CONCEPTUAL DESIGN FOR THE HANDLING AND
REMOTE DISASSEMBLY OF THE FUEL ELEMENT
FAILURE PROPAGATION LOOP AT THE HFEF

by

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ABSTRACT

The Hot Fuel Examination Facility (HFEF) was assigned the remote disassembly and examination of the Fuel Element Failure Propagation (FEFP) loops. These loops, containing bundles of fast-reactor fuel elements, will be irradiated in the Engineering Test Reactor to obtain information on failure propagation in this type of fuel. A detailed preliminary plan and procedure have been developed by the HFEF staff for handling, disassembling, and examining the irradiated loops. The concepts developed meet the functional criteria established by the FEFP Project in the System Design Description.

The disassembly and examination will be performed in the HFEF/N main cell, which is large enough to accommodate a loop in the vertical position. The equipment to be added to HFEF/N for the handling of the FEFP loop will include a loop-insertion cell, support structures for the loop and test train, a tube heater, several cutting machines, and many disassembly and examination fixtures.

I. INTRODUCTION

The Hot Fuel Examination Facility (HFEF) has been assigned the remote disassembly and examination of the Fuel Element Failure Propagation (FEFP) loops. These loops, containing bundles of fast-reactor fuel elements, will

be irradiated in the Engineering Test Reactor (ETR) to obtain information on fuel failure propagation. The response of a fuel-element bundle to such malfunctions as release of gas, release of molten fuel, and blockage of coolant flow will be studied. The loop coolant will be sodium. Appendix A describes the FEFP Program, and Appendix B gives a detailed description of the FEFP loops.

The disassembly and examination of the irradiated FEFP loops will be done in the HFEF/N building,* which has an argon-atmosphere hot cell large enough to accommodate a loop in the vertical position. Appendix C gives a detailed description of HFEF/N.

The present report is a conceptual design of the methods and equipment for doing the required work on the FEFP loops in HFEF/N. The concepts developed meet the functional criteria established by the FEFP Project in the System Design Description¹.

II. GENERAL REQUIREMENTS

A. System Functions

The system for handling, disassembling, and examining the FEFP loops in HFEF/N must have the following capabilities:

- (1) Receiving an irradiated loop
- (2) Maintaining the loop sodium in a liquid state
- (3) Remelting the loop sodium if necessary
- (4) Visual examination of the loop exterior
- (5) Disassembly of the loop and examination of the components
- (6) Disassembly and examination of the test train
- (7) Preparation of the fuel elements for examination, storage, and shipment

*The HFEF complex comprises HFEF/N (a new hot-cell facility completed in 1972) and HFEF/S (formerly the Fuel Cycle Facility for Experimental Breeder Reactor II). The N and S stand for north and south.

- (8) Examination of the fuel elements
- (9) Installation and checkout of instrumentation on pre-irradiated fuel elements
- (10) Assembly of test trains with preirradiated fuel elements.

Because of budget and schedule restrictions, the requirements have been separated into two main groups, giving priority to the first. The first group, Phase 1, consists of the capabilities required for handling the first loop.

The second group, Phase X, consists of the possible future capabilities of HFEF/N for future FEFP loops. Several intermediate steps will be needed to reach Phase X. Development of new remote-handling techniques, additional funding, and project justification will be required to achieve these final capabilities.

B. Special Features of Phase-1 (Startup) Functions

(1) The reuse of a loop and test train is not planned for the initial tests. Special equipment to accommodate reuse will not be provided at startup; however the equipment provided at startup should be adaptable to reuse operations by future modifications and additions.

(2) Two methods of loop disassembly will be available at startup. The normal disassembly method will involve removal of the loop top closure and withdrawal of the test train. The loop sodium coolant will be molten for the test train's removal. A second method, available for unusual loop conditions, will involve sectioning of the loop in-pile tube just below the loop's pump, with the sodium frozen.

(3) The test train will be cut into sections during removal from the loop.

(4) Examination of fuel elements will consist of both nondestructive and destructive examinations. The nondestructive examinations may involve diameter profiles, gamma scans, weight and balance-point determinations, and visual inspections. The destructive examinations may include fission-gas sampling, metallography, and analytical sampling. The above examinations are not intended to be an all-inclusive listing. Future documents will delineate the examination requirements.

(5) Shipment of full-length post-test fuel elements for post-test examinations will not be required. Small sections of fuel elements may be shipped elsewhere for final detailed examination.

(6) Collection of a qualitative fission-gas sample from the loop gas plenum is required.

(7) A gross gamma scan of the loop and test train prior to disassembly is desirable but not mandatory. Analyses will be required to see if meaningful test results can be achieved.

(8) HFEF/N will be equipped to receive a loop with its sodium coolant either solid or liquid, provided that the required work on the loop does not violate the HFEF safety and operational procedures.

(9) HFEF/N will be equipped to remelt a loop's sodium coolant.

(10) The loop's experimental fuel elements will not have to be maintained in a vertical attitude either before or after irradiation; i.e., they can be handled horizontally during storage, transfer, and examination.

(11) In HFEF/N an attempt will be made to collect the test-train fuel from the loop for a material balance. Fuel collection procedures are as yet unspecified, and material-balance criteria have not been established. The minimum material balance to be performed will involve an inventory of the fuel remaining in the test train and the fuel collectable from the loop sodium coolant. Actual, achievable fuel-collection limits will be dependent on acceptable procedures and fundings.

(12) Neutron radiography of the test section (fuel bundle) is desirable and can be accomplished if the HFEF/N main cell is equipped with a neutron source.

(13) Neutron radiography of the full length of the individual fuel elements is required.

(14) Neutron radiography of the loop is not required.

(15) Auxiliary cooling is not required during removal of the test train from the loop.

(16) The ETR water-flow shroud will not be attached to the loop when it arrives at HFEF/N.

(17) HFEF/N will be equipped to perform gross examinations of failed loop components. Equipment will be supplied at startup to section the loop into components. Additional examination equipment will be determined as special requirements are developed. Potential component failures that may require examination include deformation of the primary in-pile tube, pump failure, heat-exchanger failure, and instrumentation failure.

(18) After removal from a loop, the test-train fuel can be stored for eight months, after which arrangements must be made with the HFEF staff for its disposal.

(19) HFEF/N will package the loop sodium coolant for storage within the facility. The final disposition of the sodium is presently undetermined.

(20) HFEF/N will dispose of the loop sections and components, using the normal procedures for disposal of radioactive waste.

C. Phase X (Final) Functions

(1) HFEF/N will continue to provide all of the functions listed above for Phase 1.

(2) Loop components will be reclaimed for reuse where possible.

(3) HFEF/N will be equipped to install instrumentation on pre-irradiated fuel elements.

(4) HFEF/N will be equipped to assemble instrumented preirradiated fuel elements into test trains.

(5) Complete loops will be reused if experience indicates that reuse is practical.

(6) HFEF/N will be equipped to remove a full-length test train from a loop. The full-length test trains, which may be reused, are to be maintained in a vertical attitude.

(7) Neutron radiography of the test sections of full-length test trains will be required if the HFEF/N main cell is equipped with a neutron source.

(8) Mixed-oxide fuels will be shipped to reprocessing facilities.

(9) A method will be provided for disposing of contaminated sodium.

(10) HFEF/N will be equipped to provide gas cooling to test sections both before and after irradiation.

(11) An improved method will be developed for disposing of loop components.

D. Summary Description of Phase-1 Equipment

The following equipment will need to be provided in HFEF/N to carry out the Phase-1 work:

- (1) Contamination-control areas and structures
- (2) Support structures for experimental equipment
- (3) Cutting machines
- (4) Tube heater
- (5) Sampling devices
- (6) Disposal systems
- (7) Devices for nondestructive and destructive examinations of fuel elements.

Figure 1 shows the general layout of HFEF/N and the proposed location for the handling system for FEFP loops.

E. Design Restrictions

While providing all the functions listed above for Phase 1 and Phase X, the system will have to comply with the following restrictions:

- (1) The operations shall not chemically deplete or disrupt the argon purification system for the HFEF/N main cell.
- (2) The operations shall not violate the criticality rules for remote facilities.
- (3) The operations shall not violate the operating procedures for remote facilities.
- (4) The HFEF/N equipment shall interface with the loop handling machine.

Fig. 1. Handling System for FEFP Loops in HFEF/N Building

III. PRINCIPLES OF OPERATION

The following section is a brief description of the loop-handling concept for the HFEF/N operations with the FEFP loops. A more detailed description is given in Appendixes D and E.

A. Normal Operations

1. Receiving

The transporter, carrying the loop-handling machine (LHM), will be backed into the HFEF/N truck lock upon arrival from the Engineering Test Reactor. The transporter will be positioned entirely within the building and the truck door closed before the LHM is unloaded. The LHM utilities supplied by the transporter will be switched to building supplies as required. (Figure 23 in Appendix D shows the transporter and LHM.)

The roof hatches of the truck lock will be removed just before transfer of the LHM to the high bay. The high-bay crane will be attached to the LHM while it is in the horizontal position prior to rotation of the LHM to a vertical position by the transporter's lift.

The LHM will be raised to the high bay by the crane and placed in a support fixture. The roof hatches of the truck lock will then be replaced and the transporter moved outside for storage.

2. Preparation of Main Cell

All Phase-1 equipment must be checked out and ready to accept the loop before the first loop is inserted into the main cell.

The shield plug for the loop-transfer penetration must be removed before the first loop is received. The plug will be hoisted into a bag enclosure connected to the top of the loop-insertion cell (LIC) and stored.

3. Loop Insertion

The LHM will be transferred to the roof of the LIC (see Fig. 2).

Fig. 2. Insertion of FEFP Loop in Main Cell

The bottom surface of the LHM will be sealed to the LIC to prevent inleakage of air and outleakage of contamination. The LHM will be attached to a superstructure so that the high-bay crane can be available for other operations.

The LHM loop supports will be retracted, the shield valve opened, and the LIC roof hatch opened before the LHM and the LIC are purged with argon to exclude all air. Upon completion of the argon purge, the LIC bottom hatch will be opened and loop insertion started. A gross gamma scan of the loop may be performed during insertion to determine the approximate fuel dispersion. The loop will be lowered slowly into the cell while the LHM load cells are closely monitored.

The loop will be lowered through the hole in the loop-disassembly machine and into the tube heater, which is supported by the disassembly machine. When the loop reaches the fully inserted position, the LHM grapple will be disengaged.

The LHM grapple will be retracted into the LIC and the LIC bottom hatch closed. The grapple will be checked for contamination and decontaminated as required. Damp rags will be brought into the LIC through the transfer port and the decon operation performed by hand, using the glove ports.

4. Loop Disassembly

As soon as the grapple is released from the loop, in-cell-supplied utilities will be connected to the loop. The tube heater may also be activated at this time and the loop brought to the appropriate temperature.

A gas sample will be collected from the sampling tubes at the closure seal welds (see Fig. 3). Analysis of this gas sample will reveal the effectiveness of the "K" seal in the loop's top closure. The closure seal welds will then be milled away and the seal removed with the use of the grapple-guide-pin holes as lifting points.

A gas sample from the loop plenum will be obtained using conventional fission-gas puncture-and-collection equipment. The gas sample will be obtained from the short sodium-fill line.

The test-train closure will be unbolted and the bolts captured for removal. A grapple will be attached to the test train. The test train will be hoisted to the desired elevation with the LIC hoist or electromechan-

Fig. 3. Top Closure of Loop

ical manipulator and secured by the test-train support-structure clamps. During hoisting, the hoist force applied to the test train will be monitored when possible. Hoist load limits will be established at a later date.

The test train will be cut into two or more sections. The location and number of cuts have not been established. The last cut will be just above the top end of the fuel element in the area of the test train's upper pressure transducers. The top section of the test train removed during the above operation will be placed in storage to await further cutup and possible examination prior to disposal.

The experiment section of the test train will be transferred to a holding fixture with the electromechanical manipulator. This section is composed of the lower part of the test train and a section of the flow divider. The test-train grapple will be removed and a new grapple attached to the experiment section. The experiment section will be pulled out of the flow divider and transferred to a tilting support fixture. The experiment section after being clamped in the fixture will be ready for disassembly and examination.

5. Examination and Disassembly of Test Train

The actual amount of nondestructive (NDT) examination to be performed on the experiment section of the test train has not been fully established by the experimenter. Visual examinations and diameter measurements will probably be the main examinations to be performed before disassembly. Additional examinations may be performed as required.

