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Startup of the Remote Laboratory-Scale Waste- Treatment Facility

C. A. Knox
D. H. Siemens
D. N. Berger

January 1981

Prepared for the U.S. Department of Energy
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Pacific Northwest Laboratory
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STARTUP OF THE REMOTE LABORATORY-SCALE
WASTE-TREATMENT FACILITY

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SUMMARY

The Remote Laboratory-Scale Waste-Treatment Facility was designed as a system to solidify small volumes of radioactive liquid wastes. The objectives in operating this facility are to evaluate solidification processes, determine the effluents generated, test methods for decontaminating the effluents, and provide radioactive solidified waste products for evaluation.

The facility consists of a feed-preparation module, a waste-solidification module and an effluent-treatment module. The system was designed for remote installation and operation. Several special features for remotely handling radioactive materials were incorporated into the design. The equipment was initially assembled outside of a radiochemical cell to size and fabricate the connecting jumpers between the modules and to complete some preliminary design-verification tests. The equipment was then disassembled and installed in the radiochemical cell.

When installation was completed the entire system was checked out with water and then with a nonradioactive simulated waste solution. The purpose of these operations was to start up the facility, find and solve operational problems, verify operating procedures and train personnel. The major problems experienced during these nonradioactive runs were plugging of the spray calciner nozzle and feed tank pumping failures. When these problems were solved, radioactive operations were started. This report describes the installation of this facility, its special remote design feature and the startup operations.

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INTRODUCTION

The Remote Laboratory-Scale Waste Treatment Facility (RLSWTF) was designed, constructed and installed in a radiochemical cell (Hanson, Knox, Berger 1980) at Pacific Northwest Laboratory (PNL), which is operated by Battelle Memorial Institute for the Department of Energy. This radiochemical cell is located in the Radiochemical Cell Complex of the 324 Building, 300 Area, Richland, Washington. The RLSWTF was designed to solidify small volumes of high-level nuclear waste solutions to 1) evaluate solidification processing 2) determine the effluents generated and test methods for decontaminating them, and 3) provide radioactive solidification products for evaluation. The waste processing and effluents investigations are being done for the High-Level Waste Process Development Program. The product evaluations are being done as part of the Waste Rock Interaction Technology Program and the Alternate Waste Forms Program. All of these programs are funded by the Department of Energy.

The RLSWTF had to be designed and constructed so it could be installed and operated remotely. Several special remote features for handling radioactive materials had to be incorporated into the design. The equipment was first assembled outside of the cell for preliminary design-verification tests. After the equipment was installed, an operational checkout was completed, first with water and then with a simulated nonradioactive waste solution. After trouble-shooting operations were completed and several nonradioactive runs were successfully finished, radioactive operations were started.

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INSTALLATION

A remotely operated system requires special services and special methods for installing the equipment when the radiochemical cell has previously been contaminated. This section discusses where the RLSWTF is located, how services are provided and how the equipment was installed.

CELL DESCRIPTION

The remote, laboratory-scale equipment was installed in D-Cell of the Radiochemical Cell Complex. Personnel operate the equipment from the service gallery located outside the south wall of the cell. The cell is 4 m by 6.7 m by 3.6 m high (13 ft by 22 ft by 12 ft high), has 1.2 m (4 ft) of high-density concrete shielding and is stainless steel-lined to facilitate future decontamination. It is serviced by two oil-filled lead-glass viewing windows, a 5-ton-capacity, remotely operated crane, four master-slave manipulators and one electromechanical manipulator, and a gallery-to-cell transfer mechanism. The laboratory-scale equipment occupies about one-half of the floor space that is available in D-Cell. A top view of the equipment arrangement in the cell is shown in Figure 1.

PROCESS EQUIPMENT MODULES

Radiation levels in D-Cell from other experiments made personnel access impossible. Consequently the process equipment had to be designed for remote installation. It was desirable to have as much equipment assembled outside of the cell as possible. However, the assembled components had to pass through a 1.52 m x 2.13 m (4 ft x 7 ft) door. To satisfy these requirements, a three-module design was used.

