that formed within the mixer blade. The cobbles impinged on the inside of the drum causing several dents. The pressure of the cobble against the drum also bent the shaft of one of the blades.

The soil test used a phosphate based ceramic binder to stabilize the soil. The ceramic binder consists of magnesium oxide (MgO) and potassium hydrophosphate (KH_2PO_4). Boric acid was also added to slow the reaction time. Reaction of the binder with soil and water results in a chemically bonded phosphate ceramic (CBPC) that is highly impervious and an excellent capability to immobilize heavy metals. The test run used 180 kg of soil, 24 kg of MgO, and 80 kg of KH_2PO_4. Once mixing of the soil began, the motor current vs. speed profile was consulted to determine additional water requirements. The initial moisture content was 14%. Small increments of water, about 8 liters, were added to the soil and the change in the profile noted. A total of 57 liters of water was added to the soil, bringing the moisture content of the surrogate waste to 34%. The 34% moisture content was within the acceptable range required to use the CBPC.

After the appropriate moisture content had been reached the binder was added to the surrogate waste. The binder was mixed with the soil for 18 minutes, then the mixing blades were retracted. A thermocouple was inserted into the center of the mixture to measure the temperature. Figure 3 displays the change in temperature with time for the surrogate sample and a small bench-scale sample completed earlier. The temperature of the surrogate waste form rose from 30 °C to 57 °C in 15 minutes, then shot up 10 °C in 1 min. The temperature topped out at 80 °C. The solidified material could not be penetrated by hand pressure 40 minutes after addition of the binder. The drum and the solidified form were sectioned vertically (See Figure 4). The final product did not have any void spaces and appeared relatively homogenous.

The first waste materials to be treated in the system were non-hazardous, low-level radioactive waste oils and oil/water mixtures. The waste oils were generated from various research and cleanup activities at the Laboratory. A combination of Aquaset II-H and Petroset II®, proprietary products of Fluid Tech Inc., were used to solidify the waste. Bulk oil drums were moved into the solidification room. Approximately 132 liters of liquid was transferred into open-top drums. The solidification products were added in amounts specified by the manufacturer. Drums were mixed for 1 hour and then removed to harden.

During the transfer and mixing phases, the waste mechanics wore protective coveralls and gloves. The workers added a full-face respirator when cleaning the blades after mixing was complete. Although most of the tasks only required one worker, ANL-E is currently utilizing two workers to aid in moving the solidified waste product and increase the training opportunities.

The material feed hopper was originally designed for use with the CBPC solidification media. The Aquaset II-H and Petroset II® had a lower coefficient of friction and would not stay in the hopper. Material placed in the hopper would empty directly into the solidification room below. The waste mechanics began to add the solidification media directly into each individual waste drum. The loading of all the material at once on top of the waste resulted in poor distribution of the material through the waste. The limited axial mixing produced by the system blades compounded the problem.

Impurities in the waste oil and variances in the oil/water ratio disrupted the process. Drums of pure oil were solidified with Petroset II® and were hard within 48 hours. Oil with water or other impurities, however, had to be treated multiple times before a solidified product could be produced. Most of the time too little Aquaset II-H was added to the waste. After 24 hours a pool of water would collect on top of the semihardened oil. Additional solidification media was added to the waste and the reagent stirred in manually.

Conclusion

The solidification system provides a flexible means to manage many of the disparate waste streams generated at ANL-E. Waste can be treated in its original container, limiting the amount of handling. The final product meets the land disposal requirement for the respective waste types.

ANL-E will begin treating radioactive mixed waste sludges in Spring 1997. Samples of the various waste streams requiring treatment are currently being treated at bench-scale to verify the proper reagent mixture needed to pass the Toxic Characterisitic Leachate Procedure for land burial. Portland cement, Aquaset II-H, and CBPC are all being evaluated.

Planned future modifications to the system to support the process control program include installing an infrared temperature monitoring system to measure the temperature of the drum during the mixing process and a set of thermocouples and a recorder to monitor the temperature of the drums while they are hardening. The temperature profile will be part of the process control program to provide measurable indications that the hardening process occurred as expected.

