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**WASTE SOLIDIFICATION PROGRAM
VOLUME III
DESIGN FEATURES OF THE FACILITIES
AND EQUIPMENT FOR THE WSEP
PRODUCT EVALUATION PROGRAM**

DECEMBER 1968

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Waste Disposal and
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WASTE SOLIDIFICATION PROGRAM
VOLUME III
DESIGN FEATURES OF THE FACILITIES AND EQUIPMENT
FOR THE WSEP PRODUCT EVALUATION PROGRAM

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This report is one of a series of reports from the Waste Solidification Program being performed by Battelle-Northwest. Other current reports in this series are:

K. J. Schneider, editor, Waste Solidification Program, Volume 1, Process Technology for the Pot, Spray and Phosphate Glass Processes, In progress.

K. J. Schneider and V. P. Kelly, Waste Solidification Program, Volume 2, Design Features of the Waste Solidification Engineering Prototypes, In progress.

J. L. McElroy, C. R. Cooley, J. E. Mendel, W. V. DeMier, J. C. Suddath, and J. O. Blomeke, Waste Solidification Program, Volume 4, Pot Solidification Performance During the First Radioactive Tests in WSEP, U.S. AEC Report BNWL-814, December, 1968.

ABSTRACT

A program has been implemented within Pacific Northwest Laboratory to study the waste pots filled with solidified highly radioactive wastes in the Waste Solidification Engineering Prototypes. The program, termed the WSEP Product Evaluation Program, was established to evaluate properties such as waste pot integrity and solidified waste stability relating particularly to the nuclear safety aspects of waste management. Three separate activities are involved in the Program:

- Nondestructive and destructive testing such as waste pot leak testing, wall thickness measuring, fission product heat generation rate measuring, pot weight and dimension measuring, and pot sampling by rotary core drilling;
- Controlled environment storage of waste pots in the Solids Storage Engineering Test Facility under conditions permitting continuous surveillance of pot pressures and temperatures, and maintaining the pot under various gas, liquid, or solids storage environments during the test storage period; and
- Laboratory scale studies of properties of actual solidified high level waste in the Hot Laboratory Facility using samples obtained by coring pots or by taking dip samples of waste melts during filling. The Product Evaluation Program, expected to extend up to 5 years, will be followed by removal of pots to "final" storage facilities.

Facilities and equipment provided for the Product Evaluation Program are described. The safety analysis reviews and equipment design verification test results are also summarized.

1.0 INTRODUCTION

1.1 RADIOACTIVE WASTE PROBLEM

In the course of reprocessing spent nuclear fuels, essentially all of the fission products are accumulated as an aqueous waste. Traditionally these "high-level" wastes have been stored in large, underground tanks. Since many of the nuclides will constitute a hazard for centuries,* storage in tanks is considered a temporary or interim approach.⁽¹⁾ More permanent disposal methods which improve isolation of these hazardous nuclides must be developed if full benefits of nuclear power are to be realized.

Responsible authorities in the United States and abroad generally agree that the best management approach involves converting the wastes to an inert, refractory solid before storage. Such a solid can be isolated from human environment by storage in man-made vaults of high integrity or in geologically remote formations such as rock salt. Progress towards developing processes for managing high-level waste has been reported comprehensively in three international symposia.^(2,3,4)

1.2 WASTE SOLIDIFICATION

Fluidized bed calcination was the first solidification process placed in routine radioactive operation. In this application, aluminum-bearing wastes from enriched uranium fuels were processed at the Idaho Chemical Processing Plant (ICPP).⁽⁵⁾ The three other processes in advanced stages of engineering development in the United States are the pot calcination process developed by Oak Ridge National Laboratory (ORNL),⁽⁶⁾ the phosphate glass solidification process developed by Brookhaven National Laboratory (BNL),⁽⁷⁾ and the spray solidification process by the Pacific Northwest

* This is true for many fission product radionuclides; for some of the transuranic radionuclides, the hazard exists for thousands of centuries.

Laboratory of Battelle Memorial Institute (Battelle-Northwest, or BNW).⁽⁸⁾ Two waste solidification methods under development abroad include the FINGAL process in the United Kingdom⁽⁹⁾ and a pot vitrification process in France.⁽¹⁰⁾

Such a diversity of effort reflects differences in needs for solidification when considering the chemical complexity of the many types of wastes to be processed, the different scales of operation required, and the different criteria set for the final products. In view of these factors, no single process is expected to be optimal for all applications.

1.3 WASTE SOLIDIFICATION ENGINEERING PROTOTYPES

The WSEP was designed to provide information necessary for a technical, economic, and safety evaluation of the pot, spray, and phosphate glass solidification processes. In addition to testing the processes with full levels of radioactivity on an engineering scale, the suitability of the processes and equipment for service as an integral part of a nuclear-power fuel-reprocessing complex will be assessed.⁽¹¹⁾

Promising laboratory and engineering development at ORNL and a favorable economic evaluation⁽¹²⁾ first led to the scheduling of a pilot-plant demonstration with radioactive wastes at the ICPP.⁽¹³⁾ In 1962, however, plans for testing the pot process at the ICPP were replaced by a plan for a multiprocess pilot-plant demonstration for cooperative studies by ORNL, BNL, and BNW using the newly conceived Waste Solidification Engineering Prototypes.⁽¹⁴⁾ The WSEP was designed and constructed at the AEC's Pacific Northwest Laboratory (PNL) during the period 1962 through 1965 by Battelle-Northwest. By the end of 1967, radioactive demonstration runs on all three processes had been conducted. Demonstration tests are planned to continue into 1970.

1.4 WSEP PRODUCT EVALUATION

Successful operation of WSEP has produced waste containers or pots filled with solidified waste from each of the three processes. The need and plans to maintain surveillance over the filled waste pots for a period of time was established early in the WSEP program. During the surveillance, evaluation of the WSEP "product", i.e., the filled waste pot, would be devoted to measuring container integrity and solidified waste stability. The part of the WSEP program devised to meet these objectives was labelled WSEP Product Evaluation Program. As defined, the Product Evaluation Program involves storage of filled waste pots under controlled-environment conditions for a period of up to three years, plus various periodic nondestructive and destructive tests to measure properties of both the waste pot and its contents. When fully implemented, the program will be carried out in three separate shielded cell facilities in the Chemical and Materials Engineering Laboratory (C-MEL) in accordance with the following:

- Short-term and interim storage and initial tests will be done in B-Cell with equipment originally provided for WSEP operations;
- Controlled-environment storage of up to 16 waste pots will be carried out in the adjoining A-Cell, which has been converted to a test storage facility and termed Solids Storage Engineering Test Facility (SSETF);
- Hot laboratory studies to measure the physical and chemical properties of samples of solidified wastes will be conducted in the adjoining C-Cell.

The conversion of the A-Cell facility, SSETF, starting in mid-1966, involved installation of shielding windows and remote handling equipment. Beneficial occupancy of the cell was achieved in March, 1968, and storage testing equipment was installed to activate the cell as a storage facility.

This report describes the design features of the A and C-Cell facilities and the equipment and systems installed in A, B, and C-Cells to carry out the WSEP Product Evaluation Program. The safety analysis reviews for the A and C-Cell facilities and the results of equipment design verification testing are also summarized.

2.0 SUMMARY AND CONCLUSIONS

The WSEP Product Evaluation Program was designed to study WSEP "product", i.e., the waste pot filled with solidified wastes, during a test storage period of from two to five years. The objective of the program is to characterize the physical and chemical properties of the product, particularly those waste pot integrity and solidified waste stability properties relating to the nuclear safety aspects of waste management.

Equipment and facilities within the Radiochemical Engineering Cell complex of the Chemical and Materials Engineering Laboratory for performing Product Evaluation are provided as follows:

- The Solids Storage Engineering Test Facility (SSETF) is located in A-Cell, where filled pots will be stored in environmental test pods. Environmental conditions inside the test pod will be controlled, and pot pressure and temperatures will be observed during a nominal 3-year test storage period.
- Nondestructive and destructive test equipment will be located either in B-Cell, A-Cell, or both for pot leak and pot wall thickness tests, fission product heat generation rate tests by calorimetry, solids waste sampling, pot closure by fusion welding, and pot dimensions and weight.
- The Hot Laboratory Facility, containing remotely operated laboratory-scale equipment for testing leach-rates on core samples, or dip samples of solidified waste will be located in C-Cell.

The SSETF, a 30-foot deep, 9-foot wide, 21-foot long shielded cell (internal dimensions), is equipped both on the first and second floor levels with a lead-glass viewing window. Up to 16 environmental test chambers (pods) can be

installed in the cell for Product Evaluation testing. The test pods "plug in" to horizontal penetrations formed in the vertical face of one of the cell walls, and hang vertically downward in the cell space.

Test pods are closed and insulated stainless-steel vessels about 9 feet in length (to contain 8 foot long waste pots) and containing cooling coils, heaters, circulating and sparging lines, and other plumbing features. These features allow dry operation of the test pod at temperatures up to 600 °C, or wet operation at or below boiling water. Special gas, liquid, or solid environments (e.g., salt from a salt mine) may be provided as specified by program requirements. In addition, the waste pot is assembled in the test pod to permit monitoring both the internal pressure and temperature, and sampling of the pot off-gas.