The tilting support fixture with the experiment section will be lowered to a horizontal position for disassembly. The fixture will be mounted on a milling-machine table, where disassembly will be performed. Appropriate mill cuts will be made to remove the experiment section's hex can. Various clamping fixtures will be provided to assist in the disassembly. Several cutting sequences have been developed for disassembly of failed EBR-II fuel, and these same operations and equipment will be evaluated with the experimenter to determine the best method for the FEFP Project.

The fuel elements will be removed from the experiment section one at a time. Photographs will be obtained during each step of the disassembly. The fuel elements and debris will be collected and placed in appropriate holding

fixtures to await examination.

An alternative method of test-train disassembly will be available for the case where the experiment has not resulted in relocation of the fuel. The test train may be placed in the vertical subassembly dismantler for disassembly in a vertical orientation. The hex can will be cut below the grid piece and pulled off the fuel pins. Clamps will be placed around the fuel pins as they are exposed by the hex can. The fuel-bundle examination and fuel-pin removal will be performed with the test section in the vertical orientation.

6. Fuel-element Examination

Sodium clinging to the fuel elements will be removed prior to the NDT examinations. A rag wipe or soft wire brushing should remove the sodium.

The fuel elements will undergo the normal HFEF complement of NDT examinations, which may include gamma scans, measurements of diametral variances, and neutron radiographs. The actual complement of examinations to be performed has not been specified.

Selected fuel elements will receive a destructive examination. These examinations may include fission-gas sampling and analytical and metallurgical sampling.

7. Sodium Collection

The loop's sodium will be maintained liquid with the assistance of the tube heater after test-train removal. The sodium will be pressurized out of the loop and passed through a vessel containing a series of screens, through a final filter, and into a storage tank. The graded screens will remove the large pieces of fuel at various stages, and the final filter will remove the fine particulates. The method of sodium disposal has not yet been established.

8. Loop Disposal

The first step of loop disposal involves cutting it into pieces small enough to fit into waste cans 11-3/4 in. in ID by 5-1/2 ft long. The

capacity of each can is approximately 250 lb. All sodium and fuel material will be removed from the loop sections prior to their disposal.

The loop secondary vessel will be parted near the top. Upon completion of this first cut the entire primary vessel can be hoisted out of the secondary. During the hoisting, the primary will be cut into manageable sections. The secondary will also be cut into sections following removal of the primary.

The loop pieces will be transferred to the decon cell and loaded into the waste cans. Approximately 40 waste cans will be required for disposal of one loop. The waste cans will be transferred to the storage grounds for disposal.

B. Special or Infrequent Operations

1. Remelting Sodium for Disassembly

The disassembly of a loop with frozen sodium is the same as outlined in Section A.4 above with one exception. The loop will have to be sequentially heated from the top to the bottom. The tube heater will provide the proper zones for the remelting steps. The center of the test train is equipped with a heating element to provide additional heat during the remelting operation.

2. Loop Dissection for Test-train Removal

If it is not possible to remove the test train from the loop in the normal manner, the loop may be cut in half while containing the sodium and test train. The sodium is allowed to freeze. The loop is hoisted to the proper elevation with the LIC hoist and cut in half between the lower end of the ALIP pump and the top of the fuel elements. The in-pile section of the loop is next placed in the tube heater with the open end attached to a sodium catch tank. This section is sequentially heated to remove the sodium.

Upon completion of sodium removal, the in-pile section is transferred to the milling machine, where it is cut open. The test train is

disassembled similarly to the description in Section A.5 above.

The remaining portion of the loop is reinserted into the tube heater after the cut end is sealed. The sodium is remelted and a normal type of disassembly and disposal operation can resume, with the exception that the experiment section of the test train has already been removed.

C. Emergency Operations

1. LHM and LIC Hoists

To provide backup in case of operational failures of the LHM and LIC hoists, each of the hoists will be equipped with a manual override. The manual override permits a component to be lowered to the loop-disassembly machine until normal operation can be resumed.

2. Main-cell Equipment

The emergency operation of main-cell equipment is presented in the HFEF Operating Manual.

IV. DESIGN CRITERIA AND DESCRIPTION FOR REMOTE EQUIPMENT

A. Design Criteria

Given below are the assumptions made and general criteria established for disassembly equipment for FEFP loop:

(1) Argonne National Laboratory drawing No. R-1020-0002-DE-00 was used as a basis for sizing the loop and the various loop components.

(2) The design basis for the loop weight is 5 tons².

(3) The design basis for the weight of the loop-handling machine (LHM) plus loop is 40 tons².

(4) No external cooling of the fueled section of the test train is required once the test train is removed from the loop.

(5) The FEFP loop may be received at HFEF/N with the sodium either molten or frozen.

(6) The reuse of the FEFP loop is not a design requirement; however, major components such as the pump and heat exchanger may be reused.

(7) The loop will not be protected from alpha contamination during disassembly.

(8) The sodium coolant of the FEFP loop shall be recovered to determine fuel-particle-size distribution and fuel-material balance.

(9) The test train shall be removed from the FEFP loop for examination following the removal of the loop's closure seal.

(10) Sectioning of the loop for disposal will be required.

(11) All equipment shall be designed with modular components or assemblies so that in-cell repair or replacement is possible by remote methods.

(12) All equipment shall be designed so that all components or assemblies can be removed from the main cell via the equipment lock (penetration 7.1001), or via the loop-insertion cell. If disassembled components of equipment are placed in the main cell, remote assembly of the equipment shall be required.

(13) Insertion of the loop into the main cell of HFEF/N shall be performed without polluting the main-cell atmosphere and with a minimum of alpha contamination of the loop-handling machine (LHM).

(14) All processes required by loop disassembly shall be compatible with other ongoing work in HFEF/N. This requirement includes the equipment-installation step.

(15) Equipment to take fission-gas samples from the loop and fuel-element plenums will be required.

B. Design Descriptions

Brief descriptions of the function of each major equipment item, along with the preliminary design criteria for each item, are given below.

1. Loop-insertion Cell (LIC).

The LIC is in essence a radiation-shielded, gastight glovebox that is considered an extension of the main cell. It will provide both radiation shielding and atmospheric containment. The inleakage criterion for the LIC has been tentatively set at 0.005 cfm of air at 1 in. WG differential pressure with respect to the high bay. The argon purification system has adequate excess capacity to maintain the desired oxygen concentration of 25 to 50 ppm during loop insertion with this added impurity burden. During normal main-cell operation, the LIC will be isolated from the main cell with a hatch, and air leakage to the main cell will be essentially zero.

Preliminary shielding calculations suggest that administrative control will be required, to limit personnel exposures in the LIC area during loop insertion. The calculations also indicate a LIC shielding-wall thickness equivalent to approximately 3 ft of concrete; hence normal main-cell operations should not require administrative control in the LIC area.

Functionally, the LIC will provide the following:

- (1) A gastight mate-up with the LHM during loop insertion and an enclosure to facilitate handling of loop components.
- (2) Radiation shielding during loop insertion and handling of loop components.
- (3) A hoist of about 5-ton capacity for handling loops and components.
- (4) A glovebox facility to permit repair, activity assay, decontamination, and contamination control of loops and loop-handling equipment.
- (5) A system for removal and replacement of the shield plug for the main-cell penetration.
- (6) A base and superstructure for supporting the 5-ton LHM*.

*The LIC is being designed to support a 50-ton LHM for future FEFP Project requirements. The HFEF/N high-bay crane is being evaluated for potential upgrading to 50-ton capacity.

The design concept for the LIC is shown in Fig. 4. The cell consists of a rectangular gastight glovebox approximately 4 x 6 ft x 4 ft high. Two opposed sides each contain one window and six gloveports. A swinging gastight hatch isolates the LIC from the main-cell penetration. A sliding roof hatch seals the cell from the high-bay atmosphere. A 5-ton hoist contained within the gastight cell is provided for loop and loop-component handling. A load cell provides load monitoring ranging from about 100 to 14,000 lb. A transfer lock permits the introduction of tools, contamination smears, and decontamination agents. The glovebox shielding walls are built on a base approximately 4 ft square; therefore one of the shielding walls is contained within the 4 x 6 ft gastight enclosure. Movable shielding walls are used for the two gloved walls. Additional shielding is needed on the cell roof surrounding the LHM valve. The actual shielding thickness at this place has not been determined, but will meet the main-cell shielding criteria. An I-beam structure capable of supporting the 50-ton LHM and the cell-roof shielding straddles the shielding wall and distributes the load to the main-cell roof. The hoist drive is separated from the remainder of the cell by the shielding wall. Access to the hoist drive is provided by a removable gastight panel. An argon-purge-gas inlet to the cell is provided, with the effluent discharging to the suspect-exhaust system. The sliding roof hatch is sized sufficiently large to permit removal of the shielding plug for the cell-roof penetration.

2. Support Fixtures for Loop and Test Train

The support fixtures for the loop and test train are the primary fixtures used in loop disassembly. The fixtures are shown conceptually in Figs. 5, 6, and 7. The loop-disassembly machine provides support for the loop tube heater, which in turn supports the loop. This disassembly machine must support a load of about 7 tons. The machine also provides for 360° rotation of the loop and a vertical motion of about 3 ft. The rotation speed shall be variable and shall cover the range from 0.1 to 2 rpm. The vertical-motion speed shall cover the range from 1 in./min to 6 in./min. A tool-positioning table is an integral part of the loop-disassembly machine. As presently

Fig. 5. Elevation Section of Loop-disassembly Machine

Fig. 6. Plan Section of Loop-disassembly Machine

Fig. 7. Test-train Support Fixture

envisioned, the table provides support for the cutoff machines and an independent vertical lift of about 1 ft. The loop-disassembly machine shall be positioned in the main cell so that the axis of the rotating support plate coincides with the axis of the pit and penetration 7.1005. Support and locating pins for the machine shall be mounted in the main cell prior to final filling of the cell with argon.

The test-train fixture provides support for the test train during disassembly operations. This fixture provides clamping to the test train at two points. Each clamp can be individually controlled. The vertical design load for the fixture has been tentatively set at 1000 lb. The fixture provides a vertical lift of about 5 ft and a 90° rotation to permit the fixture to be moved clear of the vertical movement of the loop. The rotation speed shall be about 1 rpm and the vertical lift about 1 ft/min.

The control console containing the operating controls for both the loop and test-train support fixtures shall be located near station 9M.

3. Tube Heater

The main function of the tube heater is to maintain the loop sodium molten prior to test-train removal during normal procedures, or to remelt loop sodium if it becomes frozen. The tube heater is shown conceptually in Fig. 8. The heater is approximately 25 ft long and has a diameter of $24\frac{3}{4}$ in. to permit its introduction to and removal from the main cell via the loop penetration. The inner heater wall contains a loop support capable of bearing the entire weight of the loop. Preliminary calculations show that a $\frac{3}{4}$ -in. thickness of insulation will be adequate to maintain an inner-wall temperature of 700°F while maintaining an outer-wall temperature of 200°F . Under these conditions the heat loss to the pit lining will be 5 kW, hence a heater power level in the range of 20-30 kW may be adequate for temperature maintenance and remelting of loop sodium. The heater shall be temperature-zoned to permit a melt zone to travel from the top of the heater to the bottom. The heater shall have the capability of heating the loop sodium to 700°F without depending upon heat generation from within the loop. The temperature of the heater wall and loop sodium and power readouts will be provided at the control console located near station 9M.

Fig. 8. Tube Heater for FEFP Loop

4. Loop-cutting Machines.

The machines under consideration to make the loop-disassembly cuts are commercially available milling cutters, hacksaws, and plasma-jet torches. The milling cutter,* under present evaluation, will be fastened to the loop by a timing chain. The milling head will be driven circumferentially around the loop by means of sprocket and idler wheels that engage the chain. The mill will be positioned by the tool-positioning table while the chain is being tensioned with a torque wrench. A test program is being developed to evaluate this cutting machine for (a) dry versus lubricated cutting, (b) chip collection, and (c) remote operation.

Another machine under evaluation is a portable pipe saw,** which can be clamped to the loop with a chain pipe vise. As with the mill, the saw will be supported by the tool-positioning table until secured by the chain pipe vise. A test program will be developed to include the tests specified for the milling cutter. Tests will also include cutting through loop-mockup test sections containing frozen sodium to evaluate the saw for the special cutting procedures required.