The three modules, which are shown in Figure 2, are feed preparation, waste solidification and effluent treatment. The feed-preparation module contains an evaporator, an evaporator feed tank, an evaporator bottoms tank, an evaporator condenser, a condensate tank and a venturi scrubber. The waste-solidification module contains the spray calciner/in-can melter and an off-gas

FIGURE 1. Laboratory-Scale Waste-Treatment Facility Equipment Arrangement

sampling system. The effluent-treatment module contains two fission-product adsorbers, two seal pots, an iodine adsorber, a nitrous oxides destructor, a heat exchanger, a packed scrubber and a high-efficiency particulate air (HEPA) filter.

SERVICE RACKS

Approximately 75 lines were required to connect the process equipment to various nonradioactive services and pneumatic instruments. As only about ten lines were available in D-cell, it was necessary to build and install two "service racks." One rack provides 60 service lines through a new 305-mm (12 in.) wall penetration; the other provides 6 service lines through an existing 101-mm (4-in.) wall penetration. These service lines are terminated outside the cell on the third floor of the 324 building, and both penetrations are above the process equipment to prevent siphoning of contaminated solutions into the service gallery.

FIGURE 2. Laboratory-Scale Waste-Treatment Facility Equipment Modules

The service racks are shown schematically in Figure 3. The asymmetrical configuration of the 60-line unit was necessary to position the in-cell connections where they could be seen through the cell window and reached with the master-slave manipulators. This rack contains fifty 6.4-mm (0.25-in.) and ten 12.7-mm (0.5-in.) schedule-40 lines. The lines are threaded on each end. A compression-type pipe-to-tubing fitting was installed on the cell end of each line. The other service rack contains six 12.7-mm (0.5 in.) schedule-40 lines. These lines terminate in the cell with a semiremote connector.

A horizontal offset in all of the service lines is provided where they pass through the service plugs. The void spaces around the lines in the service plugs are filled with lead shot to provide the required shielding.

EQUIPMENT INSTALLATION

Before placing the equipment modules in the cell, alignment devices were installed. These devices aligned the three modules in correct relationship to each other and to the two service racks. This alignment feature assured that the interconnecting jumpers between the modules and from the service racks to the modules would fit. It also assured that the nozzle locations would be known so that the piping could be modified in the future. When the alignment

FIGURE 3. Laboratory-Scale Waste-Treatment Facility Service Racks

devices were in place, the service racks and the equipment modules were moved into D-Cell via the Airlock Cell. The service racks were installed first, followed in order by the effluent module, the vitrification module and finally the feed-preparation module.

Following proper placement of the equipment modules, the interconnecting process and service jumpers were remotely installed. For the most part the jumpers are stainless steel tubing with compression fittings. These fittings were used to connect the process equipment to their respective service rack connections and to complete the connections between the modules. To the extent possible the intertie piping was made (modular construction) before the equipment was placed in the cell. Stainless steel flex hoses were used in locations where frequent changes will be made in the process flow configuration, especially around the effluent-treatment equipment. Semiremote connectors developed at PNL were used on jumpers where access by manipulators was severely limited.

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REMOTE DESIGN FEATURES

Several special design features were incorporated into this facility to provide for ease of remote operation and to provide for safe operations. These are described below.

FAIL-SAFE SPRAY CALCINER FEED SYSTEM

To attain the droplet size required for operating the spray calciner successfully, it was necessary to use an internal-mix nozzle for feeding the liquid waste to the calciner. As implied, the feed and atomizing air mix inside of the nozzle. In the unlikely event that the orifice in the air cap of the nozzle should plug at the same time that there is a loss of atomizing-air pressure, it is possible to pump liquid waste out of the cell via the atomizing-air line. To prevent this from happening, a fail-safe system was required.

A schematic of the spray calciner fail-safe feed system is shown in Figure 4. The operating principle is simply that the atomizing-air pressure must be greater than the feed or flush pressure or the pressure switch on the atomizing-air line will de-energize the normally open relays that are on the main power lines to the feed/flush pumps. Thus, if there is a loss of air pressure, the pumps are automatically shut off. As a further precaution, there is a radiation detector on the cell wall where the atomizing-air line leaves the cell.