To install a pot of solidified waste into the SSETF, operations consist of (1) transfer of the waste pot by crane from B-Cell to A-Cell, (2) transfer of the test pod by crane and special handling fixtures into A-Cell from outside, (3) assembly of the waste pot with the test pod flange, (4) assembly of the waste pot, now supported from the flange, into the test pod and sealing of the flange and vessel, (5) assembly of the test pod into the wall opening, and (6) connecting the required services by contact maintenance to gallery connections. Services may include pod heater power supply, cooling water or air supply, off-gas venting, air sparge or sampling systems, pot pressure monitoring system, and 300-point digital temperature recorder.

Waste pot testing equipment and auxiliary systems consist of:

- Pot leak tester, for pot integrity verification. The helium-traced mass spectrometer leak testing system verifies the pot to be hermetically sealed (inleakage less than or equal to 10^{-7} std. cm^3/sec of helium). A vacuum

roughing pump located in the gallery, connected by through-the-wall piping and mechanically coupled to the top of the pot, is used to evacuate the pot for helium leak test.

- Pot wall thickness tester ultrasonically scans the pot wall vertically as the pot rotates to measure pot wall thickness along the cylindrical length of the pots. Special ultrasonic signal converters are combined with vertical and horizontal position indicators to "map" wall thickness dimensions.
- Internal radionuclide heat generation rate measurements, using a pot calorimeter consisting of an insulated water-filled vessel containing a cooling coil. Heat generation rate is calculated from the heat rise in cooling coil water.
- Waste pot diameter is measured using a special micrometer adapted for remote handling. Weight is obtained from an indicating crane hook weight meter.
- Core samples for hot laboratory studies are obtained by radially coring through the pot wall with conventional, air lubricated diamond-set rotary core bits. The core drill unit consists of a worm-gear jack clamp mechanism to hold the pot during drilling, an air-powered core drill mechanism with mechanical feed, and a centrifugal dust separator with filtered discharge for dust control.
- A remote welding system is used to make fusion weld closures by the tungsten-inert gas (TIG) process of either the top of the pot or of the core holes. The system includes a turntable which rotates the pot beneath the TIG torch for capping by use of a completely automatic weld cycle.

Core samples from pots and grab samples from B-Cell, obtained during filling of pots with melts, are transferred

to the hot laboratory facility (C-Cell). Samples will be physically inspected, tested for leach rate and melting point, and tested for dispersibility and crystallinity in the laboratory. Leach tests are performed in an air-lift device which circulates water past a waste sample in a closed system. The liquid is periodically drained and the activity measured to determine leach rates.

The safety analysis review for the SSETF showed that the probability of a serious incident resulting from any one of the six major potential hazard areas studied is extremely low. Further, the review showed that the radiological consequences of the "worst case" incident, i.e., melt-down due to loss of pod coolant of all of the 16 pots which could be stored in A-Cell, would not result in the release of significant amounts of radionuclides to the environs or to the building interior. It was concluded that the SSETF could be operated with a high degree of confidence in its inherent safety. A similar conclusion was reached in the C-Cell hot laboratory.

Design verification tests of the various systems and equipment used in the Product Evaluation Program showed:

- Environmental test pods can be remotely assembled with pots and handled in the cell.
- Environmental test pod heating, cooling and fluid flow systems are adequate.
- Helium-traced mass spectrometer leak testing of waste pots is feasible.
- Heat content of waste pots can be effectively measured by wet calorimetry.
- The welding station turntable should be rotated from outside the cell in order to remove from the cell components susceptible to nuclear radiation damage.

- Automatic fusion welding using the tungsten-inert gas welding process can be used to reliably produce good quality, high integrity welds for closure of waste pots under remote welding conditions.
- New concepts for the pot wall thickness tester crystal positioning mechanism should be developed, to improve the crystal aligning capability and mechanism remoteability.

3.0 WSEP PRODUCT EVALUATION PROGRAM

The objective of the WSEP Product Evaluation Program⁽¹⁵⁾ is to determine the behavior of solidified waste and waste containers under various environmental conditions, and to translate the resulting information into meaningful engineering, safety, design and economics bases for management of high level radioactive wastes.

The need for improved techniques in the management of high level nuclear wastes has been known for some time. Immobilization of nuclear power wastes for storage in a stable form, and containment of these wastes out of man's environment is of prime importance to high level waste management. It is equally important that new facilities be designed and built to provide reasonable assurance of economical competitiveness. The purpose of the WSEP Product Evaluation Program is to provide the foundation for the development of sound waste management practices.

The characterization of the properties of solidified wastes will be achieved through an extensive experimental program. The experimental program will include destructive and nondestructive testing of the solidified wastes and waste containers from the three processes demonstrated in WSEP. A closely related laboratory program of testing "grab" samples from the WSEP equipment and nonradioactive laboratory program is also scheduled. The objectives of the product evaluation program can not be reached until all the experimental work is correlated into meaningful safety, economics, and engineering data. The successful conclusion of the experimental program will provide the basis for:

- Predicting behavior during storage and transportation,
- Estimating safety of solidified wastes,
- Predicting gross process or storage conditions that significantly affect product integrity,

- Selecting a process, a container, and economically competitive storage schemes and media,
- Developing improved solidification processes and products.

The broad scope of the program product characterization phase is represented pictorially in Figure 3.1. As shown, the waste pots are measured, leak-checked, and radiographed after fabrication and before processing to provide a base for correlating subsequent evaluation data. After filling with solidified wastes, the pots are weighed, leak-checked, ultrasonically scanned for pot wall thickness, and calorimetry-checked. The pots then are mechanically capped and placed in storage until transfer to SSETF.

When the waste pot is to be placed in storage under preselected environmental conditions, it is assembled in its individual environmental test pod and placed in SSETF. Storage environments selected to date are:

- Dry air, at temperatures up to 600 °C,
- Water, at temperatures at or below boiling, and possibly
- Salt from a salt mine, at temperatures up to 250 °C.

The waste pot may be removed from its pod at intervals for both nondestructive and destructive tests. Destructive tests, although primarily involving core drilling to obtain samples of the solidified wastes, may also include sectioning of pots to examine internal deposition and structural affects.

Specific nondestructive tests to be carried out during the waste pot cycle are

(1) Prefill testing of waste pots to include:

- Wall thickness by ultrasonic scans,
- Outer diameter,
- Weight measurement,
- Leak check by helium-mass spectrometry,

FIGURE 3.1 Waste Solidification Product Evaluation Program

- Overall appearance by photography, and
- (2) After-fill testing of the waste pot and solidified wastes to include:
- Wall thickness by ultrasonic scan,
 - Pot outer diameter and length measurement,
 - Weight measurement,
 - Heat generation rate by calorimetry measurement,
 - Temperature distribution and thermal conductivity by carefully positioned thermocouples,
 - Overall appearance by photography, and
 - Pressure measurement using pressure gages.

In general, all WSEP pots are scheduled for testing immediately after filling. However, a complete schedule of testing will be followed for only a few selected pots after SSETF storage begins.

Hot laboratory studies in C-Cell of solidified waste samples taken as grab samples during waste pot filling or as core samples from filled pots will be carried out concurrently with SSETF operations. The studies are expected to permit final characterization and behavioral predictions of the WSEP product, particularly when correlated with non-radioactive or tracer-level laboratory studies. Hot laboratory tests will include:

- Measurements of leachability, dispersibility, and crystallinity, and other characteristics of conditioned samples.
- Measurements of fission product migration.
- Melting point measurements.
- Pot wall corrosion analysis and determination of the physical appearance of the solid.

Nonradioactive and tracer level studies are being carried out in conjunction with the radioactive portions of the program. The advantage of the "cold" studies lies primarily in the large number of relatively inexpensive samples and

subsequent data. Measurements of leachability, crystallinity, dispersibility and other characteristics are being made on the "cold" samples for correlation with the "hot" data. The importance of the "cold" work lies in the connecting link it can provide for the "hot" wastes and waste compositions from new or different systems.

4.0 SHIELDED CELL FACILITIES FOR PRODUCT EVALUATION

4.1 THE C-MEL RADIOCHEMICAL ENGINEERING CELL COMPLEX

Shielded cell facilities for the WSEP Product Evaluation Program are contained within the Radiochemical Engineering Cell complex of the Chemical and Materials Engineering Laboratory.⁽¹⁶⁾ The latter, a multipurpose facility, currently includes the Radiochemical Engineering Cells, the Shielded Material Facility for radiometallurgical studies, a Sodium Studies Facility used in the Fast Flux Test Facility Program, an Engineering Development Laboratory for nonradioactive chemical processing and equipment studies, and an Engineering Development Laboratory used for tracer-level chemical processing studies.

A floor plan of the Radiochemical Engineering Cell complex (Figure 4.1) shows the four operating cells grouped in the complex in a "Tee" arrangement. Access to each is gained through the central airlock. Upon entering the airlock, Cell A is on the viewer's right hand on the north side of the airlock, Cell B is in front of the viewer on the east, and Cells C and D are on the left, one above the other.

Three of the four cells, A, B, and C, are used in the WSEP Product Evaluation Program. Cell B, housing the WSEP processing equipment and interim storage and testing equipment for filled pots, is described elsewhere.⁽¹⁴⁾ Cells A and C respectively comprise the controlled-environment storage test facility for waste pots and the hot laboratory facility. Detailed descriptions of these facilities are given below.

4.2 SHIELDED CELL FACILITY FOR SOLIDS STORAGE ENGINEERING TESTING

The shielded cell facility for waste pot storage testing is referred to as the Solids Storage Engineering Test Facility (SSETF) and is identified as A-Cell in the 324 Building

FIGURE 4.1 *Radiochemical Engineering Cells in Chemical and Materials Engineering Laboratory*

Radiochemical Engineering cell complex. The plan view, cell arrangement, and tabulation of the major cell features are shown in Figure 4.2.