A rapid method of cutting thick-walled pipe is provided by a plasma-jet torch. In a recent demonstration by a vendor, plasma-jet cutting was used on a 20-in.-dia stainless steel pipe having a wall thickness of 1-3/8 in. The demonstration showed that the pipe wall could be easily cut at a rate of about 40 in./min, hence the circumferential cutting of a loop could be completed in about 2 min. The effluent gas and fumes were successfully collected by subjecting the pipe to an air sweep, which exhausted through a filter can filled with Pyrex wool. The bulk of the molten metal removed from the cut was found condensed on the inner wall of the pipe opposite the cut. The torch can be equipped with an expendable torch nozzle*** or can be water-cooled. If water-cooling is chosen, a commercial recirculating heat

*E. Wachs Co., Trav-L-Cutter, Model E Pipe Saw

**E. Wachs Co., Guillotine Pipe Saw, Models C and D

***Mr. S. O'Hara, Thermo Dynamics, private communication

exchanger of about 1-1/2 gal is available. It is expected that this small volume of water will permit the use of the torch within criticality and safety limits. The cutting gas used was nitrogen, supplied at a rate of 125 cfh, hence the nitrogen addition to the cell atmosphere would be about 4 ft³ per cut. Since this is in the range of the normal nitrogen inleakage per day to the cell, it may be a tolerable rate. Because of the many additional cuts required to reduce the loop secondary and primary vessels to manageable pieces for scrap disposal, plasma-jet cutting is undergoing serious evaluation as a loop-cutting technique.

5. Sodium Removal and Analysis

A concept for the removal of sodium and collection of the dispersed fuel is shown in Fig. 9. The analysis consists of filtering the sodium through graded screens to determine the particle-size distribution of fuel dispersed during the fuel-element failure-propagation tests. The loop sodium is transferred through a heated line by pressurizing the loop primary with argon gas. The sodium is screened, passed through a final filter, and collected in a containment tank. The containment tank has provision for core sampling after the sodium is allowed to freeze. The containment tank can be used to remelt the sodium prior to transferring the sodium to waste-disposal cans. Operating controls and instrument readout will be mounted on the control console located near station 9M.

6. Fission-gas-sampling System

The sampling system shall permit the sampling of loop gas by drilling into the appropriate gas-sample tube. The samples required are (a) the gas above the test-train closure, (b) the gas in the loop plenum, and (c) the gas in the fuel-element plenum.

7. Control Console and Feedthrus

Much of the equipment for FEFP loop disassembly will operate

Fig. 9. System for Removal of Sodium and Collection of Dis

with electric or pneumatic actuators. A great many position, temperature, force, and speed readouts are required. The control console is located at station 9M.

The specific equipment that will be operated from the control panel will include the loop-disassembly machine, LIC hoist, test-train support fixture, sodium-removal system, fission-gas-sampling system (drill fixture), tube heater, power supply for loop pump and heater, power supply for mill and saw, and plasma-jet torch. Electrical feedthrus are required for all equipment except the LIC hoist. Pneumatic feedthrus through the cell floor to the service floor are located near the work station for the loop.

8. Auxiliary Systems, Fixtures, and Tools

In addition to the major equipment items listed above, many auxiliary pieces of equipment, fixtures, and tools are required. The main categories of auxiliaries anticipated at this time are listed below. A more detailed listing will be developed as the design progresses.

<u>No.</u>	<u>Description</u>	<u>Function</u>
1	Preparation of workstation in main cell	Provide the pit liner, wall mounts, and floor anchors re- quired prior to installation of major equipment and before the final argon fill of the main cell.
2	Loop gamma-scanning system	Determine the distribution of the irradiated fuel within the loop prior to disassembly.
3	Tool for disengaging LHM grapple	Disengage grapple once loop is in the main cell.
4	Seal-weld cutter	Remove the two welds in the seal above the test-train closure.

<u>No.</u>	<u>Description</u>	<u>Function</u>
5	Tool for removal of steel scrap	Remove the scrap resulting from cutting of the closure seal welds.
6	Wrench for test-train flange	Capture and remove the bolts holding the test train to the loop primary vessel.
7	Grapple for test-train flange	Permit the attachment of the LIC hoist to the test-train flange.
8	Fixture for small hacksaw	Support the small hacksaw in the cutting position on the tool-positioning table.
9	Fixture for travelling mill	Support the mill on the loop in the cutting position.
10	Fixture for large hacksaw	Support the large hacksaw in the cutting position.
11	Argon supply for travelling mill	Provide the motive power to drive the mill. About 100 cfm at 90 psig is required.
12	Chip and fume collector	Collect the effluent from cutting operations.
13	Grapple for small scrap	Handle tubes of the following sizes: Primary - 4.345 and 5.550 in. OD Secondary - 5.25 and 5.45 in. OD
14	Grapple for large scrap	Handle the following: (a) 13-in.-dia primary flange (b) 19-in.-dia secondary shell (c) 18-in.-dia secondary shell
15	Support collar for pump	Attach and support the lower plenum of heat exchanger.
16	Support collar for secondary vessel	Attach and support loop secondary vessel

<u>No.</u>	<u>Description</u>	<u>Function</u>
17	Fixture for test-train mil-ling machine	Provide sequential dismantling of the test train to its elements.
18	Fixtures for fuel-element storage	Store fuel elements and pieces of elements.
19	Fixture for fuel-element neutron radiography	Support the fuel elements during neutron radiography.
20	Fuel-element transfer cask	Transfer fuel elements to TREAT for neutron radiography.
21	Fuel-element sodium-removal system	Remove sodium from fuel elements without affecting test results.
22	Cable-cutting tools	Cut loop power and instrument leads.
23	LHM auxiliaries	Provide pump and heater power to the LHM during transit in HFEF/N. Provide a support pad for storage of the LHM in the high-bay area (omit if LIC support pad can be used for storage).
24	Waste-disposal containers	Provide burial cans for loop scrap.
25	Storage and transfer containers	Provide cans to store loop components and scrap prior to disposal.
26	Tool-storage bench	Provide for storage of tools and fixtures.

V. SAFETY PRECAUTIONS

The principal hazards that must be anticipated during handling of the FEFP loop are discussed below. These will be controlled by comprehensive and thorough design and administrative procedures. A brief description of HFEF emergency control is also provided below.

A. Criticality

Criticality hazard controls, similar to those presently in force at the HFEF complex, will be developed for the FEFP loop. The effects of fuels different from those currently being handled in the HFEF complex will be evaluated. Geometrically safe configurations, physical barriers, and poisons will be employed where applicable, and administrative controls will be rigorously exercised.

High-level-radiation detectors with distinctive alarms are provided to warn personnel when necessary to evacuate the premises.

Criticality hazard controls will be detailed in the HFEF Operating Manual as they are developed.

B. Radiation

Irradiated materials emitting intense beta and gamma radiation are routinely handled in the HFEF complex. Radiation exposure of operating personnel is held within recommended limits by the following:

- (1) Provision of adequate shielding in every direction from all in-cell positions of the radioactive sources
- (2) Administrative control of personnel access to areas with high background radiation (such as the repair areas)
- (3) Provision of extensive remote-repair capabilities to minimize the need for contact maintenance of contaminated equipment
- (4) Provision of efficient means for decontaminating equipment that must be serviced by contact.

C. Contamination

Much of the fuel material handled in the cells is expected to contain high concentrations of hazardous isotopes, including plutonium. The biological hazard of these materials is very high, and tolerances for personnel exposure are extremely small. Accordingly, a very high degree of containment of particulate material must be maintained.

Much of the fissile material has received considerable burnup and is intensely beta-gamma radioactive. However, in fuels that have not received intense irradiation, the readily detected beta-gamma radioactivity may not be sufficient to act as a "tag" for the plutonium under all conditions. As a result, alpha monitors are required as well as sensitive beta-gamma monitors.

D. Fire

The building is provided with a fire-alarm system consistent with those of other buildings in the EBR-II area. A sprinkler system is provided in most of the areas where there will normally be no radioactive contamination. Other appropriate fire-fighting equipment is strategically located through the facility.

At the HFEF complex, the fire hazard involved in handling materials that are wet with sodium, or have been contaminated by sodium, is reduced to a minimum by exposing the materials only to an argon atmosphere. Areas in which sodium-bearing items are handled in an air atmosphere are equipped with smoke detectors connected to an alarm system.

E. Emergency Control

Certain building equipment would require control if the building were inaccessible because of fire, explosion, or release of contamination. Control of this equipment would limit damage to property and could aid in the rescue of personnel who were incapacitated within the building.

Such equipment, including equipment for site communications, ventilation, and area radiation monitoring, is controlled from the HFEF/N operations office. The operations office is provided with an outside entry to permit direct access for emergency-control personnel. Emergency procedures are included in the HFEF Operating Manual.

During a normal power outage, electrical power is provided to vital equipment by an emergency diesel generator.

VI. MAINTENANCE

To assist in achieving and maintaining the highest practicable operating efficiency and reliability, the following criteria have been established.

A. Quality Assurance and Control

A thorough quality assurance program will be enforced during design, manufacture, and installation of loop-handling equipment. All designs and all items of procurement will be critically judged for probable reliability and endurance. Proven equipment with an established reputation for reliability will be selected whenever possible. The EBR-II Policy and Procedure Manual and the FEFP Project Quality Assurance Program document have been prepared by others and issued as separate documents.^{3,4}

B. Preventive Maintenance

Provisions will be made for regular preventive maintenance of loop equipment and facilities as required. A preventive maintenance program will be outlined in the appropriate operating manuals.

C. Repairs

Since equipment failures will occur in spite of the most comprehensive maintenance program, all in-cell equipment is either designed for practical remote repair or designed with modular components. Modular components can be readily removed using the in-cell material-handling system, decontaminated, and repaired by contact methods.

In-cell repair will be performed where possible. The decon cell, repair area, and material-handling equipment are arranged for effective support of contact maintenance procedures.

Repair and maintenance instructions will be maintained in up-to-date and readily available form. Frequency-of-repair records will also be main-

tained, and these will be periodically analyzed for early recognition of recurrent problems.

APPENDIX A

Description of Fuel Element Failure Propagation Program

1 Program Definition

The Fuel Element Failure Propagation (FEFP) Program is a research project at ANL, in which ANL, in consultation with other AEC contractors, is studying the propagation of fuel-element failures under normal and near-normal operating conditions in liquid metal fast breeder reactors.^{5,6,7,8,9}

The principal objectives of the program are

- . To investigate the consequences of local malfunctions within at LMFBR core
- . To establish the circumstances under which such malfunctions could cause failure propagation and thus involve a larger segment of the core
- . To investigate methods for detection of and protection against the phenomena that could cause failure propagation.

Both experimental and analytical studies are being made to investigate the thresholds of reactor operation that cause failures to propagate, the modes of failure transport, and the consequences of failure propagation. Instrumented loops simulating near-normal operating conditions will be used to investigate the modes of failure and the subsequent events that determine the type of failure that will propagate to neighboring fuel elements.

The FEFP loops are envisioned to be major LMFBR safety-test vehicles capable of accommodating a wide range of tests, including tests of loss-of-flow effects, potential failure propagation due to inherent pin failure, and operation with failed fuel. Once developed, the loop system will be used effectively not only by ANL but by other AEC contractors as well. Consequently, there has been a conscious effort to build as much flexibility into the loop system as is consistent with cost and schedule considerations.

Much of the detailed planning for these experiments is based on considerations directly related to the Fast Flux Test Facility (FFTF),* including

*Although the reactor portion of the FFTF is often referred to as the FIR, the designation FFTF is used throughout this report for consistency.

core geometry, nominal operating conditions, postulated accidents, and specific steps in accident sequences for that reactor. The experimental results should therefore be applicable to the support of FFTF safety analyses. From a more general viewpoint, the test conditions, the design of test assemblies, and the instrumentation are selected so as to provide significant checks on, and data for, analytical models of the postulated accidents and associated phenomenological events.

2. Description of Test Program*

A proposed set of reference in-pile experiments for the FEFP Program is described herein. This set is representative of the first series of experiments that are to be run in the FEFP loops. The reference experiments serve the following three general purposes: (a) to act as a starting point for the development of an experimental plan in support of design and startup of the FFTF, (b) to provide a basis for the design of the FEFP loops and, (c) to establish a plan consistent with the safety analysis for the FEFP loop.¹¹ It is expected that the experiments will be revised before they are actually conducted. However, the philosophy of experimentation is expected to remain constant in spite of possible changes in experimental order, types of fuel elements used, methods of initiating failure, and severity of test conditions.