SPRAY CALCINER NOZZLE FLUSHING SYSTEM

Standard spray calciner operating procedure is to feed water to the spray calciner for a few minutes at the start of a run and again at the end of the run to flush out residual feed from the spray calciner feed line and nozzle. Periodically it is also necessary to water-flush the spray calciner feed nozzle during a run to clear out minor plugs that may form in the liquid side of the nozzle. To satisfy these flushing requirements and still assure that there is no possibility of pumping contaminated solutions into the operating area,

FIGURE 4. Laboratory-Scale Spray Calciner Fail-Safe Feed and Nozzle Flushing System

a special flushing system was required. No service line to the cell could be connected to any line on the discharge side of any pump in the facility. This presented a problem when it was necessary to install a water line to the nozzle. Therefore, a cell-contained flushing system as shown in Figure 4 was installed, which made use of stored condensate as a flush source. As previously noted, the condensate tank pump is also tied into the feed fail-safe system.

CLAMPING MECHANISMS FOR THE CANISTER AND SPRAY CALCINER NOZZLE

Special remote clamping mechanisms were used for securing the in-can melter canister to the outlet of the spray calciner and for clamping the feed

nozzle to the barrel of the spray calciner. These are shown graphically in Figures 5 and 6. The two clamping mechanisms are quite similar in that both use single-acting air cylinders to provide the required clamping force.

The in-can melter is operated at 1050⁰C; consequently, the top of the canister is at a temperature that would cause the threads of a conventional clamp to gall. Not only would a conventional clamp be difficult to remotely secure vacuum-tight, it would be almost impossible to remove if the clamp galled. The clamp also has a canister-lifting mechanism that has a plate for easily slipping the canister into position. Thus, the canister is lifted into place and secured in a single step.

In the case of the spray calciner feed nozzle, the nozzle is in a location that cannot easily be reached with manipulators, yet it still must be removed frequently for inspection and/or replacement. A simple method for clamping the nozzle in place was prudent to avoid costly delays with long periods of time devoted to remote replacement operations. This unique clamping mechanism eliminates the need to align the nozzle to the spray calciner and bolt it into position.

GAMMA-EMISSION MONITOR

Due to the high concentration of radioactivity in solidified nuclear waste, a unique method can be used for determining the level of the waste in the canister. A gamma detector (see Figure 7) aimed through a plug in the cell wall measures the background activity at two points, one of which is the top of the canister at the desired maximum fill line. When the activity in the canister greatly exceeds the background reading, the fill line in the canister has been reached, and the feed is shut off until the full canister can be removed and an empty canister installed.

FIGURE 5. Clamping Mechanism for Feed Nozzle

FIGURE 6. Clamping Mechanism for Canister

FIGURE 7. Gamma-Emission Detector

STARTUP OPERATIONS

When the waste-treatment system was assembled in the hot cell and all instrument, electrical and piping connections were completed, a "nonradioactive checkout" of the facility was started. The objective of the first portion of this checkout was to verify that everything had been installed and connected correctly. First, all of the out-of-cell connections to the 4- and 12-in. service plugs were traced, checked and labeled. Next, all of the in-cell connections between the two service racks and the equipment racks were traced and checked. Then the connections between the equipment racks were traced and verified to be correctly installed. Finally, all the instruments were checked to verify that they were installed, labeled, calibrated and operational.

When these preliminary checks were completed, the facility was ready for operational checkouts with water. The first step was to fill the D-cell sump with water and then jet the sump contents to the high-level vault. The objective of this test was to verify that the sump alarm sounded when the sump level reached the alarm set points and to make certain the new sump jet functioned correctly. With this important feature operational, the process equipment checkout was started. High-pressure cooling water was turned on to the cooling-water header. One by one valves were opened between this header and each of the process vessels with cooling coils. In this manner, all water leaks were located and fittings were tightened. Next, the waste-treatment facility was connected to the 324 Building process vent system by opening the D-Cell intertie to that system. A jumper was already installed from the effluent discharge of the waste-treatment facility to the D-Cell connection to the vent system. A canister was then clamped into place against the spray calciner to create a vacuum. The connections in the effluent-treatment system were tightened until a 10-in.-H₂O vacuum was maintained at the calciner with only an 8-in.-H₂O pressure drop across the entire effluent system. All of the off-gas heaters were heated to operating temperatures. Water was added to all of the feed and effluent system tanks to verify weight factor and specific gravity readings. Then each of the pumps in the facility was primed and

operated to determine pumping rates at different speed-control settings. Water was pumped between each of the process tanks to verify the correct valving for those transfer operations.