As shown, the cell is 9.25 feet wide, 21 feet long, and 29 feet deep from the floor at ground-level elevation to the overhead crane rail. Concrete walls have a minimum thickness of 54 inches and are lined with 1/8-inch thick stainless-steel sheet to facilitate decontamination.

Cell features include the access doors, viewing windows, cubicles, transfer sleeves, manipulator sleeves, 4 inch stepped plug sleeves, service piping connections, filters, lighting, ventilation, and overhead crane.

The three cell doors are mechanically-operated hinged steel doors varying in thickness from six to eighteen inches. At the top of the cell is the horizontal crane door extending the cell length and operating independently of the vertical door. The latter, a five foot wide, two-piece door, enables access without opening the entire door to minimize impact on the ventilation system. Doors are sealed by air-inflated rubber gaskets and are latched by air-operated locking pins.

Two viewing windows, located at the first and second floors, are centered along the north wall of the cell. Both are multi-paned, oil-filled, lead-glass shielding windows with a 36 inch by 40 inch cell side opening. On the cell side, the windows are protected by removable screen guards, and one inch thick, tempered cellside cover glass.

Since the field of view provided by the windows does not cover the entire cell, additional viewing is provided by TV cameras mounted in the third floor 10 inch sleeves, or by remotely-operated in-cell mirrors. The mirrors are mounted on conventional TV pan-tilt units and are hung from brackets

FIGURE 4.2 SSETF Shielded Cell Facility Arrangement

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on the south wall. By panning and tilting the mirror, the entire north wall can be scanned by viewing through the window.

One of the unique features of the cell is the six cubicles in the north wall. Steel castings 18 inches thick by 54 inches square were set flush with the inside wall of the cell to create a 3 foot deep cavity in the cell wall and form the cubicles. Cubicles are sealed by 4 inch thick hinged steel doors on the operating gallery side. They are also sealed by ventilation barriers consisting of either aluminum or acrylic plastic doors. The plastic doors are fitted with glove ports and gloves so that minor maintenance or adjustments may be made in the cubicle without spreading contamination. Service piping including radioactive off-gas and sewer connections and nonradioactive utility lines extend into each cubicle. From the cell side, each cubicle casting is penetrated by four 9 inch inside diameter cylindrical openings. Equipment inserted through the cubicle openings can be connected to required services without entering the cell, and the connections can be maintained by personnel without significant radiation exposure.

Figure 4.3, showing a simplified half-section of the cell, illustrates use of the cubicles for the SSETF. Environmental test pods, described in the following, are built with integral cylindrical plugs which fit into the cubicle openings. Thus, when the plug is inserted in the opening, the test pod vessel hangs vertically downward and is supported from the plug. Four cubicles at the second and third floor levels can be used for placing environmental test pods, providing space for 16 pods in SSETF.

Utility penetrations into a cell include:

- Paired 10 inch diameter straight sleeves above each window for master-slave manipulators.

Neg 0671892-3

CELL CAPACITY: 16 PODS

FIGURE 4.3 SSETF Equipment Arrangement

- Paired 10 inch diameter straight sleeves at the third floor level for future television or special handling fixtures.
- Four inch diameter stepped sleeves located under each window (four each), on either side of each cubicle (four per floor), and on each of the other three walls. Some of the uses of the 4 inch stepped sleeves are described in the section describing the auxiliary systems.
- One inch and 2 inch piping entering the cell from the cubicles, operating galleries, and from adjoining hot cells. Each pipe end is fitted with a "Purex" nozzle⁽¹⁴⁾ to facilitate remote connection to the lines.
- A 10 inch diameter transfer sleeve located near the second floor window. A drawer type push-pull transfer device is provided in this sleeve by which small tools, sample casks, and other equipment may be transferred without opening the main cell doors.

The cell is arranged for downdraft ventilation. A normal airflow of 2000 cfm enters through remotely controlled dampers in the ceiling and exhausts through filters located at floor level on the east and west walls. Opening of the cell doors automatically adjusts ventilation dampers to provide a maximum airflow of 5000 cfm.

The cell filtration system, which must prevent the release of air-borne radioactive contamination to the environs, includes in-cell medium-efficiency "roughing" filters and out-of-cell high-efficiency "absolute" filters. This combination is expected to provide maximum protection with minimum filter changing and maintenance.

The two in-cell filters each consist of two 6 inch deep, 2 foot square filter units assembled in a 2 foot wide by 4 foot high frame. Filter units are constructed of

fire-resistant glass microfibers rated for about 80% efficiency, according to National Bureau of Standards air filter testing techniques. Filter frames are positioned over the wall duct opening by special wedge-type brackets, to permit remote removal and replacement of the filters by use of the overhead crane. When lowered into place, the brackets cause the filters to wedge against the wall. The weight of the filter itself plus differential pressure across the filter thus seals the filter to the wall. Cell ventilation air passes through two sets of high-efficiency "absolute" filters before exhausting from the building stack. The first set consists of a group of A-frame filter assemblies located in a shielded ventilation tunnel. Four absolute filters are bolted to each A-frame unit, providing 16 square feet of filter area for each one of the cells. A-frames may be lifted semiremotely by crane into a plastic bag for removal. The final set of filters is located in a ventilation room accessible to contact maintenance.

In-cell lighting consists of two rows of four outlets each, located on the north wall of the cell opposite the shielding windows at 8 and 27 foot elevations. Each outlet consists of a multipin Cole^R connector. The mating light fixture has three sockets for 400 watt mercury vapor lamps, or for incandescent lamps up to 900 watts. Lighting fixtures are fitted with special lifting bails and guides for remote handling, i.e., by using only the crane for removal and replacement.

Remote handling in the cell is done with the overhead travelling-bridge crane and with conventional master-slave manipulators. Crane rails, located 29 feet above floor level, extend across A-Cell and through the airlock into D-Cell so that intercell crane transfers can be made. The crane is dc-powered for variable-speed control up to 20 feet per minute.

^RLockheed - Cole Co.

4.3 HOT LABORATORY FACILITY

The WSEP Hot Laboratory Facility is housed in the C-Cell of the Radiochemical Engineering Cell group. Overall inside cell dimensions are 19.25 feet wide, 12 feet deep, and 15 feet high. Essential features of C-Cell include:

- Two lead-glass shielding windows identical with the A-Cell windows located side by side at the ground-floor operating level.
- Paired master-slave manipulator sleeves located above each window.
- A 2 ton capacity dc-powered in-cell crane (travel restricted to the cell) with 11 feet of hook lift.
- A door transfer tray fastened to the cell side of the hinged steel access door. Equipment is transferred from the airlock to the cell by opening the door, placing the object to be transferred upon the tray, and then closing the door.
- A 500 pound capacity, through-the-wall transfer mechanism for transferring small objects from the airlock to the cell. The mechanism is located in a 2 foot square opening in the north wall.
- An 11 gage stainless steel liner covering the walls and floor from the crane rail downwards.
- A wall-mounted periscope for detailed viewing in the cell.
- Four foot thick, high density concrete walls on the operating gallery side.
- Numerous 4 inch diameter stepped service sleeves and in-the-wall piping outlets for providing special services and for making connections in the cell.

The cell may also be connected with D-Cell above by removing a 4 foot square block set into the floor of D-Cell. C-Cell ventilation system, including control dampers, in-cell filter arrangement, duct routing, and out-of-cell filter provisions, is identical with that of A-Cell.

5.0 ENVIRONMENTAL TEST PODS FOR SSETF

5.1 DESIGN CRITERIA

The storage testing of nuclear waste containers in controlled environments requires a closed chamber into which the container can be placed and sealed, and which can be installed in the shielded cell test facility. The chamber, or environmental test pod, must also provide the required gaseous, liquid, or solids environment specified in the testing program. Design criteria for SSETF environmental test pods (ETP) are described as follows:

- 1) The pod must be capable of maintaining a specified environment for one waste pot produced in the WSEP program for a minimum period of three years.
- 2) The WSEP waste pots can be up to 12 inches in diameter and 8 feet in length, and may contain sufficient fission products to generate a radiation field up to 10^5 R/hr and thermal heating up to 25 kilowatts.
- 3) The services and features of ETP's must include:
 - Heating capacity up to 15 kilowatts to maintain low-activity pots at temperatures up to 600 °C.
 - Sufficient cooling capacity to remove up to 25 kilowatts with pot wall temperature at 600 °C, to operate as a reboiler in a boiling water environment, or to subcool in a below boiling environment.
 - Sufficient auxiliary features to sample the contents of the pod vessel, to add special chemicals, or to sparge.
 - Adequate piping to vent or pressurize the pod vessel, and to monitor internal pressure of the pot while in place in the pod.
 - Thermocouple instrumentation to monitor both pod and pot temperatures.

- 4) The mechanical features of the pod must be such that the pot can be readily assembled with it by use of the remote master-slave manipulators.
- 5) The pod geometry must be adapted to the remote handling facilities in the radiochemical cells and, in particular, to storage in A-Cell.

Major components of the pod assembly (Figure 5.1) are the pod vessel, vessel cover flange, the service plug, support frame, interconnecting piping and wiring, and insulating jacket.