The philosophy adopted is that the design of each experiment builds upon the knowledge gained from the totality of preceding tests. Hence, the first series of experiments are planned to be conservative with respect to risk; they will not approach the design conditions for the loop. These conditions will be approached in succeeding experiments only when the necessary knowledge is gained that allows more accurate estimation of the results expected in each test.

In addition to the general purposes cited above, the reference experiments are designed to supplement information derived from TREAT tests. In

*Abstracted from Ref. 10.

particular, they are directed toward improved understanding and eventual resolution of key uncertainties in possible single-subassembly accidents in the FFTF. The results will form a base for an initial assessment of related assumptions and analyses, made in support of the design and operation of FFTF from the standpoint of safety.

During the initial period, a total of ten experiments of three different types will be conducted. These types are

- (1) Gas release that simulates the effects of fission-gas release from fuel elements due to a cladding failure
- (2) Molten-fuel release that simulates the effects of the release of small amounts of molten fuel from within fuel elements
- (3) Loss-of-coolant test to determine the effects of large and complete coolant-flow blockages.

The individual experimental objectives are described below and are summarized in Table I.

Experiment 1.

The purpose of experiment 1 includes the following:

- (a) To conduct comprehensive, in-pile checks of the FEFP loop, test assembly, and instrumentation,
- (b) To demonstrate the interface between the loop and the Engineering Test Reactor (ETR) during insertion, operation, and removal, including the use of the loop-handling machine,
- (c) To demonstrate the insertion, operation, removal, and disassembly of the test assembly,
- (d) To check out the instrumentation response and control-system capability, and
- (e) To perform several tests with simulated fission-gas release.

The loop used for experiment 1 will be the first FEFP loop to be actually operated in the ETR and thus the first time the complete loop system will be tested in the reactor. For example, individual tubes in the heat exchanger may have been tested, but the entire heat-exchanger system will be operated

TABLE 1. SUMMARY OF IN-PILE EXPERIMENTS^a

<u>Number</u>	<u>Fiscal</u> ^b <u>Year</u>	<u>Title</u>	<u>Objectives</u>	<u>Number</u> <u>of</u> <u>Elements</u>	<u>Average</u> <u>kW/ft</u>	<u>Total Loop</u> <u>Power, kW</u>
1	73	Checkout and Gas Release	Loop checkout and effects of worse-case gas releases	19	up to 13.1	up to 1019
2	74	Molten Fuel Release	Effects of release of a small amount of molten fuel	19	up to 13.1	up to 1019
3	74	Loss of Flow: Flow Coastdown	Characterization of expulsion and reentry of coolant and fuel movement for loss of flow	7/19	10.9	893
4	74	Small Flow Blockage	Effects of release of a small amount of molten fuel	19	13.1	1010
5	74	Total Blockage of Single Subassembly	Characterization of expulsion and reentry of coolant for assembly blockage and energy release interaction of molten fuel with coolant	7/19	10.9	893
6	75	Loss of Flow: Pipe Rupture or Flow Coastdown	Characterization of expulsion and reentry of coolant and fuel movement for loss of flow	7/19 ^c	10.9	893
7	75	Gas Release: Preirradiated	Effects of gas release	37 short preirradiated	15.0	896
8	75	Small Flow Blockage: Preirradiated	Effects of release of a small amount of molten fuel	37 short preirradiated	15.0	896
9	75	Melt-through Total Blockage: Preirradiated	Ability of duct to resist melt-through	19/37 short preirradiated	15.0	896
10	76	Total Blockage of Single Subassembly ^d	Characterization of expulsion and reentry of coolant for assembly blockage and energy release from interaction of molten fuel with coolant	19 (or 37 short)	13.1	1019

^aFirst six experiments agreed to by HEDL and RDT.

^bBased on four experiments per year.

^cIf flow coastdown is simulated, flow may be reduced on all 19 pins.

^dDesign-basis experiment for Safety Analysis Report for FEFP loop.

for the first time during this experiment. This first experiment will also establish the operating characteristics for components such as the pump, test section, and instrumentation and control systems under in-pile conditions. Although every experiment will contain a pretest loop-check-out and evaluation phase as part of its normal operating procedure, this first experiment is designed to provide the comprehensive loop-performance information required for all future experiments.

In addition, this will be the first time an irradiated FEFP loop is discharged from the ETR. To aid in removal, shipping, and disassembly operations, all tests in this initial experiment will be performed in such manner that a minimum of fuel and fission products are dispersed throughout the loop. Consistent with this philosophy are the gas-release failure-propagation studies planned for this first experiment.

The gas-release tests, the second phase of experiment 1, are designed primarily to determine fuel-element failure thresholds, mode of fuel-element failure, and the possibility of fuel-element failure propagation caused by the release of fission gas into an FFTF-type geometry. In addition, these experiments will allow the loop response to be studied under two-phase coolant-flow conditions. The two-phase flow data obtained from these low-safety-risk gas-release tests will be used to predict loop performance during later experiments where sodium voiding is expected.

Experiment 2.

The purpose of this experiment is to study the effects of the release of a small amount of molten fuel from a failed element. It is designed to observe the associated effects occurring over several minutes in a cluster of fuel elements; in particular, to determine whether fuel-element failure propagation occurs. Based upon calculations, out-of-pile tests, and results of the TREAT capsule and Mark-II fuel-failure tests, it is expected that this experiment will demonstrate that only limited failure of adjacent pins will occur.

Experiment 3.

The purpose of this experiment is to determine fuel and coolant response to a loss-of-flow accident caused by a loss of power to coolant pumps. Fuel movement and coolant dynamics, including coolant expulsion from and reentry to the fuel region, will be studied. The resulting interaction between molten fuel and coolant can be examined and loads on the shroud determined.

Experiment 4.

This experiment will examine a partial blockage in the core region large enough to cause local boiling and fuel-element failure. The failure will be severe enough to release both fission gas and fuel (solid or molten fuel or both). The effects of the fuel-element failure on the surrounding fuel elements will be determined.

Experiment 5.

The purpose of this experiment is to determine fuel and coolant response to a loss-of-flow accident caused by the total blockage of the inlet of a single subassembly. It is designed to characterize the expulsion and reentry of the coolant, to measure the energy release from the interaction between molten fuel and coolant, and to gain insight into fuel movement and deposition.

Experiment 6.

This experiment has a purpose similar to that of experiment 3 and will be conducted in a very similar manner, except that the transient flow conditions in the test section will be modeled to simulate a pipe rupture in the FFTF. (It is also possible that because of the importance of the pump coastdown to the FFTF, experiment 3 will be repeated, even to using 19 instead of 7 fuel elements.)

Experiment 7.

The purpose of this experiment is to study the effects of a severe failure of a fuel element. It is designed to determine the effects caused by the rapid release of fission gas, probably accompanied by ejection of solid fuel. It will assess the potential of the shock pressures and other occurrences to propagate failure through a test assembly that has been irradiated to an end-of-life condition. Immediate propagation of failure may not occur, and so a contingent final purpose will be to determine the effects of continued power operation with one or more failed fuel elements. The purpose of this test might be to confirm the results of experiment 1 with preirradiated fuel, should test results and analyses warrant the need. If experiment 1 and out-of-pile experiments indicate that no further gas-release experimental work is warranted, experiment 8 will be performed at the time experiment 7 is scheduled, and a loss-of-flow experiment using preirradiated fuel will be designed to replace the cancelled experiment.

Experiment 8.

The purpose of this experiment is to study the effects of the release of a small amount of molten fuel from a failed element. It is designed to determine whether fuel-element failure propagation occurs when fuel is in an end-of-life condition and to observe associated long-term effects of continued operation in the event rapid propagation does not occur.

Experiment 9.

The purpose of this experiment is to determine the ability of a subassembly duct to contain the molten fuel resulting from a total flow blockage. This experiment is a continuation of experiment 5, but the effects of an interaction between molten fuel and coolant and the effects of molten-fuel movement on a subassembly duct wall will be investigated. Of particular interest is the ability of molten fuel to penetrate into and cause failure propagation in an adjacent unblocked subassembly.

Experiment 10.

The purpose of this experiment is to improve the simulation of a total subassembly blockage performed in experiment 5, by blocking a 19-fuel-element bundle instead of a 7-fuel-element bundle. The experiment is the most severe experiment possible with loops of the initial design. It is intended to characterize the expulsion and reentry of the coolant, to measure the energy released from an interaction between molten fuel and coolant, and to gain insight into fuel movement and deposition. The experiment may block a 37-fuel-element bundle of half-length fuel elements, depending upon which case is the most severe. This experiment is the design-basis experiment for preparation of the Safety Analysis Report.

APPENDIX B

Description of FEFP Loop*

1. General Description

The loop design basis, conforming to the program definition, is to construct the FEFP loop as strong as is practical, consistent with the ETR environment, the cost limitations, and the basic performance requirements for the testing of fuels in the LMFBR-like environment. The total capability limits of the loop are then defined and each experiment is planned so that these limits bound the possible test results. If certain experiments require higher performance limits, the loop will be modified to increase its capabilities. To meet the overall requirements, a packaged concentric loop was selected (see Fig. 10).

The loop meets the ETR double-containment criterion by suspending the fuel and instrumentation bundles within two concentric independent pressure tubes. Test fuel elements and instrumentation packages are inserted and removed from the containment vessel via a top closure that extends outside the reactor. The sodium coolant is charged into the loop prior to its insertion in the reactor.

As shown in Fig. 11, the sodium, starting from the upper plenum, flows down through the heat exchanger, through the pump, and along the outside of the flow divider to the bottom of the loop. It then reverses direction and flows up through the fuel bundle and the bypass, through the inner hole in the pump core and the center tube of the heat exchanger, and returns to the upper plenum.

The loop dimensions are as follows:

Loop length	-- 27 ft
Loop diameter	-- 5-1/4 in. to 19 in.
Loop weight	-- 9000 lb
Sodium volume	-- approximately 30 gal
Test-train length	-- 26 ft, sized to accept 61 FFTF fuel elements

*Abstracted from Ref. 1

Fig. 10. Cutaway Isometric Drawing of FEFP Loop

Fig. 11. Vertical Section of FEFP Loop (Diameter Exaggerated)
Showing Path of Sodium Flow

Note: The loop description that follows will not call out details such as connector type or component manufacturer. Loop design drawings will be consulted during design of the equipment for handling the FEFP loop in HFEF/N.

2. In-pile Tube

The in-pile-tube section is made up of a number of concentric tubes, as shown in Fig. 12. Space is provided for a test train that may contain up to 61 FFTF-type fuel elements. In-pile-tube materials are generally type 316 stainless steel, with the exception of the neutron filters.

The in-pile-tube section is capable of accommodating two neutron filters. The major filter is a layer of cadmium, bonded to the exterior of the secondary vessel and clad with type 316 stainless steel. A second filter that may or may not be used, depending upon the experiment, is a layer of borated stainless steel attached to the flow divider.

The bulk of the loop's sodium coolant flows down between the primary vessel and the flow divider, makes a 180° bend, and proceeds up through the test section. Calibrated amounts of the sodium coolant will flow up between the test-section hexagonal can and the flow divider. This flow will be set at various amounts depending upon test conditions.

The in-pile-tube section is 10 ft long up to the pump inlet. It has a diameter of 5.45 in. without the in-reactor flow shroud.

3. Pump

The configuration of the concentric, counterflow loop requires the sodium pump to be of the annular linear induction (ALIP) type, using a counterflow geometry.

The sodium-pump stator is located in the annulus between the primary and secondary vessels, in close thermal contact with the inner wall of the secondary vessel, and thermally insulated from the outer wall of the primary vessel. The pump core is outside the flow divider, and, with the inner wall of the primary vessel, defines the annulus of the induction pump.

The flow of sodium is in the downward direction between the pump core

Fig. 12. Full-size Cross Section of Test Section of FEFP Loop

and the primary vessel, with the return flow of sodium upward from the test section through the hollow pump core and within the flow divider to the loop plenum. The sodium passes downward through the heat exchanger, and is cooled before entering the pump annulus.

The outer diameter of the ALIP stator is fixed by the 16-1/4 in. ID of the secondary vessel. The maximum OD allowed for the pump section is 18 in., including the secondary vessel.

4. Heat Exchanger

The heat exchanger is located between the ALIP and the top closure. It is a tube-and-shell design.