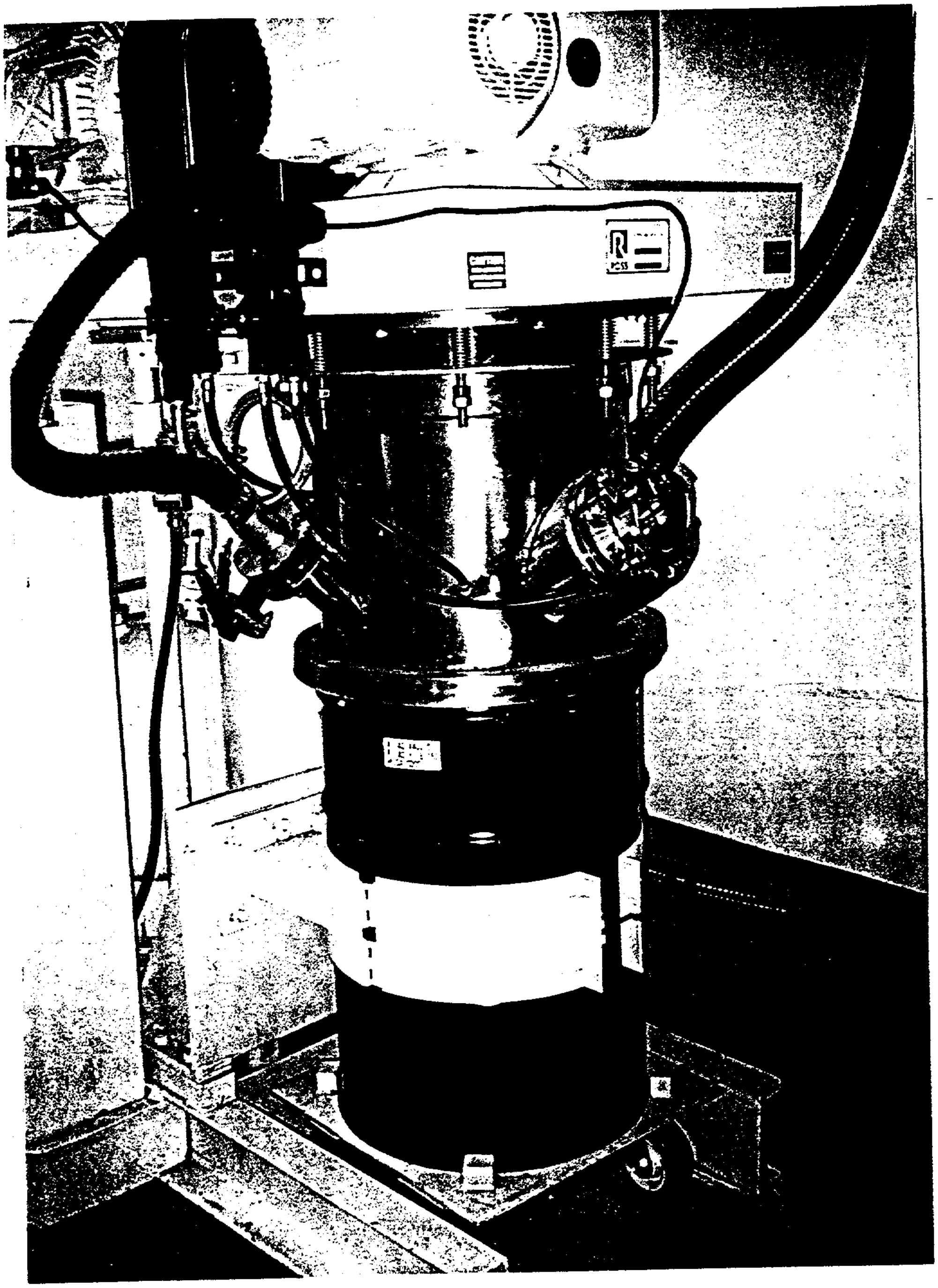