In operation, the pod is transferred to A-Cell, and the vessel flange removed and temporarily stored. The waste container is also transferred into A-Cell from B-Cell and placed at the window work location. The vessel cover flange is positioned over the pot and the two are mechanically connected by bolting flange brackets to the pot lifting ears. The pot off-gas line is also connected and the flange/pot subassembly is helium leak tested to verify the integrity of the pot off-gas system. The flange and pot are then lowered into place with the pot inside the test pod. Following, the test pod is hoisted into position to insert the pod plug into the designated cubicle opening. A locking ring is installed on the cubicle end of the plug to hold the pod in place. Piping and electrical services are also connected to the cubicle end of the plug and the appropriate environment control systems are activated to begin test storage. Detailed descriptions of the test pod follow.

5.2 THE POD VESSEL

The pod vessel is a 22 inch OD by 9 foot long 304L stainless steel vessel with an inverted dished bottom and a 15 inch ID center nozzle at the top. The vessels are designed and fabricated, though not stamped, in accordance with Section VIII of the ASME Unfired Pressure Vessel Code.

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FIGURE 5.1 *Environmental Test Pod*

Inside the vessel are two cooling coils, each rolled from 1/2 inch schedule 40 pipe to 2 1/2 inch outside diameter. The lower coil has 36 turns on 2 inch centers, and is designed to maintain a 25 kilowatt pot at 600 °C or less with 100 cfm of air flowing inside the coil. The 6 turn upper coil is designed to condense the steam vapor generated by a 25 kilowatt pot immersed in water.

Vessel heaters are provided to maintain low-activity pots at elevated temperatures. The electric resistance heaters are specially built 3/4 inch diameter by 8 feet long cartridge heaters inserted into the vessel through six equally spaced nozzles. Each Inconel-sheathed heater has a 6 foot heating length and is rated for 2500 watts with 220 volt ac power supply. The heater electrical connector is a radiation-resistant thermocouple connector adapted for remote handling.

Pod temperatures are monitored by six thermocouples, grouped in threes in two thermowells located diametrically opposite in the vessel. The thermocouples are 1/8 inch diameter, 310 stainless steel-sheathed, magnesia-insulated, Chromel-Alumel couples with ungrounded junctions. Thermocouples are vertically spaced at approximately one foot intervals so that the temperature profile along the length of the pod can be monitored. Thermocouples are sealed into the vessel with multihole lava-packed compression glands. Asbestos-insulated, glass-sheathed lead wire from each thermocouple is routed directly through the plug without an intervening connector on the cell side.

The pod vessel is also fitted with (1) an air sparger ring at the bottom of the vessel, for agitation or direct pot cooling, (2) a jet-out line to empty the vessel, (3) a vessel off-gas connection, (4) an auxiliary line for adding

special chemicals or for circulating contents of the tank, and (5) weight-factor dip tubes to read out the tank liquid level.

5.3 POD FLANGE

WSEP waste pots designed for test storage are fitted with top caps integrally equipped with Conoseal^R pipe flanges. The pipe flange allows the pot to be mechanically connected for venting or pressure monitoring. Waste pots are also equipped with up to 20 thermocouples, both internal and external, for experimental purposes.

The pod flange, therefore, must provide a connection to the pot flange, a support for the pot, and a means of making a connection to the pot thermocouples so that pot temperatures can be monitored. The pot thermocouple connector, rated for about 200 °C, must be cooled when higher pod temperatures are required. Figure 5.2 shows some of the details of the ETP flange and waste pot assembly, and illustrates the following various design features of the pod flange:

- A gasketing surface to seal to the pod vessel,
- Bolting and guide dowels holes for assembly with the pod vessel,
- Pot support bars projecting vertically downward from the underside of the flange, with bolts inserted through the bars to securely fasten the waste pot to the flange,
- The pot off-gas connecting system, consisting of interconnected Conoseal pipe connectors above and below the flange. An expansion bellows below and

^RMarman Division, Aeroquip Co.

FIGURE 5.2 *Environmental Test Pod Flange and Waste Pot Assembly*

an off-gas filter above (10 micron sintered stainless-steel) are also included in the system;

- The pot thermocouple cooling system consisting of an insulating seal can below the flange and an air cooling supply line.

In order to complete the assembly shown in Figure 5.2, the pod flange is removed from the empty pod and transferred to the assembly point where the pot is supported. The flange is then lowered over the pot until the support bars engage the pot lifting ears. Bolts are inserted through the support bars to connect the flange and the pot. The vee-flange coupling is then tightened and the flange/pot sub-assembly is helium leak-checked to verify integrity of the mechanical joint.

The pot thermocouple connector is then swung into place and bolted into the flange with a special yoke. The flange/pot subassembly is then lowered into the pod, bolted to seal the flange to the pod vessel, and connections completed to the pot off-gas, thermocouple connector, and thermocouple cooling lines.

5.4 SHIELDING PLUG AND FRAME

The shielding plug and frame are welded into an integral structure which provides the cantilever support for the pod vessel when the plug is inserted into the cell wall. The shielding plug also serves as the pipeway for the piping and for the electrical services previously described.

Pipe in the plug is schedule 40, 304L stainless steel and is offset to provide a radiation barrier. Pipes are cut to lengths during plug assembly, bent for offset, and assembled in a cluster. The cluster then is assembled in the plug and the plug is filled with lead to provide an effective shielding thickness of 6 inches.

The stainless steel pod frames are welded from plate and pipe members. Right and left side versions of three different configurations are required for efficient utilization of available cell space. Frames are designed for cantilever support of 4000 pounds at a maximum distance of 51 inches from the cell wall.

5.5 PIPING AND ELECTRICAL

Services required to maintain and control the test pod environment are listed in Figure 5.3. Test pod nozzles and service plug nozzles are also identified.

Test pod piping outside of the plugs is mostly 304L stainless steel tubing, 0.065 inch in wall thickness, and of the size indicated in the figure. Compression tube fittings are used for interconnections. The waste pot off-gas connections and the thermocouple cooling lines each consist of a 1/4 inch corrugated and sheathed flexible hose readily moved out of the way when removing the pod flange. The pot off-gas line also has a welded bellows sealed valve on the gallery end of the plug to permit positive line sealing for sampling connections.

Test pod heater power leads are asbestos-insulated and sheathed in braided, fibre-glass coated glass sleeving. The leads are connected to the power supply system with conventional wire lugs in the cubicles.

The test pod thermocouple system includes the eighteen waste pot thermocouples (two waste pot liquid-level probe thermocouples are not wired up in the pod system), and the six test pod thermocouples previously described. The asbestos-insulated, glass-sleeved leads from the pod thermocouples and the pot thermocouple connector are routed through a common conduit and are terminated on the cubicle side with a 56-pin Cannon^R KPTM connector. The conduit is sealed with potting compound on the cubicle side.

^R ITT Cannon

PLUG CONNECTION		RUN	POD CONNECTION		FUNCTION
NOZZLE NUMBER	SIZE AND TYPE		NOZZLE LETTER	SIZE AND TYPE	
1	1/2" NPT	3/4" Tubing	E	1/2" NPT	Air Sparge
2	1" NPT	2-#12 Conductors (ea HTR) Dble Asbestos Insul.	F	Special Connector	Heater Power
3	1/2" NPT	3/4" Tubing	B	1/2" NPT	Lower Coil Outlet
4	1" NPT	1" Sch 40 S. ST. Pipe and Weld Ells	G	1" SCR CPLG	Pod Off-Gas
5	1/4" NPT	3/8" S. ST. Flex Hose	M	3/8" Conoseal Block Connector	Pot Pressure Tap
6	1/4" NPT	3/8" Tubing	J	1/2" NPT	Liquid Add
7	1/4" NPT	3/8" Tubing	K	1/2" NPT	Sample Return
8	1/4" NPT	3/8" Tubing	H	1/2" NPT	Weight Factor
9	1/4" NPT	3/8" Tubing	L	1/2" NPT	Weight Factor Ref
10	1" NPT	Asbestos Covered T/C Lead Wire	C	3-Hole T/C Gland	Thermocouples
10	1" NPT	3/8" Tubing	O	3/8" Tubing	Pot T/C Cooling Connection
10	1" NPT	T/C Lead Wire	N	T/C Connector (Cannon KPTM)	Pot T/C Connection
11	1/2" NPT	3/4" Tubing	A	1/2" NPT	Upper Coil Inlet
12	1/2" NPT	3/4" Tubing	B	1/2" NPT	Upper Coil Outlet
13	1/2" NPT	3/4" Tubing	A	1/2" NPT	Lower Coil Inlet
14	1/2" NPT	3/4" Tubing	D	1/2" NPT	Jet Out

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FIGURE 5.3 Environmental Test Pod Nozzle List

The pot thermocouple connector consists of a 48-pin Cannon KPTM connector mounted in a special aluminum shell designed to protect the connector against excessive heat.

5.6 INSULATING JACKET

The insulating jacket is a 27-inch OD, 11 gage stainless steel shell with a two inch thickness of magnesia block insulation inside. Thermal conductivity of the insulation is $0.54 \frac{\text{Btu} \cdot \text{in.}}{\text{ft}^2 \cdot \text{hr} \cdot ^\circ\text{F}}$ at a mean temperature of 300 °C. The jacket was designed to prevent the pod heat loss from exceeding 12 kilowatts at an internal temperature of 600 °C.

The jacket is secured to the test pod frame with four stud bolts arranged to allow remote removal and replacement of the jacket.