Sodium flows upward through the 3-5/8-in.-dia central tube to the loop's top plenum. There the sodium flow direction is reversed and the hot sodium enters the heat-exchanger upper plenum. The flow is distributed at the upper tube sheet to a parallel array of 108 tubes. The tubes have a 3/4-in. ID and a 0.049-in. wall. The lower 18 in. of the tube bundle is spiralled to provide for differential expansion between the heavy center tube and the smaller heat-transfer tubes. The center tube is insulated from the hot sodium flow to reduce the differential expansion. The sodium leaves the tubes and enters the heat-exchanger lower plenum before passing downward to the pump.

Secondary helium coolant enters the annular space between the helium flow divider and the helium containment jacket near the top of the loop. The jacket is designed to contain the high-pressure helium, providing double containment for the gas. The cold helium passes inside the jacket and down the heat exchanger to the region of the lower plenum, where it reverses direction and flows upward on the shell side of the heat exchanger, counter-current to the sodium-flow direction. Baffles are provided to direct the helium flow across the tubes at each baffled section. The helium leaves the heat exchanger through the annulus between the upper sodium plenum and the helium flow divider. A double-walled helium-flow separator is required to prevent regenerative heating of the inlet helium by the hot effluent helium. The helium side of the heat exchanger is provided with heaters rated at 30 kW.

The heaters will keep the loop's sodium molten during periods when the reactor is not operating.

5. Top Closure

When the FEFP loop is installed in the ETR, the top end of the loop will extend above the ETR top dome so that none of the loop-access penetrations need pass through reactor water, but rather are directly accessible (see Fig. 3). The loop's maximum OD of 19 in. extends from the top end of the secondary vessel down to a point below the heat exchanger. There is a sealing surface at the top of this cylinder on which a double-flanged seal ring is attached, providing a means for sealing the gap between the ETR top and the loop. A 10-in. Schedule-80 pipe nozzle penetrates the center region of the top of the secondary vessel. Helium is supplied to the heat exchanger and is removed via two concentric flow annuli inside this nozzle.

The primary-vessel closure (test-train closure) consists of a 7-in.-OD bolted flange cap through which the test-train instrument cables pass. Above this closure, a light-gauge metal sleeve encloses a space where the instrument cables are terminated, and heavier, flexible wires are connected to a multipin connector at the top of the sleeve. The connector face is flush with the nozzle flange. Two 1/2-in.-OD tubes penetrate the test-train closure, as well as a smaller pressurizing tube with 3/16-in. OD and 1/16-in. ID. The larger tubes provide access to the primary vessel for sodium filling and circulating operations prior to a test. All three tubes are welded closed at a point slightly above the helium-pipe nozzle flange, outside the diameter of the multipin connector. A flow divider for the helium terminates at a mating surface in the helium annulus below the test-train closure. The removable helium-manifold assembly has a helium-flow-divider sleeve that mates with the loop flow divider.

The bolted test-train closure is sealed to the top of the primary vessel by means of a metal "K" seal. The closure is held in place by eight 5/8-in. high-strength-alloy bolts designed for 1100°F. The holes in the closure have internal threads so that lifting studs can be installed for handling the test train before and during installation. A ring is welded into place over

the bolts as the final seal weld. This ring serves as a gas barrier to back up the "K" seal and the tubing-closure welds.

Quick-disconnect electrical connectors are arranged around the helium nozzle to provide for all loop instrumentation as well as pump-power and heater-power connections. Three tubing quick-disconnects provide means for utilizing a gas purge to monitor the annular space between the primary and secondary vessels.

6. Loop-annulus Gas Purge

The loop is equipped with internal tubing in the space between the primary and secondary vessels so that the gas is supplied at the bottom of the primary vessel. Two vent tubes are installed to sample the annulus gas. One is at a point near the bottom of the ALIP and the other near the top of the heat exchanger.

From the quick-disconnects connecting the vent tubes to the monitoring system, small-diameter tubing is routed past a gamma detector (a Geiger tube, well shielded from background). Both lines are monitored simultaneously. Each line is then routed to a moisture analyzer to check water content, and to a sodium detector (flame spectrophotometer) connected in parallel with the moisture analyzer. Each detector is equipped with gas-flow-control and pressure-control regulators; gas from the monitors is vented to the ETR stack. Alarm points on the monitors are set to alert operators when limits are exceeded.

7. Test Train

The test train consists of a fuel-element bundle, instrument sensors, failure-mechanism device, double seal plug, and structural members that support the fuel bundle, sensors, and special devices. Instrument sensors are provided to measure sodium flow, pressure, and temperature. The test train is inserted in the FEFP loop at the filling, storage, and repair facility near the Engineering Test Reactor.

The test train is 26 ft long and is surrounded by a 3-1/16-in.-ID flow

divider. A typical test train, containing 19 FFTF fuel elements and weighing approximately 400 lb, is shown in Fig. 13.

The fuel elements have an OD of 0.23 in., a total length of 93.8 in., an active-fuel-section length of 36 in., and a cladding thickness of 0.015 in.

The elements are spaced with 0.056-in.-dia spiral-wrapped thermo-couple cable. Seven of the 19 elements contain eddy-current-type pressure transducers to measure fission-gas plenum pressure. The fuel bundle is enclosed in an insulated hex can. Sodium enters the fuel bundle through a permanent-magnet-type flow-through flowsensor, passes through the active section of the fuel bundle, and exits through an eddy-current probe-type flowsensor. Twenty-four thermocouples and 20 pressure transducers are located throughout the active fuel region. The number of instruments may be varied, but the total number of instrument cables cannot exceed 63 nor the instrument leads exceed 139.

Some sodium bypasses the fuel bundle and recombines with the fuel-bundle coolant above the exit flowmeter. The combined flow then passes another probe-type flowsensor and travels upward to the loop's top plenum. After flowing downward through the heat-exchanger tubes and pump annulus, the sodium travels down the outside of the flow divider, makes a 180° turn, and reenters the test train.

The flow divider separates sodium downflow from sodium upflow. It can be designed to reduce regenerative heat transfer in the opposing flow streams. The flow divider is constructed in sections with each section having a different design configuration. In the section surrounding the fuel bundle, the flow divider may be constructed with laminated tubing and wire screen, to provide thermal insulation. An insulated flow divider may not be required within the heat-exchanger region. The loop-top-plenum region of the flow divider will contain slots and baffles to direct the flow into the plenum. A wire-screen debris collector may be located in this section.

It is possible to locate three fuel-meltdown cups at the bottom of the loop. The innermost cup would be 2-1/2 in. in diameter and 5 in. long.

The first several experiments will be performed with 19 fuel elements. The loop and test train are designed to also accommodate bundles of 37 and 61 fuel elements.

Fig. 13. Typical Test 1

8. Loop-sodium Filling, Storage, and Remelting

An FEFP loop is filled with sodium after the test-train assembly is bolted in and the loop preheated. Two 1/2-in.-dia tubes are provided on the top of the test train for this purpose. A sodium-charging facility has been built to circulate and purify sodium when connected to a loop. Flanged connections are made between a new loop and the charging facility. Clean sodium is pumped into the FEFP loop until the loop is completely filled and all gas has been vented out of the upper plenum. The ALIP is turned on at low power to establish circulation in the loop. Sodium circulation is established through the charging-facility connections, and the purification system is used to reduce sodium oxides to < 10 ppm. Loop temperature is increased while sodium purification continues, ultimately reaching 900°F with a sodium oxide content of < 10 ppm. The loop cover gas (argon) is introduced through a smaller tube while the sodium is siphoned down to the level of the lower fill tube. The sodium tubes are blown clear with argon and are then cut by hand through ports on a glovebox around the top of the loop. Plugs are TIG-welded into the tubes, and the cover-gas line pressure is adjusted to a predetermined value. This line is then crimped, cut, and welded, accomplishing the final loop-closure seal. After isothermal check-outs, and after the secondary containment is installed, a cover is welded over the test-train closure bolts and sodium-fill tubes to provide a backup seal. The loop is now ready for transport for storage.

A vertical, shielded, electrically heated cylindrical heater will be used to remelt the sodium in a loop that has been inadvertently allowed to freeze. This tube heater will be constructed with five or six separately controlled zones so that the loop can be heated sequentially downward from the top sodium free surface. The entire loop will be preheated to about 175°F uniformly, then the top zone raised to approximately 225°F . The second zone will be raised to 225°F when it is apparent that the first zone is molten, by means of thermocouples on the loop and test train. In the above manner, each zone will be melted until the entire loop has been melted. The ALIP will be powered and circulation established.

APPENDIX C

Description of Hot Fuel Examination Facility

1. General Description

The Hot Fuel Examination Facility (HFEF) is a hot-cell complex designed and operated for the Atomic Energy Commission by Argonne National Laboratory. This complex is located in Idaho at the EBR-II site of the National Reactor Testing Station.^{12, 13}

The HFEF complex is composed of heavily shielded cells, nonshielded laboratories, support areas, and special equipment, which are housed in two separate buildings. The HFEF is capable of handling and examining highly radioactive and toxic reactor materials.

Generally, the materials examined in the HFEF complex will have been irradiated in the EBR-II reactor to support fuel and structural-material development in the Liquid Metal Fast Breeder Reactor (LMFBR) Program. In support of LMFBR safety programs, the HFEF will accommodate equipment for preparing test specimens and will provide for examining loop experiments that have been irradiated in the Transient Reactor Test Facility (TREAT), the Engineering Test Reactor (ETR), and the Power Burst Facility (PBF). Irradiations from other programs and facilities may be similarly accommodated.

For versatility and efficiency, the basic functions of the HFEF complex are grouped in two separate buildings designated HFEF/S and HFEF/N. Each building contains two hot cells. HFEF/S has the argon cell and air cell, while HFEF/N has the main cell and decon cell. HFEF/N and its relationship to the FEF Project are discussed in this appendix.

The two adjacent, shielded cells of HFEF/N--the main cell and the decon cell--are enclosed within a three-story building, as shown in Figs. 14, 15, 16, and 17. Offices, laboratories, and other personnel-related areas are located on the operating floor, which is slightly above grade level. A truck lock is located at the west end of the cell complex at this level. The service floor below contains the subcell tunnels and most of the building equipment. The second floor contains additional building equipment, lab-

Fig. 14. Elevation Section of the Portion of HFEF/N Main Cell Used in Handling FEFP Loops

Fig. 15. Elevation Sections of HFEF/N

Fig. 16. Plan of Operating Floor of HFEF/N

Fig. 17. Elevation Section of Main and Decon Cells

oratories, and space for the in-cell utility service equipment.

A high-bay area, which covers the entire cell complex and is served by a 40-ton* bridge crane, provides access to the tops of the cells for bottom-opening casks. The high-bay area also has an enclosed repair area consisting of repair rooms, change room, and access room. The high-bay area includes space for clean-equipment repair and mockup and for cask storage. Also included is space for the future installation of high-resolution neutron-radiography equipment or low-level examination cells.

The design of HFEF/N incorporates features that will enhance the adaptability to future programs. Examination, general-purpose handling, and service equipment can be changed remotely or supplemented without major interruptions of the operations in progress. This feature will make it practical to update equipment as the technology develops. The facility also includes built-in expansion capabilities in the form of unequipped work stations, which can be activated with only temporary interruption of normal operations.

2. Configuration of Main Cell

The heart of the facility is the main cell, where most examinations are carried out. The cell is 30 x 70 ft x 25 ft high inside. A removable steel floor provides access to a subcell space 8 ft deep x 30 x 50 ft. The space beneath the removable floor is used for shielded storage of radioactive samples, storage of equipment, and inert-gas return ducts and filters, and also provides additional space for vertical handling of long items. Two work stations have 3-ft-dia steel-lined pits extending 30 ft below the level of the removable floor for vertical positioning of long loops.

The walls of the main cell are 48-in.-thick, 3.5-sp-gr concrete (220 lb/ft³) up to a height of about 14 ft above the operating floor. The cell walls above this height and the cell roof are 48-in.-thick, 2.3-sp-gr concrete (147 lb/ft³). The walls are lined with a gastight steel liner

*The crane is being evaluated for potential upgrading to 50-ton capacity.

capable of containing a high-purity argon atmosphere. The cell penetrations into the cell are also steel lined and welded to the cell liner. Closures or inserts for these penetration liners are gastight or have double seals with the space between the seals pressurized with fresh argon.

The main cell has 15 workstations, each 10 ft wide, and each of which can be equipped with a pair of manipulators, a shielding window, lighting, a utility-distribution system, examination equipment, and suitable work tables. A few workstations are equipped with specific-purpose ports for periscopes, stereomicroscopes, and gamma-scanning equipment. Workstations that are not provided with examination equipment at startup are provided only with sealed and plugged ports for windows, manipulators, and utilities. This equipment can be added later without releasing radioactive contaminants, polluting the cell atmosphere, or extensively interrupting work at adjacent stations.