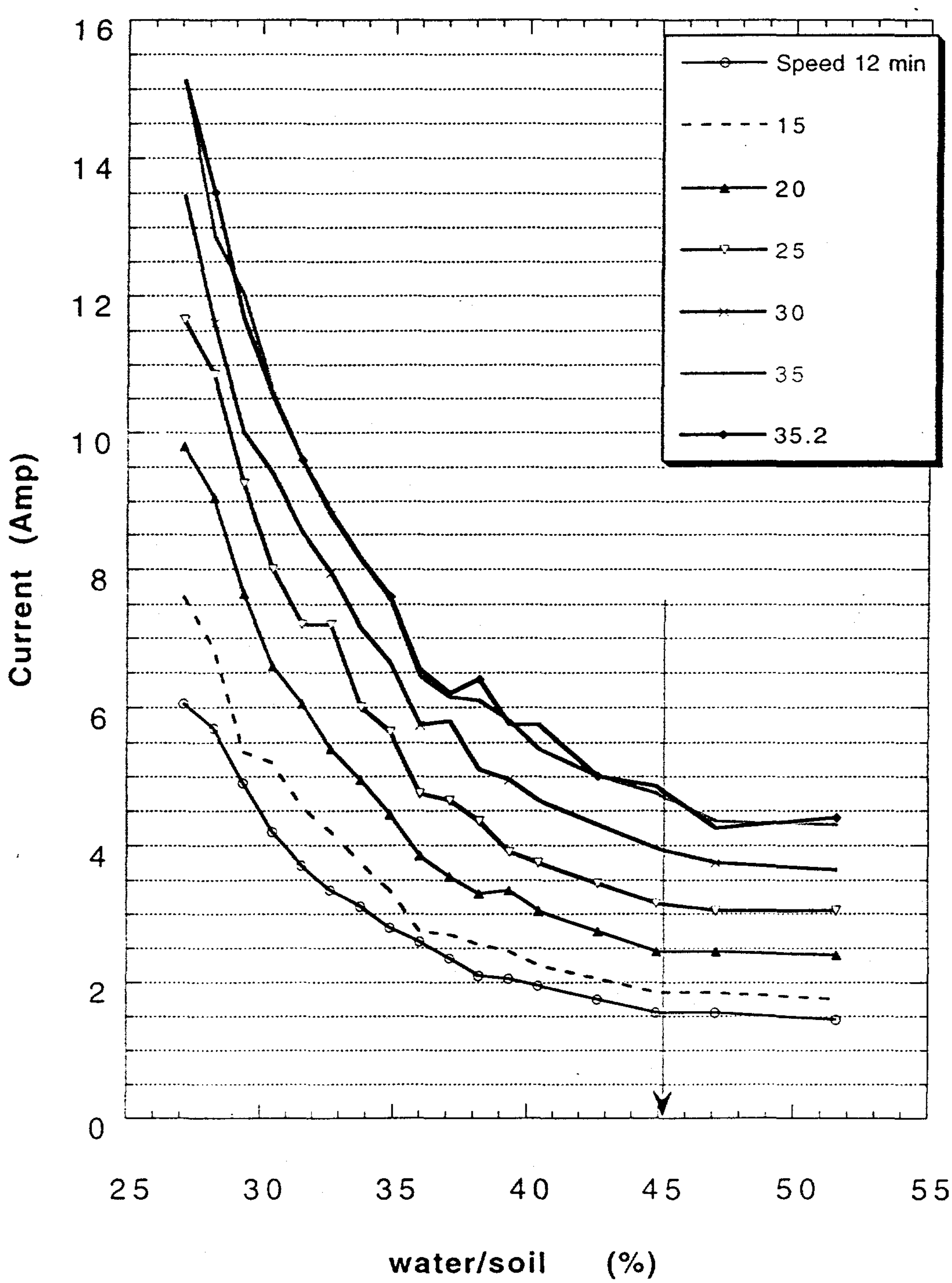