Figure 5.4 shows a photograph of two completed environmental test pods that are ready for installation in the SSETF.

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FIGURE 5.4. *Two Environmental Test Pods*

6.0 ENVIRONMENTAL CONTROL AND MEASUREMENT SYSTEMS

Test environments specified for pots in the WSEP Product Evaluation Program range from storage in air at 600 °C to storage in water at temperatures below boiling. In addition, pot pressures and temperatures must be monitored. The required control and measurement services are performed by the pod heater control and power supply system, the pod coolant control system, the pot temperature monitoring system, and the pot pressure system. These systems are represented diagrammatically in Figure 6.1.

6.1 POD HEATER CONTROL AND POWER SUPPLY SYSTEM

Test pod heater systems (Figure 6.1) supply up to 15 kilowatts to each pod from a 220-volt, single-phase ac power source. Two types of power supply, both basically on-off control systems, are used.

For the first type, 440 volt, 3-phase ac power is transformed to single-phase 220 volts and fed to fused, knife-edge disconnects in the transformer rack. Power from the rack is fed to control consoles containing the power supply and control modules for two pods. Each module consists of a two-pole, 100 ampere contactor, a 220 volt, 15 kilowatts autotransformer, and Pyrovane^R indicating temperature controller. Signals from the pod thermocouple feed into the Pyrovane which, in turn, energizes the contactor. The autotransformer is adjusted to limit power input to the pot and minimize the frequency of contactor operation.

Silicon-Controlled Rectifier (SCR) units are used for the second type of power control. The SCR unit consists of a contactor, Pyrovane controller, and six SCR modules, one for each of the six pod heaters.

^RBrown Instrument Company

FIGURE 6.1 SSETF Engineering Flow Diagram of Environmental Test Pod

The 10-ampere rated SCR control module and the electrical schematic of the controller system are shown in Figure 6.2. Each SCR voltage control module consists of the fused SCR control unit, a voltage control potentiometer, on-off switch, and indicating ammeter. The SCR unit itself consists of:

- A case housing the unit and serving as a heat sink for dissipating heat from the components,
- The TRIAC^R, a high-speed switching device formed by connecting two SCR's in reverse-parallel with the load,
- The DIAC^R, a gating device for pulsing the TRIAC,
- A variable resistance-capacitance circuit for controlling the pulse time of the DIAC.

A voltage pulse from the gating circuit DIAC is introduced into one of the SCR units on the TRIAC. The pulse causes the SCR to function as a closed switch and allows its power to be dissipated into the load from the positive side of the ac sine wave.

The second SCR acts as an open switch until a voltage pulse is received from the gating circuit on the negative half of the sign wave. Its power is then dissipated to the load.

Proportional control is achieved by the variable RC circuit which allows each SCR to be pulsed at a specific time in the appropriate half-cycle of the line voltage frequency. The SCR unit thus has a continuously variable power output.

6.2 POD COOLING CONTROL SYSTEM

Pod cooling control racks supply cooling water, air, or steam to the pods, plus pod jet control, and liquid level control. Each rack (Figure 6.1) services up to four pods and features a 4-tube, 100-inch manometer

^RGeneral Electric Company

FIGURE 6.2 Test Pod Heater Control

(with 3.0 specific gravity manometer fluid), air or water rotameters, and manual control valves for air, steam, or water. Operation of the rack is completely manual.

Special devices such as mixing chambers for special atmospheres or pH monitoring chambers may be added to the system as future test conditions demand.

6.3 POT TEMPERATURE MONITORING SYSTEM

Pot and pod temperatures are monitored by the Digital Data Acquisition (DDA) unit located in the third-floor control room. Figure 6.3 shows a photo of the DDA Unit and a block diagram of the system.

The system is connected by 48 pairs of sheathed copper cable extending from the cubicle to the DDA unit. Inside the cubicle, the cable splits into two 24-pair groups, each group terminating to mate with the pod connector. Thus, each cable services two pods. The cable terminates at the DDA unit in miniature thermocouple jacks plugged into the rear of the DDA unit. The DDA unit has fourteen 24-socket subpanels, or a total of 336 plug-in-points, three hundred of which are connected for temperature readout, sixteen for the previously described power supply control consoles, and the balance for spares. One of the 24 thermocouples from each pod must be selected for control. Selection of readout thermocouples may also be required in time, as the total potential number of the thermocouples ($16 \text{ pods} \times 24 \text{ thermocouples/pod} = 384$) exceeds the number of readout points.

Included in the DDA unit, Figure 6.3, is a crossbar scanner, a signal converter, digital voltmeter, and paper tape printer. The crossbar scanner is a mechanical multi-position switch capable of selecting and routing any one of 300 signal inputs to the digital voltmeter through the

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FIGURE 6.3 SSETF Temperature Monitoring System

signal converter. Readouts are either visually displayed on the voltmeter panel or printed. Temperatures can be read in sequence, at timed intervals, in continually repeating sequences, or singly at the operator's selection.

6.4 POT PRESSURE SYSTEM

Systems for remotely monitoring and recording pot pressures, for sampling and venting gas which may build up in the pot, or for evacuating all or any part of the system, are considered to belong to the pot pressure system, Figure 6.4. The pot internal volume connects through the in-cell piping system to the shut-off valve at the end of the pod plug in the cubicle. At installation, the shut-off valve may be connected to one of the following:

- A pressure gage for visual readout,
- A manifold with pressure gage for visual readout plus sampling/venting connection,
- A manifold with pressure gage for visual readout, plus sampling/venting connection and remote pressure readout.

The pot pressure remote readout transducer (Figure 6.4) consists of a pressure-actuated bellows driving the armature of a linear variable differential transformer (LVDT). Electrical output of the LVDT secondary winding is an ac voltage varying in magnitude with the armature position. LVDT output is transmitted to the pressure monitoring console and converted in a computing amplifier to a dc signal suitable for printout by the multipoint potentiometric recorder. Twelve channels are provided in the recorder, which is provided with an upscale trip for the high-pressure alarm system.

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FIGURE 6.4 SSETF Pot Pressure Monitoring System

7.0 WASTE POT TESTING EQUIPMENT AND SYSTEMS

Both nondestructive and destructive testing of pots and controlled environment storage, as discussed earlier in this report, are required for product evaluation. Instrumentation and equipment to be used for waste pot testing (Figure 7.1) includes:

- Pot leak testing systems to verify integrity of the waste pot,
- Pot wall thickness tester, also to verify its integrity,
- Pot calorimeter, to measure its heat content,
- Pot measuring instruments, to determine the extent of pot distortions due to thermal or mechanical stress and weight,
- Pot core driller unit, to sample its contents for hot laboratory studies,
- Welding station, which serves as the focal point for most of the pot testing activities, and
- The Tungsten-Inert Gas (TIG) welding system for welding closures of pots after filling or coring.

Testing equipment and systems are described in the following subsections.

7.1 POT LEAK TESTING

Waste pot leak tests must quantitatively measure in-leakage and positively indicate the location of the leak. Helium-traced mass spectrometer leak testing is used to meet these requirements.

The system (Figure 7.1) consists of the leak test wall plug, the roughing pump cart, the mass spectrometer leak tester, and the helium supply bottle. The wall plug is a steel shot-filled, 4 inch step plug containing the vacuum leak test and the helium sniffer piping. Insertion of these lines through the solid steel, helically-formed

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FIGURE 7.1 SSETF Test Systems and Equipment

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plug without removing the helix is also possible. Piping continues in-cell with 10 foot leads of flexible metal hose, the vacuum line terminating in a 3/8 inch Conoseal block connector, and the sniffer with a short section of 1/8 inch tubing. For leak test, the pot is chucked in the turntable and the vacuum line is coupled to the top of the pot. The sniffer is used to spray helium around the pot at various locations of suspected leakage.

The roughing pump cart is a portable unit bearing the cold trap and a 400 liter mechanical roughing pump. The cold trap is filled with liquid nitrogen during leak test to aid the pumping system in obtaining the extremely low vacuum required for test (0.2 microns or less), and to aid in trapping any radioactive contamination emitted from the pot during test. Lead shielding 4 inches thick around the trap minimizes radiation exposure in case of build-up. Other system features serving to prevent spread of contamination into the gallery are:

- The in-cell pot filter, a 10 micron sintered stainless-steel filter in the pot neck, and
- The discharge of the roughing pump to the cell.

During leak testing, the system is pumped down to the limit of the roughing pump (about 10 - 20 microns) before the mass spectrometer unit is valved into the system.

The mass spectrometer leak detector has, among other features, an ion chamber where incoming helium molecules are ionized with an electron charge. The charged molecules then pass between the poles of a magnet and are deflected to strike a target. Thus, in effect, the unit "sees" only helium molecules striking the target to produce a voltage proportional to the leak rate of helium into the system. Leak rates as low as 10^{-10} std. cm^3/sec of helium can be

measured with the unit. Leak rates of 10^{-7} std. cm³/sec of helium have been defined as "hermetic", i.e., the equipment essentially is perfectly sealed.

In the event of severe outgassing when the pot is pumped down to the low pressures required for leak testing, "by-pass" leak testing is used. By-pass leak testing consists of operating the roughing pump and mass spectrometer leak tester in parallel, with the inlet valve to the leak tester throttled so that the tester "sees" the required low pressure. Since any incoming helium is diluted by the ratio of gas flow through the roughing pump to that through the tester, sensitivity is reduced by an estimated log factor of at least two. However, even this reduced sensitivity is considered suitable for waste pots, and is to be preferred over nonquantitative methods such as soap bubble testing.