For storage of fuel material, ten pipes, each 12 in. in diameter and 10 ft deep, are located in the center aisle. Two of these pipes are initially connected to an argon-cooling system for subassembly storage, while the other pipes are provided with supply piping for future attachment to a cooling system. Thick-walled steel sleeves are installed around the two cooled pipes to reduce the radiation exposure to in-cell equipment. Special containers will be used in these storage pipes to obviate criticality problems. Metallurgical samples are stored in the uncooled pipes and in the metallograph room. The progressive buildup of radioactive debris is prevented by dry vacuuming the pipes whenever necessary. Covers over the pipes minimize the need for vacuuming.

The main cell is designed to handle both contained and uncontained sources in a single large cell rather than in separate cells. Measures are taken to minimize the particulate contamination of experiments and the radioactive contamination of equipment that must be serviced by contact. These measures include the local containment of operations generating large quantities of particulate material, and filtration and uniform distribution of the recirculating argon atmosphere. The advantages of the single large-cell concept include its capability for handling large loops and associated equipment, and its adaptability to future programs by the regrouping of examination equipment.

3. Main-cell Manipulator and Material-handling System

Sealed master-slave manipulators are installed at workstations to perform many of the operations required in the examination work.

A dual-level overhead system is provided to carry out handling tasks beyond the reach or capacity of the master-slaves. This system, shown in Fig. 17, consists of a 5-ton crane on the upper-level rails and two telescoping-tube electromechanical (E/M) manipulators on the lower-level rails. Each E/M manipulator is capable of lifting 750 lb and has a vertical travel of approximately 11 ft 9 in. The lower end of a telescoping tube is fitted with a parallel-jaw tong or a double closable hook to grip and rotate equipment, tools, and supplies about a vertical axis. An articulated E/M manipulator can also be attached to the lower end of the telescoping tube.

A small cart, running on rails below the windows and close to the walls inside the cell, is provided to transport materials, tools, fuel samples, and small equipment from one workstation to another. Two gas-lock penetrations permit the transfer of small nonradioactive items directly into the main cell without polluting the cell atmosphere or releasing contaminants. These penetrations enter the main cell at workstations 1M and 15M so the master-slave manipulators can be used to load the interstation cart with materials for workstations throughout the cell. Similar penetrations in the wall between the main cell and the decon cell provide a direct route for transfer of materials between these cells.

4. Main-cell Shielding Windows and In-cell Lighting

Combination oil-and-glass windows are designed for the cell to provide shielding approximately equal to that of the wall. A window is composed of only two basic sections: a 46-in.-thick oil-and-glass tank assembly, and a 2-in.-thick protective plate. The tank assembly has a 40-in.-wide by 24-in.-high aperture at the observer's side and tapers outward to a 64- by 44-in. aperture. The in-cell side of the tank is sealed by a 9-in.-thick glass slab. This slab provides radiation protection for the tank's oil-seal gaskets. As a cost savings, several windows were blanked

off and filled with shielding blocks. The windows can be installed at a later date as needed. The windows can be installed without the loss of cell atmosphere or spread of contamination.

A 2-in.-thick glass plate protects the glass slab on the in-cell side of the tank from mechanical damage. This protective plate is supported by a frame hinged from the liner so that it can be swung into the cell for cleaning or remote replacement with the overhead crane.

The efficient performance of remote hot-cell operations is aided considerably by the proper distribution of high-intensity lighting. Experience with existing hot cells has indicated that an "as-viewed" illumination level (product of the in-cell level and the window transmittance) of 100 to 150 lm/ft^2 on a vertical plane 3 ft from the window is satisfactory for most examination work. This general level is provided by remotely replaceable luminaires with 400-W color-improved mercury-vapor lamps at each active workstation. Additional luminaires are provided at other areas in the cell for general lighting. Emergency lighting, which starts instantaneously, is provided by tungsten-iodine lamps to give an as-viewed level of about 10 lm/ft^2 .

5. Main-cell Electric and Pneumatic In-cell Service

Each active workstation is provided with a variety of electrical and pneumatic (argon) services. The electrical services include multiple supply circuits for 115-V and 240-V ac power, power lines from the lighting ballasts, about 100 conductors for various control functions, and about 50 instrument lines (at several stations only). The power circuits are controlled from a wall-mounted panel outside the cell, and terminate in receptacles on vertical panels on both sides of each workstation. These in-cell utility panels are positioned so they can be reached with the mechanical master-slaves. The control and instrument lines terminate at receptacles on these same panels both inside and outside the cell so a variety of equipment, each with its own control console, can be interconnected. A gas-distribution system is also provided at each active station to power and control pneumatically-operated tools and equipment. Quick-disconnect couplings are provided at the in-cell utility panels.

6. Main-cell Argon System

The main cell contains a high-purity argon atmosphere of 65,000 ft³ at startup. The gas recirculates through a high-volume cooling system (about 14,000 cfm) and HEPA filters. Part of this flow is also passed through carbon filters to remove iodine. A small portion of the gas flow passes through a purification system to remove oxygen and water vapor to nominal levels of 25 and 50 ppm, respectively. The nitrogen concentration is controlled by exhausting the cell gas and replenishing it with fresh argon. The main-cell atmosphere is maintained at a reduced pressure (-0.75 in. to -4 in. WG).

Most of the penetrations into the main cell have double seals with the space between them pressurized with clean argon to prevent in-leakage of air and to aid in leak detection.

7. Decon Cell

The decon cell has six workstations. Two stations are utilized for the decontamination of equipment, irradiated components, and loop hardware. One station, separated from the rest of the cell by an enclosure, is used for clean transfer and packaging of radioactive materials prior to shipment. Two stations are used basically for transfers, and the sixth, nonequipped station is for future projects. The loop-decon station is also a nonequipped station, but this station can be activated without a great deal of interference with normal cell operation..

The decon cell is separated from the main cell by a shielding wall of 48 in. of 2.3-sp-gr concrete. This cell is the same width and height as the main cell, and its outer walls are shielded in the same manner. The cell floor is lined with stainless steel, and the walls are lined with carbon steel coated with an epoxy paint to a height of 13 ft 6 in. above the cell floor.

The workstations in the decon cell are the same size as those in the main cell. The decon cell is equipped with three shielding windows from the central control room of the argon cell of HFEF/S, and one large shielding window identical to those in the main cell. The electrical and pneumatic

services in the decon cell are generally similar to those in the main cell. One workstation in the decon cell is equipped with a vapor-containment box for use with a pressure-spray decontamination system, and one station is provided with a 30-ft-deep pit for loop handling.

Materials for shipment can be decontaminated at the spray-chamber station. Low-pressure spraying and immersion decontamination are provided at this station.

Wet decontamination of in-cell equipment prior to contact maintenance in the hot repair area is also performed in the decon cell. Since some of the equipment cannot be disassembled into small packages, the transfer penetrations between the cells and repair area and the decontamination facilities are capable of accepting the largest units.

The decon cell has an air atmosphere and provides containment to prevent the release of particulate contamination to out-of-cell areas. The cell is maintained at a negative pressure with respect to the operating corridor, the cask tunnel, the high-bay area, and the transfer tunnel. Filters are installed on the inlet ducting to prevent gross spread of contamination in the unlikely event of cell pressurization. Remotely replaceable filters and demisters are provided on the exhaust ducts within the cell. The spread of vapors from decontaminating reagents is minimized by performing all wet operations within closed and vented vessels such as the spray chamber.

Three 12-in.-dia, 10-ft-deep pipes are located in the floor of the decon cell. These pipes are being used initially to store capsules, samples, waste cans, and other radioactive items that do not require forced-gas cooling. The pipes have a shielding cover to permit personnel entry into the decon cell. A liquid-tight cover prevents seepage into the pipes during a wash-down of the decon cell. In addition, the storage pipes are designed for criticality safety even if flooded, although drains are provided in each pipe.

Extended-reach master-slave manipulators are installed at all active stations. A crane and an overhead E/M manipulator are provided. These units are identical to those in the main cell, and are equipped with the tongs and hooks described previously.

Most of the decon-cell equipment is maintained or serviced without having personnel enter the cell. Some major equipment changes or repairs,

however, are carried out only by direct contact, using tunnel suits.

8. Hot Repair Area

The hot repair area is located on top of the main and decon cells within the high-bay area. The repair area is divided into a number of separate rooms. These include the hot repair room, suspect repair room, access room, isolation room, and hot change room. Hatches and doors are provided for the transfer of equipment or personnel between the rooms, to the high-bay area, and to the decon cell. A steel containment wall separates the hot and suspect repair rooms from the isolation room. This wall contains removable panels for the future insertion of glove ports, tunnel suits, and transfer devices. Windows are located in the walls of the repair rooms and access rooms.

The purpose of this area is to provide a contained enclosure in which contaminated or suspect equipment can be repaired by personnel wearing protective clothing. These repair operations include rebuilding of mechanical master-slave manipulators, repair of the telescoping tube and crane carriages for the main and decon cells, and maintenance or modification of examination equipment.

Experience at other facilities has shown the need for at least two types of repair areas. One type of area is required to perform extensive repairs requiring extended personnel contact. This area in HFEF/N is designated as the suspect repair room. Items entering this room are thoroughly decontaminated in the decon cell. The maintenance of mechanical master-slave manipulators falls into this category. Space is provided for the storage of equipment and components that may be reused. Workbenches and a sink connected to a suspect drain are available for the repair operations. The room is routinely cleaned to minimize the contamination level.

A second area is required to perform minor adjustments or repairs that cannot be done remotely in the main or decon cells. Experience has shown that wet decontamination is both time-consuming and damaging to some machine components. Therefore, an area is provided in which rapid contact maintenance can be performed without decontamination. This area, the hot

repair room, is located for convenient access to the decon and main cells without disruption to other cell operations. Equipment entering this area may have higher contamination levels than the items transferred to the suspect repair room.

The shielded penetration between the decon cell and hot repair room (penetration 7.2008) is sized to pass the 7-ft-dia by 10-ft-high transfer chamber used in the transfer tunnel. The roof hatch into the access room and the door between the access room and hot repair room are also sized to pass the chamber. The transfer chamber is the largest single piece of equipment to be removed from HFEF/N. Large clean equipment enters HFEF/N through the roof hatch in the access room for subsequent transfer into the decon or main cells. Bag-out ports are provided in the repair-room containment walls for the insertion or removal of small equipment and tools.

The containment walls in the repair rooms consist of sheet-metal walls attached to structural support members. Penetrations having flanged sealing surfaces are provided in the walls for the installation of gloved-repair panels, tunnel suits, gloveboxes, transfer devices, and windows.

The pressure in the repair room is maintained negative with respect to the high-bay area and the access room. The pressure within the suspect change rooms and isolation areas is also maintained negative with respect to the high-bay area, but positive with respect to the repair rooms. Air from the entire repair area is exhausted through the suspect-building-exhaust system. The walls of the hot repair area are 8-in.-thick hollow concrete blocks; however, provision has been made for the future installation of additional shielding around the hot repair room.

9. Material-handling Routes

EBR-II subassemblies and capsules, TREAT loops, and other items under 10 ft in length that are contained in existing top-opening casks are usually transferred into the HFEF/N cells through the cask tunnel. The cask tunnel may accommodate specially designed casks that fit within the space available. The tunnel height is approximately 16 ft. Gastight casks may be coupled directly to the main cell and items transferred without exposure to an air

atmosphere. Casks that are not gastight are coupled to the decon cell and the items are transferred to the main cell through the intercell transfer tunnel and a large vacuum lock. EBR-II subassemblies requiring forced-gas cooling are transferred directly into the main cell from a gas-cooled cask by means of a grapple supplied with recirculating cell gas.

Long loops, up to about 30 ft in length, are lowered into the main and decon cells from the high-bay area from bottom-opening casks. The penetrations into these cells are positioned over the deep pits. This arrangement permits any part of a loop to be positioned vertically at the desired height in front of a workstation, or permits the loop to be stored temporarily. The loop casks are brought into the truck lock horizontally and are lifted vertically into the high-bay area by a 40-ton bridge crane.