The spray calciner and in-can melter furnaces were checked out by heating them in 200°C increments to operating temperatures where they were maintained for several hours. Air was turned on to the frit-addition jet and to the calciner filters to note any upsets to the system vacuum. Finally, the evaporator boildown rates were measured. Water was added to the evaporator and boildown rates were recorded with the steam-to-evaporator automatic valve open 30%, 50%, 75% and 90%.

After the nonradioactive checkout was completed and all features of the waste-treatment facility were determined to be operational, a nonradioactive run was initiated. The objective of this run was to operate the facility for the first time using a nonradioactive simulated waste composition. This run was used to correct the run book procedures, train personnel and determine problems that had to be corrected before radioactive operations could be started. The simulated waste was transferred from a nonradioactive make-up room into the evaporator feed storage tank in the waste-treatment facility. This feed was concentrated in 14-L batches to a predetermined specific gravity and was stored as feed for the spray calciner.

When the spray calciner and in-can melter furnaces were turned on for the nonradioactive run, the calciner and off-gas system heaters continued to heat past the set points. They could only be shut off by throwing the circuit breakers for those units. An investigation indicated that a defective pump-speed controller was sending a faulty signal that caused the affected heaters to continue to heat past the set points. Once the controller was replaced, the heaters correctly maintained set-point temperatures.

When the heaters were at set-point temperatures, calcination/vitrification operations were started. Within the first hour the electronic flowmeter for measuring the feed rate to the calciner plugged up. Flow rates then had to be observed by the feed-tank dropout rate. When this rate dropped off, flush water was pumped from the evaporator condensate tank through the transfer

header to the spray nozzle. However, this flushing procedure was time consuming and by the time the flush water reached the spray nozzle, the nozzle was plugged solid. Upon further investigation it was discovered that the cleanout needle was not retracting. Since either this or the flush water delay or both of these problems could have contributed to the plugging, the facility was shut down while both were corrected. A jumper was installed directly from the condensate tank to the spray nozzle. Thus, by closing one valve and opening another the system could be quickly switched from feed to water or vice versa. At the same time, the nozzle was modified and the cleanout needle was changed to a double-acting air cylinder to insure that the needle would retract.

When these problems were corrected, the nonradioactive run was restarted. This time there were frequent symptoms of plugging (loss of feed), so there were frequent switches from feed to flush water. At the same time pump pressure was difficult to maintain and finally the primes on the pumps were lost. In addition, during a simultaneous run on the nonradioactive laboratory-scale spray calciner it was observed that high atomizing-air pressure prevented atomization. The remote spray calciner was being operated at an atomizing-air pressure 30 to 40 lbs more than the feed pressure. It was recommended that the air pressure be approximately equal to or not more than 10 lbs greater than the feed pressure. At the same time, it was suggested that plugs are started by splatters of feed into the air line, so a water flush of the air line would prevent plugging. Therefore, once again, nonradioactive operations were restarted. This time the air pressure was maintained at 5 psi greater than the feed pump pressure. In addition, whenever symptoms of plugging occurred, a burst of water was added to the air line and almost everytime feed rates were restored immediately. In three successful runs, this procedure proved successful. Water flushes of the feed lines were rarely required and only when plugging occurred in the line and not at the nozzle. By measuring the volume of water added during these "bursts", the effluent data can be interpreted.

When all of the trouble-shooting operations were completed and several nonradioactive operations were successful, the facility was determined to be operable. Permission to initiate radioactive operations was then asked of and granted by the Department of Energy.

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