7.2 POT WALL THICKNESS TESTER⁽¹⁷⁾

Ultrasonic testing is used to measure pot wall thickness. Major components of the system (Figure 7.2) are:

- The mechanical system, consisting of the vertical transducer positioning mechanism, the vertical and horizontal shaft encoders, and the welding turntable (description below) used to rotate the pot for scan,
- The signal generation unit, including the ultrasonic generator, video amplifier, pulse shaper, and transducer, and
- The digital logic system, consisting of the clock scaler, multiplex circuit, and readout devices.

The system operates by pulse-exciting the ultrasonic transducer, which propagates the pulse through water to the waste pot wall. Returning echoes from the front and back surfaces of the pot wall act as gates to switch on and off a high-frequency oscillator, while a binary counter counts

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FIGURE 7.2 Waste Pot Wall Thickness Tester

the number of cycles between the two gates. Cycle counts are thickness information which may be read out directly or processed through the multiplex circuit to a computer. Vertical and horizontal position information from encoders and multiplex switches is also fed to the computer, so that wall thickness readings can be printed as a digital "map". Thus, when the pot is placed in the turntable and chucked in a preselected index position, digital thickness maps produced by the computer printout device can be compared one with the other, and areas of pot wall thickness reduction readily identified.

The transducer positioning mechanism has two vertical shafts. One is a square shaft over which a ball-bearing guided slide travels. The other is a ball-screw shaft with a nut travelling on it. The nut and slide are mechanically connected so that rotation of the screw moves the slide up or down. An adjustable mounting fixture on the slide holds the transducer and permits adjustment of the transducer position with respect to the normal plane of the pot wall. Rotation of the slide shaft is also possible, allowing the mechanism to be swung clear of the pot. Both shafts are driven from outside the cell by through-the-wall flexible shafting.

7.3 POT CALORIMETER AND STORAGE STATION (B-CELL)

Filled waste pots are temporarily stored after capping in an air or water-cooled vessel located in B-Cell. The vessel (Figure 7.3) is referred to as the pot storage station and identified as WSEP Rack 4A.⁽¹⁴⁾ Included in the station is a calorimetry system for measuring the heat content of pots.

As shown, the station consists of a bathtub-shaped outer tank mounted in a stainless-steel pipe frame and

VOLUME

Tank 120	3200 liters
Insulated Thimbles (IT-1,2)	245 liters
Large Thimbles (LT)	250 liters
Small Thimbles (ST)	145 liters

HEAT TRANSFER AREA

TK-120 Coil 3/4 in. Sch. 40 Pipe	55 sq. ft.
Cooling Capacity	~100 kW
IT Coils 1/8 in. and 1/4 in. Sch. 40 Pipe	5.2 sq. ft.
Cooling Capacity, ea.	~23 kW

OPERATING CONDITIONS

TK-120	0 psig at 100 °C
TK-120 Coil	90 psig at 175 °C

CONSTRUCTION

Type	All Welded
Material	304L SST

WEIGHT

TK-120 Empty	2,700 kg
TK-120 Water Filled	9,100 kg
TK-120 with Maximum Thimble Loading	14,500 kg

FIGURE 7.3 Pot Storage Station

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fitted internally with cylindrical compartments called thimbles and with cooling coils. The 3200 liter capacity stainless steel outer tank is 4 feet wide, 7 feet-9 inches long, and 8 feet-10 inches high. Connections to the tank provide for cooling water circulation, venting, jetting, sparging, sampling, liquid level diptubes, and temperature monitoring. All piping extends through the cubicle plugs so that service connections may be made without entering the cell.

Inside the bathtub tank are 12 storage thimbles, 6 for pots up to 8 inches in diameter and 6 for pots up to 12 inches in diameter, and the two insulated thimbles IT-1 and -2 used for calorimetry.

The storage thimbles are hydraulically isolated from the main vessel except by overflow and, hence, may be operated wet or dry as required. Each thimble is fitted with two 1/4 inch pipes used alternatively for sampling, for liquid level diptube, or for chemical addition. Thimble piping is routed to the manipulator face of the rack, where quick-disconnect fittings can be reached.

The two calorimetry thimbles are externally wrapped with Cerafelt^R insulation and have an internal cooling coil. Thermocouples are used to monitor temperatures of the water baths inside and outside the insulated thimbles, and of the thimble inlet and outlet cooling water. Temperature values and known surface areas are then used to calculate the heat content of the waste pot in the calorimeter.

The rack frame is a 6 inch stainless steel pipe structure except for the 4 x 8 box members extending horizontally along the length of the station at the top. These extra-strength members were provided for temporary storage of heavy equipment during periods of changing from one process to another. Vertical

^R Johns-Manville Co.

frame members are extended to attach to and support the service plugs on the one end and the manipulator face plate on the opposite end.

7.4 POT MEASURING

Waste pots are weighed to determine the solidified waste content and the diameter measured to detect distortions in the shell. Weight is obtained with a conventional crane scale indicating the total weight of the pot and its contents on the face of the scale dial. Weights are taken at viewing windows for direct reading of indicated values.

Pot diametral dimensions are obtained by use of C-shaped micrometers adapted for remote handling. Micrometer frames are fitted with dial indicators instead of the usual manually adjustable micrometer head. With the pot hanging in the vertical position and the frame in the horizontal position, the dial indicator is read directly in 1/1000 inch variations from the nominal diameter.

7.5 CORE DRILL UNIT

Samples of solidified wastes must be recovered from waste pots in order to complete the tests required for product evaluation. Samples from waste pots will be taken in SSETF by rotary core drilling with diamond-set bits. The core driller must be able to sample by drilling radially into the pot at any designated location along its length, and must provide containment of radioactive dust generated in the coring operation.

The core drill unit (Figure 7.4) consists of the core driller itself, a clamping mechanism to hold the pot during drilling, and the dust control system. The latter consists

FIGURE 7.4 Waste Pot Sampling Core Drill Unit

of a centrifugal dust separator discharging to the twin filters unit. These components are mounted on a structural steel frame. To sample a pot, the frame is bolted to the top of the welding station. The drill bit is then inserted and coupled to the drill drive motor and the waste pot is lowered into position and clamped. The dust separator is started and the bit is fed into the pot by actuating the core driller's mechanical feed screw drive.

The core driller itself is a conventional industrial drill unit with a standard air motor to drive the core bit. The air motor is bolted to a slide which, in turn, is positioned by a feed screw. The feed screw is operated in-cell by a through-the-wall flex shaft or by manipulator.

The core bit is a diamond-set, thin-wall masonry bit type threaded onto the spindle of the drive motor. The bit, 1-1/4 inches OD by 13-3/8 inches long, drills a core about one inch in diameter. Cooling air to the bit is supplied through a swivel mounted on the drive motor spindle. Air flowing down the hollow spindle and the bit blows past the bit face to cool and flush away dust particles.

Waste pots are clamped between a moving anvil and a stationary anvil. The moving "vee" anvil is actuated by two coupled 3-ton worm gear jacks. The stationary anvil, welded directly to the frame, forms a saddle into which the pot is firmly clamped. The stationary anvil also is integrally equipped with a sealing gland. A sponge rubber gasket on the inner face of the gland seals against the wall of the pot and against double O-rings on the outer end to seal the core bit. A guide bearing for the core bit is provided in the outer end of the gland. The inner gland is connected to the dust control system in such a manner that dust laden air passing out of the drill hole exhausts from the gland into the dust separator.

The dust separator is a size 3-1/2 Rotoclone^R centrifugal dust separator, with an air capacity of 200 cfm at 4.5 inches of water pressure. Dust carried into the separator by the air flow is discharged downward into a hopper. A discharge valve in the hopper allows dust to be emptied into a standard waste pot or other vessel for disposal. Air discharging from the separator exhausts to the cell through two back-to-back 2 foot square medium efficiency filters identical with in-cell filters.

7.6 WELDING STATION

The welding station (Figure 7.1), used to hold waste pots at the window position for various testing activities as well as for welding, consists of a tank upon which is mounted a turntable. The tank is normally filled with water for cooling the pot and for operation of the ultrasonic pot wall tester.

Inside the tank is the removable vessel coil subassembly comprising a cooling coil, weight factor diptubes, chemical addition, air sparge, and off-gas lines. A screen provided at the bottom of the assembly serves as a catch basket so that tools and other objects may be retrieved from the tank.

The turntable is designed to support waste pots for ultrasonic pot wall test, or leak test, and to rotate pots beneath a stationary welding torch for welding closure. The table, a 36-inch diameter stainless steel gear plate with a 16-1/4 inch ID throat, rotates on four equally spaced dual roller assemblies contacting the upper and lower faces of the table. One of the roller assemblies incorporates a drive pinion with an integral hex drive nut which can be engaged by standard wrench sockets to rotate the pinion and the turntable. A series of spring-loaded, carbon-graphite

^RAmerican Air Filter Co.

brushes contact the lower face of the table to provide an electrical ground while welding. Pots are chucked in the turntable with four 2-1/2 ton capacity, worm gear-driven jacks driven through interconnected drive shafts and right-angle-drive bevel gear units. Rotating the input drive nut moves the chuck jaws in or out in unison. Objects from 16 to 8 inches in diameter can be chucked, while the addition of spacers will allow smaller objects to be secured.

Standoff spacers support the turntable mounting plate which, in turn, supports the waste pots or special equipment such as the core drill unit.