Small samples and materials are transferred by pneumatic rabbit tubes to various areas. The facility is equipped with two 2-in. rabbits and one 4-in. rabbit. One 2-in. rabbit is used to transfer materials from the decon cell to the health physics laboratories. The second 2-in. rabbit transfers materials between the metallurgical sampling and preparation box in the main cell to the shielded box in the metallographic laboratory. The 4-in. rabbit transfers materials between the metallographic laboratory's shielded box and main-cell station 15M. All three systems are capable of two-way transfers.

Small tools, fixtures, and special materials are introduced into the main and decon cells directly at workstations through shielded inlet tubes. The inlet tubes are loaded from the operating floor.

Large equipment enters and leaves HFEF/N through a roof hatch in an access room adjacent to the hot repair room. Equipment and fixtures that are to be reused can be stored in a depressed, covered storage area at the center of the main cell.

10. Truck Lock

The truck lock is large enough to accommodate the various trucks and fork lifts that transport the shielded casks used in the day-to-day operation of the facility. Tall casks are transported in a horizontal attitude through the 14- x 16-ft rollup door and into the 16-ft-wide by 86-ft-long lock (see

Fig. 18).

The 40-ton high-bay crane works through a 10 x 51-ft hatch in the truck-lock ceiling. The crane either raises the cask to a vertical position and lifts it up through the hatch (a 29-ft lift) or lowers it down through the floor hatch to the cask tunnel.

The truck-lock floor-loading design criteria are as follows:

- (1) American Association of State Highway Officials Code, H-20-S16-44
- (2) 25-ton coffin and coffin carrier
- (3) 40-ton cask and cask transporter, provided that the transporter is designed to the item (1) code.

11. High-bay Area

The 68 x 154-ft high-bay area extends over the main cell, decon cell, and truck lock (see Fig. 19). This area is serviced by a 40-ton bridge crane and provides the space for transporting shielded casks between the truck lock and access ports in the cell roof.

The hot repair area and space for the repair of clean equipment are located in the high bay. Space is also provided for mockup of a full-size workstation.

The high bay provides floor loading in designated areas (cask travel aisle, loop penetrations, and cask storage area) for casks up to 40 tons. The floor-loading limits are as follows:

Clean equipment repair area	150 lb/ft ²
40-ton-cask travel aisle	40 tons dropped 1 in. on 3-ft-dia end area
Loop-transfer penetrations	40 tons
Cask storage on cell wall	40 tons/8-ft length of cell wall
Cell roof area	200 lb/ft ²
Hot repair room	5 tons concentrated
Suspect repair room	100 lb/ft ²
Hot repair room

Fig. 18. Truck Lock of HFEF/N

Fig. 19. Plan of High-bay Area of HFEF/N

Equipment access room	}	100 lb/ft ²
Suspect change room		
Isolation room		
All other high-bay floor areas		150 lb/ft ²

12. Loop Penetrations

The main cell is supplied with two 25-in.-dia loop penetrations and the decon cell with one. The general design requirements for the penetrations into the main cell are as follows:

- (1) Penetrations must be gastight at all times, with means for verifying the leaktightness of individual seals.
- (2) The interface seal between gastight shipping casks and the penetration must be gastight and have means for verifying the leaktightness of the seal before opening a cell sealing closure.
- (3) All shipping casks that are to mate with the main-cell penetrations must be gastight.
- (4) A method shall be provided to prevent the release of particulate contamination when separating the shipping cask from the penetration.

Main-cell penetration 7.1005 is a 25-in.-dia port used for the vertical transfer of loops or other items into the main cell from bottom-opening casks. The penetration is located in the main-cell ceiling above the loop-disassembly station. The penetration has been designed to accommodate loops up to 20 in. in diameter. Loop casks 30 to 48 in. in diameter, 30 ft in length, and weighing up to 40 tons can be accommodated. Other diameters can be handled by the use of adapters. However, the 40-ton limit still applies, since this is the rated load capacity of the overhead crane.

Main-cell penetration 7.1006 is identical to penetration 7.1005 but will not initially be activated. It will, in the future, provide the capability of simultaneously working on two loops in the main cell. For startup of HFEF/N, only the penetration liner, a shield plug, and a sealing plate have been provided.

The general design requirements for penetrations into the decon cell are as follows:

(1) Penetrations to out-of-cell areas shall be designed to prevent the release of radioactive particles when closed.

(2) The interface seal between shipping casks and the penetration shall be designed to prevent the release of particles during transfers.

(3) Penetrations to out-of-cell areas shall be designed to prevent the release of radioactive gases at any time.

Decon-cell penetration 7.2007 is identical to main-cell penetration 7.1005. The decon cell will, in the future, provide a facility in which loop decontamination can be performed. Loops that have been reassembled in the main cell will require decontamination prior to shipping. For startup of HFEF/N, only the penetration liner and adequate shielding have been provided for penetration 7.2007. To activate this penetration, standard bagging techniques can be used to prevent the release of contaminants.

The centerline of penetration 7.2007 is 3 ft 11 in. from the west wall of the hot repair room. Casks that are intended to utilize this penetration will therefore be limited to a maximum diameter of 7 ft 10 in. (see Fig. 20).

Penetrations 7.1005, 7.1006, and 7.2007 are designed to support the impact load of a 40-ton cask when the cask is dropped 1 in. An additional static load of 10 tons is allowed for shielding. The entire load is to be supported upon a 4-ft-square steel plate embedded in the cell roof.

13. Loop Pits

The main cell is supplied with two 3-ft-dia steel pits, each 22 ft long and extending to 30 ft below the level of the removable steel floor.

The decon cell is supplied with one 3-ft-dia steel pit extending 30 ft below the cell floor. These three pits are directly below the loop cell-roof penetrations (7.1005, 7.1006 and 7.2007) for direct access.

Fig. 20. Elevation Section of Penetration to Decon Cell

14. Equipment Maintenance

Equipment that requires maintenance is either remotely repaired within the main cell or remotely disassembled to units of convenient size for contact maintenance within the repair room. The repair room is an unshielded particle-containing area equipped with tunnel suits and gloved walls. The decontamination of equipment preceding contact maintenance includes dry vacuuming in the main cell and air-jet cleaning in the decon cell, followed by wet washdown when required. A door is provided for entry of personnel to the clean enclosed station within the decon cell. Tunnel-suit entry through the enclosure wall is provided for contact maintenance of some general-purpose equipment.

15. Radiological-safety Measures

The radiological-safety measures include the control of particulate radioactivity during transfers across primary containment barriers and the control of building air flow. In addition, adequate shielding is provided, and rigorous criticality-control measures are exercised. All these precautions are continuously backed up by radiation-monitoring instrumentation. In the development of the HFEF/N design extensive use was made of the operating experience at numerous alpha-gamma facilities.

a. Containment

HFEF/N provides radiologically safe containment for hazardous nuclear fuels and fission products. Experience at other facilities has shown that an important advantage of good containment is the ability of personnel to work without wearing protective clothing and respiratory devices in routinely occupied areas. Removal of uncontained items from contaminated cells is the usual cause of contamination releases. In addition to the radiological hazards involved, the time, effort, and facility downtime associated with recovering from such releases is significant. At HFEF/N, particle-containing transfer techniques are used for transfers

across all primary containment barriers.

Containment cell areas are isolated from clean areas by both a particle-containing barrier and an independent air barrier. An air-pressure differential is maintained across each independent barrier so the air flow is always toward the area with the highest probability of contamination. Air buffer zones are provided where required to ensure that the proper differential pressure is maintained.

Air ducts into highly contaminated areas are equipped with high efficiency particulate air (HEPA) filters to provide protection against a release of contamination if the air flow inadvertently reverses. All exhaust air or argon from these contaminated areas passes through two HEPA filters in series, separated by a duct to promote agglomeration of submicron particles. Exhaust gases that could contain radioactive iodine in excess of permissible limits are passed through carbon filters.

b. Gamma Radiation Levels

The radiological shielding is designed to attenuate gamma radiation in the operating corridor to a level of 1 mR/hr for routine operation on EBR-II-type fuel assemblies. Occupancy of other areas is administratively controlled to ensure that personnel exposures do not exceed recommended limits.

c. Radiation Monitoring

Portable and fixed instruments for monitoring both alpha and beta-gamma radiation are used to survey personnel and building areas. Hand-and-foot monitors are placed at strategic locations, such as entrances to isolation areas surrounding cell transfer penetrations and entrances to operating areas from the office area. In addition, the areas of the building adjacent to the primary containment barriers are continuously surveyed with air monitors and gamma-radiation monitors. These monitors initiate audio and visual alarms, locally and at central control areas, when specified exposure rates are exceeded. The air and gas exhausted to the building stack

are also continuously monitored.

d. Criticality Control

Features to preclude criticality include physical barriers, the use of poisons where applicable, and rigorously exercised administrative controls. A typical procedure limits the quantity of fissionable material permitted within a given cell zone. With the exception of the decontamination area, liquids and other moderators are minimized or excluded in all cell areas.

APPENDIX D

Loop-handling System

1. General Features

The loop-handling system is a transfer-transport system of equipment that provides the capability to (a) handle the FEFP loop at the various facilities within the NRTS, and (b) transport the FEFP loop between these facilities. Specific functions include

- . Transfer of nonirradiated loops from a sodium-charging facility to the Engineering Test Reactor (ETR) for irradiation.
- . Transfer of irradiated loops from the ETR to the MTR truck bay for storage during the ETR midcycle refueling period and back to the ETR at completion of refueling.
- . Transfer of irradiated loops from the ETR to HFEF/N for examination.

The loop-handling system is capable of handling the FEFP loop at each of the interfacing facilities and transporting the loop between these facilities. The following items comprise the loop-handling system:

- . Loop-handling machine (Figs. 21 and 22)
- . Transporter (Fig. 23)
- . Accessories
 - HFEF/N hook spreader
 - Support stand
 - Special tools

The loop-handling machine (LHM) is designed so that the loop can be removed from the reactor with normal handling procedures soon after reactor shutdown. For a loop experiment with fission power of 1.8 MW that has been irradiated in the ETR for two cycles, the loop can be removed after the following cooling periods: (a) 48 hr after shutdown if no fuel has dispersed, (b) 4 days after shutdown if 20% of the fuel is uniformly dispersed, and (c) 10 days after shutdown if 100% of the fuel is uniformly dispersed.⁶ The LHM is designed to transport loops without damage with the sodium molten.

ENLARGED SECTION D-D

ALL DIMENSIONS

Fig. 21. Shielding

ENLARGED SECTION E-E

ENLARGED SECTION F-F

ENSIONS IN INCHES

ENLARGED SECTION B-B

ENLARGED SECTION C-C

ding of Loop-handling Machine

Fig. 22. Loop-handling Machine

DASHED LINES SHOW LHM IN
VERTICAL POSITION FOR
REMOVAL

GROSS LOAD - 168,

Fig. 23. Transporter for Loo

CONTROL
CONSOLE

HYDRAULIC
POWER
PACK

AXLE LOAD,
28,662 lb/AXLE

- 168,439 lb

or Loop-handling Machine

The handling system provides power to the loop pump (5 kW at power factor of 0.75) and heaters (20 kW max.) as required to maintain the loop system at 450°F. The handling system provides instrumentation connections to the 12 loop thermocouples for monitoring loop temperatures. The handling system also provides cooling as required to maintain the integrity of the loop system.

The LHM is provided with argon service prior to and during loop handling in the HFEF/N main cell. When mated with the loop-insertion cell, the LHM is sufficiently leaktight to limit air in-leakage to less than 0.01 cfm at 1 in. WG.

The handling system is designed in accordance with the intent of AEC Manual Chapter 0529, dated August 22, 1966. Where exceptions must be taken, it has been shown by a fault-tree analysis or similar technique that protection of the public is not compromised. The handling system and associated control equipment is designed to withstand the forces that might be imposed by wind, ice, and other natural elements.

All structural materials and components within the control and scope of the loop-handling system are designed to ensure compatibility with the ETR coolant water and the HFEF/N cell atmosphere.

The handling system is designed to maintain the physical integrity of the ETR in-vessel and HFEF/N in-cell components during handling operations. The operation of the system is sufficiently accurate and reproducible to ensure minimum strain or impact on components during handling. The system is designed with mechanical and/or electrical interlocks to control the sequential operations of the equipment. These interlocks are coordinated with all interfacing systems and operations.

The grapple-drive mechanism of the LHM has controlled-load capability to eliminate the possibility of damage from excessive force on the loop and reactor internals before and after irradiation. The design load for the grapple system is 10,000 lb.