Fig. 1. Solidification Mixer System

Fresh EMO soil + Water



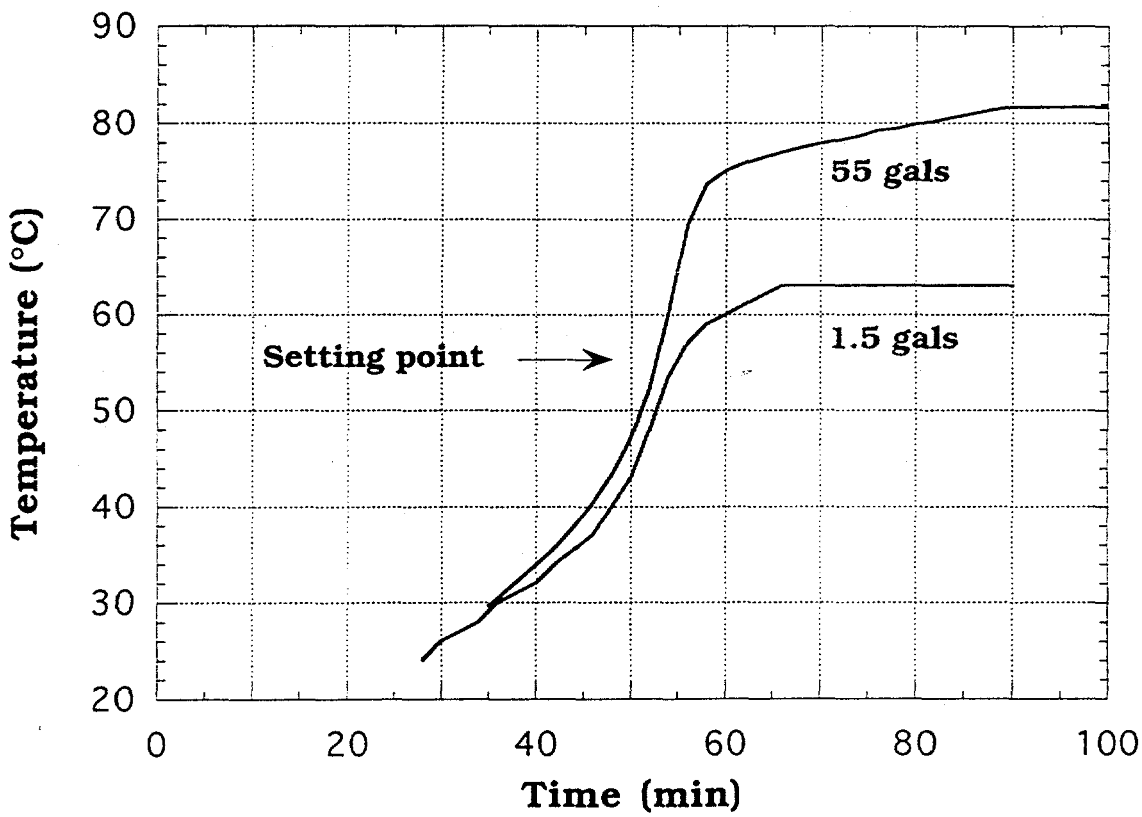


Fig. 3. CBPC Reaction Temperature Change

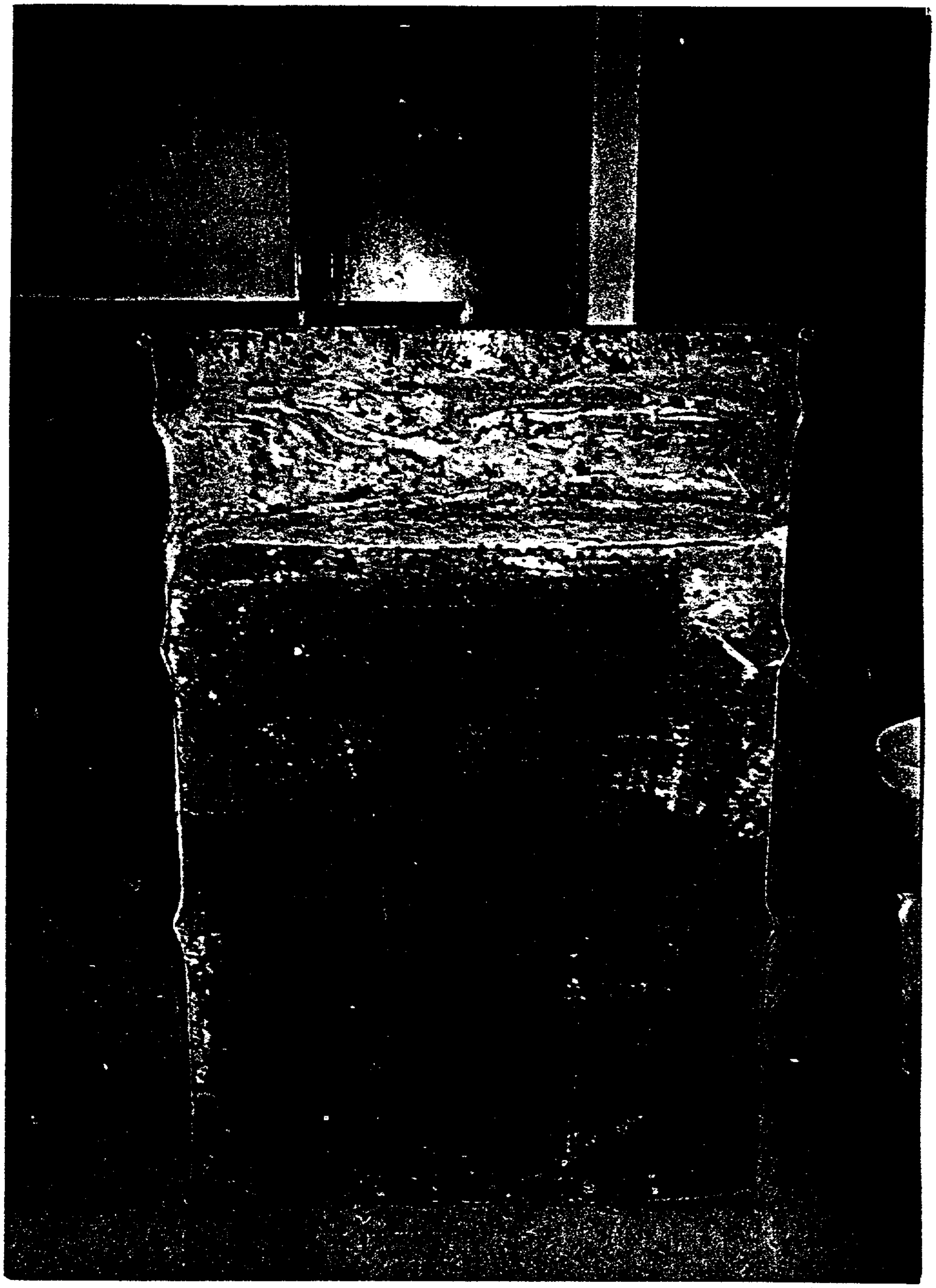


Fig. 4. Soil Solidified with Chemically Bonded Phosphate Ceramic