A flexible shaft coupled to the mechanical drive plug in the wall is used to drive the table. The gallery end of the drive plug shaft couples to a 3-way right angle drive gear which has two input shafts, one motorized and the other manual. Thus, the turntable can be positioned manually or, when welding, by a variable-speed tachometer servo-controlled dc motor system. The same drive plug system can be disconnected from the turntable and connected to other equipment to perform a variety of mechanical tasks.

The stainless steel welding station support rack, not shown in Figure 7.1, is a free-standing, 3 inch pipe structure 12 feet 7 inches high. The welding station vessel fits inside the rack.

7.7 TUNGSTEN - INERT GAS WELDING SYSTEM

Waste pots are sealed by fusion welding after filling, or after any breeching operation, using the tungsten-inert gas (TIG) welding process. The basic TIG welding system (Figure 7.1) consists of the welding torch with its leads, the welding power supply, and torch gas (argon/helium) and coolant supply. For remote welding, the master-slave manipulator and the spotting scope (or other viewing aids) are also provided.

The WSEP welding system permits welding "manually", where the torch is supported by the manipulator, and positioned by the operator in the gallery, or "automatically". In automatic welding, the torch is attached to a voltage control unit which automatically controls the position of the electrode with respect to the weld joint. Automatic welding is used where high-integrity welds are required such as on final closure of pot caps. Manual welding will be used for closing core holes or thermowell openings.

The power, gas, and coolant supply unit for both types of welding is a Sciaky 300 volt silicon-rectified dc power supply with an integral control console for control of gas flow, amperage, voltage, and weld cycle sequence. When operated in an automatic welding cycle the unit is connected electrically to the in-cell voltage control unit to form a voltage servo control system. The control unit consists of a dc motor driving a ball nut to which the welding torch is attached. If the electrode/weld joint relationship changes, the servo system senses a voltage change and energizes the voltage control unit drive motor to correct the torch position and maintain welding voltage at the preset value.

When welding automatically, the in-cell voltage control unit may be suspended from the crane and held rigid by the manipulator, or mounted on a centering jig (Figure 7.5). The centering jig consists of a clamping device for attaching the jig to the pot top, a pivot bearing, and a cross-slide for torch positioning. The jig was developed for use in instances where runout of the weld joint exceeds the positioning capability of the voltage control unit.

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7.15

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FIGURE 7.5 Remote Welding Jig

8.0 HOT LABORATORY EQUIPMENT

Evaluation of the WSEP product involves characterization of the physical and chemical properties of solidified wastes, as described in an earlier section. The hot laboratory facility required for these studies also has been previously described, while equipment to be operated in the facility is described in this section.

8.1 SOLIDIFIED WASTE SAMPLE TRANSFER AND PREPARATION

As indicated in Figure 3.1, samples of solidified waste to be used in hot laboratory studies are obtained by "grab" samples taken during filling of waste pots, or by coring filled waste pots. Core or "grab" samples are then transferred from A or B-Cell in sealed containers, or in a shielded sample cask to C-Cell. In C-Cell, samples may be further prepared for chemical or physical studies.

Samples to be prepared for the following described leachability and dispersibility tests must be sufficiently regular in shape to permit calculation of surface areas. Since core samples, particularly, may be fragmented, smaller samples must be cored from the larger fragments. The second coring step is performed with high-speed rotary diamond-set core bits 1/2 inch in diameter or less. Core sample fragments are first cast in a plastic matrix for holding during coring. A conventional drill press with spindle speeds up to 5000 rpm is used for driving the core bit. High-speed coring is done with the sample submerged in water to provide for bit cooling. Ends of the small-diameter core samples thus obtained may also be squared up in an in-cell diamond saw.

8.2 LEACHABILITY TESTS

Properties of solidified waste of major interest relate to nuclear safety. Of these properties, solubility or

leachability of the waste is of primary concern, since the products with minimum solubility may provide maximum nuclear safety.

The leach testing device (Figure 8.1) consists of a small glass vessel arranged with an airlift recirculator patterned after that used by Paige.⁽¹⁸⁾ Core samples of a known size and measurable surface area are placed in the leach vessel on the stainless steel screen support. Up to 500 ml of distilled water is added and the airlift recirculator started to circulate water past the sample at a rate of 200-300 ml/min. Temperature of the vessel is controlled at 25-100 °C. Periodically, leach water is drained from the vessel, collected in sample containers and analyzed for gamma emitters by use of a multichannel analyzer.

8.3 DISPERSIBILITY TESTS

In the event of catastrophic rupture of a waste container, the fracturing behavior of the solidified waste and the resultant susceptibility to be dispersed will be of prime importance. If the material fractures into relatively large pieces, spread of radioactivity will be less, retrieval will be much easier, and less leaching of the radionuclides will occur as compared to a material that fractures into minute particles.

Tests in which samples are fractured by impact, and the particle size distribution of the resulting fragments determined, are being made on simulated nonradioactive waste samples. Similar tests may be performed on core samples of WSEP products in C-Cell.

The presently used dispersibility tests consists of dropping a blunt-pointed 3 pound weight 4 feet onto a 1/2-inch long right cylinder of product sample in a confined tube. The fragments are collected and classified by sieving.

FIGURE 8.1. Leach Test Device for Solidified Nuclear Waste

8.4 PHYSICAL PROPERTIES OF SOLIDS

Other tests in C-Cell to be performed in measuring solid sample properties include:

- Magnified photographs of samples taken through periscope attachments for visual inspection to detect qualitative changes in crystallinity and general sample appearance,
- Melting point determination using conventional laboratory furnaces,
- Collecting samples across temperature profile of storage container. Samples will be taken from core samples with small diamond-set core bits described above and analyzed to measure segregation of melt components.

9.0 SAFETY ANALYSIS FOR WSEP PRODUCT EVALUATION FACILITIES

Safety analysis review (SAR's), consisting of a detailed review and analysis of all potential facility hazards, are prepared and reviewed within Pacific Northwest Laboratory for all nonreactor nuclear facilities in which significant amounts of radioactivity may be handled. The SAR's for the SSETF and the C-Cell hot laboratory facility are summarized briefly in the following.

9.1 SAFETY ANALYSIS FOR SSETF

Six major hazards associated with SSETF were reviewed, including probability of occurrence, preventive measures to be implemented where required, and radiological consequences of the incident which could result from each hazardous situation. These hazards were

- Waste pot failure as a result of meltdown due to loss of pod coolant, pressurization due to radiochemical or thermal chemical reactions, or mechanical rupture due to mishandling in remote transfers.
- Shielding window failures due to heavy impact against the window followed by release of window oil and possible ignition to create a fire.
- Potential hydrogen explosion due to ignition of hydrogen formed by radiolysis in water-filled test pods.
- Water flooding of the cell as the result of a coolant line rupture.
- Excessive cell temperatures in the event of disruption of normal cell ventilation.
- Cell pressurization as a result of rupturing an air or steam line.

In all cases, the probability of a serious incident occurring in connection with any one of these hazards is

extremely low due to the basic geometry of the facility, the multiple safety circuits provided to monitor or automatically correct offstandard conditions, and the operating controls imposed to guard against the incident. In only one case, that of waste pot meltdown, could significant quantities of radioactivity be released to the cell. However, even if the virtually incredible meltdown of all 16 pots in the cell is assumed, the highly efficient 3-stage building air filtration system will effectively prevent release of significant amounts of radioactivity to the environs or to the building interior. Therefore, it is concluded from the SAR study that the SSETF as designed is an inherently safe facility for storage of megacurie quantities of solidified radioactive wastes.

To further enhance the inherent safety of the facility, the following additional safety measures and systems have been implemented in SSETF:

- Emergency cooling water hookup for all pots assembled in a pod with over 5 kilowatts of heat,
- High-pressure alarms on pots in storage, and pressure relief devices on pots during transfer,
- Positive transfer and remote handling devices, auxiliary viewing as required, and proper operator training to assure remote handling safety,
- Window screen guards to protect against minor impact,
- Air sparge of pots stored in water (and pod venting to the cell) until hydrogen generation can be measured to determine the extent of the problem,
- Water spray system for cell cooling in the event of loss of ventilation, and
- Strict administrative and supervisory control of pot heat load and handling operations.

9.2 SAFETY ANALYSIS FOR THE C-CELL HOT LABORATORY

Hazards analyses in the C-Cell SAR indicate:

- A criticality accident is not credible since the total fissile material in the cell will never exceed a small fraction of the minimum critical mass.
- The probability of breaking a shielding window and then igniting the oil is even lower than in SSETF, since large, heavy objects will not be handled in C-Cell.
- Radiological consequences of an incident involving various postulated thermal and/or chemical reactions possibly resulting in release of radioactivity to the cell would be virtually nil. The maximum inventory of fission products in C-Cell will be lower by several orders of magnitude than the inventory in A or B-Cells.

Therefore, it has been concluded that C-Cell can be operated safely as a hot laboratory facility for the Product Evaluation Program.

10.0 DESIGN VERIFICATION TESTING

Design Verification Tests (DVT's) have been performed on WSEP Product Evaluation equipment to verify validity of the design and operability of the equipment. The DVT's, varying widely in scope, were carried out both in "cold" mockups, in A-Cell, or in actual service in B-Cell. Results of the DVT's are described briefly, along with the objectives of the tests and procedures.

10.1 ENVIRONMENTAL TEST PODS

10.1.1 Remote Assembly of Test Pod Flange and Waste Pot

This test was performed in a master-slave manipulator mockup to demonstrate remote assembly of the pot and pod flange as shown in Figure 5.2. The assembly was successfully made by an operator with average skills using simulated shielding window viewing, two manipulators, and an overhead crane when required. An estimated 4 to 8 hours assembly time is required.

10.1.2 In-Cell Pod and Cubicle Plug Handling

The feasibility of remotely removing dummy cubicle plugs and of transferring and installing test pods was studied in A-Cell. The cell viewing and handling equipment was used.

Removal of original dummy cubicle plugs from the cell side was required. This operation was successfully done in test by crane lift on the cell end of the plug and with the cubicle end tied with a restraining line. Removal was smooth and well controlled. However, the dummy plug design was subsequently changed to one of a straight cylinder to permit removal from the gallery side to eliminate in-cell handling. Results of handling tests with single pods in-cell indicate:

- The remotely-operated mirror is required for supplementary viewing during transfers.
- Extreme care must be employed, as expected, in transfers of the bulky test pods down the length of the relatively narrow cell.
- Test pods, particularly those with long frames, must be relatively well balanced to avoid interference with previously placed pods.
- Installation of the pod locking ring is relatively tedious because of insufficient clearance, in some cases, between the locking ring and the cubicle face. Pod plugs are being lengthened to reduce ring installation time.
- Satisfactory alignment of the pods when placed in position and filled with water indicates the structural rigidity of the pod frame to be adequate.

10.1.3 Test Pod Heat Transfer and Fluid Flow Tests

Heat transfer and fluid flow DVT's were made to determine:

- Pod heatup and steady-state heat loss as a function of temperature,
- Cooling capacity of the lower pod coil with both air and water internally-flowing coolant,
- Cooling capacity of the upper coil in condensing operation with water coolant,
- Operability of the pod jetout and sparge systems.

Heat tests were conducted using the pod heater rods (15 kilowatt capacity) for heat input. Results indicate that:

- With normal cell ventilation (about 2000 cfm air flow), steady-state heat loss from the pod is about 5 kilowatts with the pod internal temperature at 600 °C. Based on an external area of 72 square feet, the effective heat transfer coefficient of the system is about 0.2 Btu/hr-°F-ft².

- Maximum heat removal capacity of the lower coil is an estimated 10 kilowatts with maximum air flow of about 150 cfm, based on the experimentally-measured overall heat transfer coefficient (U) of 1.6 Btu/hr-ft²-°F.
- Heat removal capacity of the upper coil in condensing service was about 10 kilowatts, with water at temperature of 19 °C flowing at a rate of 6 gpm through the coil. Calculated heat transfer coefficient (U) was 400 Btu/hr-ft²-°F.
- Jet out capacity was 40-80 liters/hour using 90 psi air to jet through a 40 liters/min jet designed for steam.
- A sparger throughput of 75 scfm was obtained with the pod filled with water and using 90 psi air supply.

10.2 POT LEAK TESTING

Pot leak testing DVT's consisted of in-place demonstration of the system in leak testing filled waste pots. Major concerns of the tests were the tendency of solid wastes to outgas under vacuum and the control of radioactive contamination which might spread through gallery piping as a result of the outgassing.

In the initial leak test with a calcine-filled pot, nearly 70 hours were spent in attempting to pump down the pot to leak-test pressure (0.2 microns or less) without success. This result was attributed to outgassing of the calcine, possibly due to residual moisture or to absorption of moisture during a period of time when the pot was uncapped. Pumpdown of melt-filled pots, on the other hand, has been successful. It was concluded from these results that by-pass leak testing, involving parallel operation of the roughing pump and the mass spectrometer leak tester, would be required to satisfactorily leak test pots subject to outgassing under vacuum.

The second phase of the testing involved detection and control of radioactive contamination which might spread from the pot to the gallery through the roughing pump. After testing eight pots containing up to a maximum of 2.6 megacuries of radionuclides each in the form of mixed fission products (90% Ce-Pr¹⁴⁴), a small area of activity was detected on the cold trap adjacent to the inlet line. The activity was smearable, had an activity level of 60,000 counts/minute and was analyzed as being primarily the Ce-Pr¹⁴⁴. It was concluded that mass spectrometer pot leak test systems should be operated with a radiation probe at the cold trap inlet and that the rough pump, at least, should be located in a controlled zone to simplify handling potentially contaminated parts during cleanup and maintenance.

10.3 POT STORAGE STATION AND CALORIMETER

Pot storage station DVT's consisted mainly of calibration of calorimetry thimbles IT-1 and IT-2, with additional tests to measure liquid level calibrations for the storage vessel and thimbles, and measurements of pressure drop/flowrate relationships for coils in the calorimetry thimbles and the vessel.

Calorimeter calibration was done with both wet and dry thimbles, with an electric resistance-heated pot to simulate the waste container. The resistance-heated pot consisted of a 12 inch diameter 9 foot long cylinder with a 6 inch long pipe centered inside it. Resistance heater rods were attached to the outside diameter of the 6 inch pipe to provide heating capacity up to 12.5 kilowatts. For wet calibration, the calorimetry thimbles and tank were filled with water, a constant cooling water flow rate of up to 10 liter/min was established through the vessel coil, and the resistance-heated pot was centered in one or the other thimble. Power input

to the pot and flowrate through the thimble coil were varied. Power inputs, flowrates, various water temperatures, and thimble water boiloff rate were measured to determine system heat balance and verify operability as a calorimeter. Dry thimble tests were similar except, of course, water in the thimble was not used. Conclusions were that measurements with wet thimbles are acceptable if the cooling water flow is at least 5 liters/minute. Nearly complete elimination of heat losses will be obtained by better matching of thimble water and tank water temperatures. Measurements with dry thimbles are unacceptable. A summary of heat balances is given below in Table 10.1.

TABLE 10.1 *Heat Balances for Calorimeter Thimbles*

	Kilowatts		
	Wet Thimble		Dry Thimble
Heat Input	5.2	12.5	11.1
Recovery by Thimble Coils	3.3	10.6	5.7
Losses Out Top	~0.6	0.6 to 1.0	1.8
Other Losses	~1.3	0.9 to 1.3	3.6

10.4 WELDING STATION

Welding station DVT's consisted of in-cell testing of the welding turntable. As a result of these tests, the turntable described earlier has been designed to replace the original. Design features of the first turntable included:

- Table support on 18 inch outside diameter roller bearings,
- Electrical ground for welding circuit through a mercury pool,
- In-cell electrical drive consisting of dc gearmotor drive with dc tachometer feedback for velocity servo speed control.

Failure of the roller bearings occurred after relatively brief service, apparently because of failure or inadequacy of the mercury grounding system. Moreover, complete removal of components susceptible to radiation damage is highly desirable. Therefore, it was concluded that the following changes would be desirable (the first two items have been included in the existing unit):

- The table should be supported by peripherally-placed rollers which could be packaged for unit replacement and remote maintenance,
- Spring loaded carbon brushes should be used for grounding to replace the mercury pool,
- The turntable drive should be removed from the cell and connected to the table by flexible shafting,
- The diameter of the table should be increased to permit increasing the stroke of the chucking jacks and eliminate the need for removable chuck jaws.

10.5 TIG WELDING SYSTEM

The TIG welding system DVT's consisted of in-cell operations of welded closures on WSEP pots using the Sciaky automatic TIG welding system and fillet-type weld joints.⁽¹⁹⁾ Conclusions and results from these tests and operations include:

- Weld quality and penetration evidenced by visual examination, sectioning of nonradioactive test pot caps, and helium leak-check of sealed pots indicates the system to consistently produce high-quality welds on 304L stainless steel pots if the weld joint is clean, the weld joint runout is within plus or minus 1/8 inch, and the automatic welding control system is functioning properly. Stainless steel caps are recommended and are being used for carbon steel pots to eliminate excess weld porosity due to gasification of metal constituents.
- Weld joint runout problems can be virtually eliminated by using the self-centering welding jig mounted on top of the pot (Figure 7.5).
- Special seal-less welding torches were originally used for in-cell welding. The current trend is toward using conventional low-profile torches such as the Linde HW-25. Configuration of this torch permits pulling the torch with its leads through spiral access openings into the cell, facilitating replacement of torches.
- The automatic welding system is recommended for closure of large waste pots where container warpage or other mechanical problems causes weld joint runout, since the automatic system with its torch-positioning voltage control unit compensates for welding electrode/weld joint misalignment. However, the voltage control

unit is subject to radiation damage, is expensive, and requires careful in-cell handling to prevent damage to it. Therefore, an incentive exists to eliminate the runout problem by joint design, use of self-centering welding jigs, or development of operator skills in remote torch positioning, so that high-quality welds can be made without the voltage control unit.

10.6 POT WALL THICKNESS TESTER

Pot wall thickness tester DVT's were carried out in B-Cell by scanning pots filled with simulated nonradioactive solidified waste. Results and conclusions from these tests are that:

- Position transducers should not be used in the cell until radiation resistant encoders become available.
- Ultrasonic crystal alignment remains as the most serious problem with the pot wall thickness tester. Experience and tests with the positioning mechanism as designed indicates that a more positive aligning system is required.
- Remoteability of the crystal positioning mechanism is inadequate, largely because of inaccessibility to the adjusting mechanism and the fact that the operation of the device is largely obscured from view.
- The readout system operates satisfactorily.

It was concluded that alternate concepts for pot wall thickness testing should be developed.

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