The loop-handling system is designed to minimize the possibility of dropping a loop and to prevent the release of radioactive contaminants. It is designed with redundancy in mechanisms and process systems so that no single failure of a component or subsystem can cause equipment to be incapable

of completing functions leading to a safe condition.

The LHM is designed to handle loops in the 6 x 6 southwestern section of test channel M-7 of the ETR, and in all other 6 x 6, 6 x 9, and 9 x 9 test channels.

The loop-handling-system transporter is designed to comply with the rules and regulations of the State of Idaho, Department of Highways. Support is provided for the loop in both the vertical charging position and the near horizontal ($\sim 10^\circ$) position during transport.

The handling system is designed for 600 duty cycles. One duty cycle is defined as the steps necessary to insert the loop into the LHM, transport the LHM to a discharge location, discharge the loop, and secure the system.

The LHM hoist is designed for 1200 duty cycles. One cycle is defined as extending the lifting chains to their full extension and then returning them to the fully retracted position.

The subsystem that provides power to the loop during handling operations is designed for 1200 duty cycles as defined above.

The loop-handling system also meets the following requirements:

- . Provision of radiation protection so that radiation exposures are within the limits prescribed in AEC Manual Chapter 0524.

- . Provision for nuclear criticality safety as prescribed in AEC Manual Chapter 0530.

- . Provision for contact maintenance. This requires that the components and subsystems have configurations that facilitate decontamination.

- . Provision for interchangeability of parts where possible.

- . Provision of instrumentation to monitor and control power to the loop pump.

The LHM grapple drive is provided with instrumentation for continuously indicating (a) the force applied to the grapple chains, with provisions for stopping grapple motion if preestablished force limits are reached, and (b) the elevation of the grapple.

2. Loop-handling Machine

The LHM is basically a shielded hollow cylinder with a 20-in. ID

(see Fig. 21). The exterior shell is stepped, having a 29.75-in. OD at the lower end and a 26.50-in. OD at the upper end. Depleted uranium, cast and machined as hollow cylinders, occupies the annular space between the outer and inner shells.

At the lower end of the LHM is a nonsealing shield valve. The valve is powered by a commercial valve operator, which contains limit and torque cutout switches for the open and closed positions. Figure 22 shows the layout of various LHM components.

Penetrating the LHM just above the valve, and again about one-third of the way up, are systems of motorized screw jacks that function as loop supports. Each such system consists of three supports spaced at 120° intervals around the periphery of the LHM. The upper support jacks travel about 1 in. and the lower ones travel about 7 in. A nonmoving loop support is achieved at the very top by an insert that reduces the nominal 1/2-in. clearance between the 19-in.-dia loop and the 20-in.-ID LHM to about 1/16 in.

The lower loop-support shafts penetrate the main body of the LHM through an 11-in.-high triangular flange. The flange serves as (a) the lower closure for the LHM, (b) a jacking pad for leveling the LHM at each interfacing facility, and (c) a means of access to the inner cask region which does not require breaching of the uranium compartment.

Affixed to the side of the LHM, within a common housing, are the grapple-drive and cable-retrieval mechanisms. The drive provides hoisting capability through two triple-stranded roller chains, which are routed to the top of the LHM where they are connected to the grapple. At the drive, the chains are reeved to individual idler sprockets, which in turn are anchored to load cells external to the drive housing. The load cells are fastened to the housing through a spring device that provides some measure of impact protection to the hoist system. The chains extend from the load-cell idlers to the drive sprockets, and continue on to spring-loaded take-up drums. The transmission to the drive sprockets includes a "No-Back" device, a slip clutch, a dc motor, and a manual override for motor backup. Coupled to the transmission is a mechanical counter, synchronized to numerically display chain payout (grapple position).

Above the drive housing are the cable reels. These are commercial spring-powered cable reels, which transmit electric power to the loop via slip rings and the grapple cables. A thermocouple extension cable is rigidly wired to the top of the LHM, where it terminates in a connector. This connector mates with the grapple connector when the grapple is in its full-up position.

The LHM is designed so that its stripped-down weight combined with the weight of the loop is 40 tons; i.e., the hoist is removed, reducing the total weight to 40 tons.

3. LHM Transporter

The transporter is a jeep-rigged low-bed trailer, which serves as a mobile platform for the LHM and its ancillary equipment (see Fig. 23). It contains a hydraulically powered cradle that can place the nested LHM in either the vertical or near-horizontal position. Hydraulically operated over-center clamps secure the LHM to the cradle, which can be secured by similar clamps to the frame of the transporter.

An engine-generator set together with a power panel and three control consoles are packaged on the transporter. One console controls the transporter's hydraulic system, the second controls power to the loop pump and heaters, and the third is used to control the LHM hoist and loop-support systems.

APPENDIX E

Procedures for Disassembling a FEFP Loop

Upon completion of loop irradiation in the ETR, the loop will be hoisted into the FEFP loop-handling machine (LHM). This machine has been designed to accommodate the loop and to mate with the ETR and the main cell of HFEF/N. The machine will be transferred to HFEF/N on a transporter that is equipped to supply the required services to the loop and machine.

1. Receiving

Upon arrival of the LHM and transporter in the EBR-II area, they will be sent to the HFEF/N truck lock. The LHM will be made ready for hoisting to the high-bay area, a 30-ft lift (see Fig. 24). The loop's sodium coolant may be either liquid or solid. Every attempt will be made to maintain the sodium liquid. The transporter must be positioned completely within the truck lock so that the outside door can be closed prior to the following operations.

- (1) Check LHM surface radiation and contamination levels.
- (2) Remove temporary shielding as required.
- (3) Remove the truck-lock roof hatches.
- (4) Attach lifting fixture to LHM and 40-ton crane.
- (5) Energize the actuators on the transporter, tilting the LHM to a vertical position. NOTE: The LHM is shipped at an angle of approximately 10° above the horizontal.
- (6) Lift the loaded LHM from the transporter and through the truck-lock roof opening. Loop instrumentation, heater and pump power, and LHM cooling supplies are disconnected and reconnected at the LHM interface as required throughout these procedures. Preliminary calculations indicate that the loop sodium may remain molten 1 hour or more without internal loop heating when the loop is in an argon atmosphere.
- (7) Place the LHM in the support fixture. The LHM is not considered to be a free-standing structure.

Fig. 24. Sequence for Handling the FEFPL Loop

REMOVE LHM TIE-DOWNS
 RAISE LHM TO VERTICAL POSITION
 LIFT LHM TO CLEAR CELL ROOF BY 1 in.
 POSITION LHM OVER LOOP-INSERTION CELL
 REMOVE CONTAMINATION PLATE AND LOWER LHM TO SUPPORT AND
 ALIGNMENT PLATE MAKING A SEAL
 RELEASE LOOP SUPPORTS OF LHM
 OPEN LHM SHIELD VALVE
 COUPLE ARGON-PURGE LINES TO THE LHM
 PURGE THE LHM

RAISE GRAPPLE TO FULL-UP POSITION
 CLOSE HFEF ROOF HATCH
 SHUT OFF PURGE
 CLOSE LHM SHIELD VALVE
 RAISE AND INSTALL CONTAMINATION PLATE
 MOVE LHM TO TRANSPORTER'S CRADLE
 LOWER CRADLE TO TRAVEL POSITION
 DISCONNECT SLINGS
 RAISE LHM CONTROL CONSOLE AND RETURN
 TO TRANSPORTER
 SECURE LHM AND CC TO TRANSPORTER
 DISCONNECT POWER FROM HFEF SERVICES

2

ling the FEFP Loop in HFEF/N

The high-bay area is provided with a 40-ton travel aisle and set-down area. The LHM will be stored in the appropriate area until preparations have been made to receive the loop in-cell. Appropriate utility services will be supplied to the LHM for loop support. The radiation levels of the LHM may require an exclusion area or temporary shielding.

2. Preparation of Main Cell

The design, fabrication, installation, and checkout of all loop remote-handling equipment will be completed before the insertion of the first loop in the ETR. The equipment to be used in the main cell of HFEF/N will include the following:

- (1) Loop-disassembly machine
- (2) Loop top-closure cutting machine
- (3) Loop heater
- (4) Test-train support fixture
- (5) Sodium removal system
- (6) Loop sectioning machine
- (7) A large number of test-train and fuel-element support fixtures for disassembly and examination
- (8) Feedthrus for various power supplies and instrumentation.

The out-of-cell equipment will include the following:

- (1) Control system for the remote equipment
- (2) Loop-insertion cell (LIC), which will contain (a) hoist (b) penetration hatch (c) cask support structure.

NOTE: A complete equipment list is included in Section IV.B.8 of the report.

3. Insertion of Loop in Main Cell

The loop may be received with its sodium coolant either liquid or solid. If the sodium is liquid, power to the loop's pump and heaters should only be disconnected for short periods. The steps for inserting the loop in

the main cell are as follows:

- (1) Transfer the LHM to the roof of the LIC (see Fig. 25).
- (2) Attach the LHM to the superstructure.
- (3) Disengage the LHM loop supports.
- (4) Open the LHM shield plug.
- (5) Purge the LHM and LIC with argon.
- (6) Increase the main-cell pressure until the cell-to-high-bay ΔP is -1 in. WG.
- (7) Open the LIC penetration hatch and lower the loop into the main cell.
- (8) A gross gamma scan of the loop may be performed as the loop is being lowered into the cell.
- (9) Lower the loop into the loop-support fixture.
- (10) Clamp the loop to the support fixture.
- (11) Disconnect the grapple from the loop and retract into the LIC.
- (12) Close the LIC penetration hatch.
- (13) Check grapple for contamination and decontaminate as required.
- (14) Hoist grapple into LHM.
- (15) Close LHM shield valve.
- (16) Remove LHM from the LIC and check for contamination. Decontaminate as required.
- (17) Install LIC roof shield.
- (18) Actuate the LIC hoist and center it over the loop penetration.
- (19) Purge the LIC with argon.

4. Loop Disassembly

The loop-disassembly section covers all loop work performed in the main cell through test-train removal. This section is broken into two sub-sections. The first applies to receiving a loop with the sodium in liquid state and the second to receiving a loop with the sodium solid.

Fig. 25. Insertion of Loop in Main Cell

a. Loop with Sodium in Liquid State

(1) As soon as the LHM grapple and utility lines are disconnected, attach the in-cell utility supplies to the loop. The following service lines are to be supplied: (a) pump power, (b) internal loop heater, and (c) power for instrumentation-readout leads.

(2) Monitor and regulate loop parameters to desired levels. NOTE: The in-cell loop heater may be used to elevate the loop temperature for test-train removal.

(3) Elevate the loop with the support fixture to the proper elevation for removal of the closure seal welds.

(4) Collect a gas sample from the sampling tubes at the closure seal welds.

(5) Attach closure-seal-weld cutting equipment to top of loop.

(6) Cut both closure seal welds (see Fig. 26).

(7) Attach lifting fixture to closure seal.

(8) Remove closure seal.

(9) Collect fission-gas sample from the loop's top sodium-fill line.

(10) Position test-train support fixture.

(11) Open LIC penetration hatch and lower test-train grapple to the loop.

(12) Start loop heater if not already in service.

(13) Bring loop temperature up to 500°F.

(14) Shut down loop pump.

(15) Unbolt test-train closure.

(16) Attach hoist grapple to test train.

(17) Hoist test train to desired elevation. Monitor the load applied to test train. Load limits are to be established (see Fig. 27).

(18) Clamp test train with support fixture.

(19) Position test-train cutting device and section the test train at the desired location. NOTE: It is assumed that the test-train hex can has not expanded to the flow divider. The load-cell readout of the hoist

Fig. 26. Removal of Closure Seal Welds

Fig. 27. Removal of Test Train

should be monitored throughout the removal of the test train.

b. Loop with Sodium in Solid State

- (1) Elevate the loop with the support fixture to the proper elevation for removal of the closure seal welds.
- (2) Collect a gas sample from the sampling tubes at the closure seal welds.
- (3) Attach closure seal-weld cutting equipment to top of loop
- (4) Cut both closure seal welds.
- (5) Attach lifting fixture to closure seal.
- (6) Remove closure seal.
- (7) Collect fission-gas sample from loop's top sodium-fill line.
- (8) Position test-train support fixture.
- (9) Start heating of top section of loop heater. Loop will be sequentially heated from the top to the bottom.
- (10) Heat each section of loop until sodium is liquid. Various loop thermocouples will be monitored to evaluate progress of melting.
- (11) Start test-train heater to melt sodium in center tube.
- (12) Start power to loop pump to melt sodium in pump region.
- (13) When melting of loop sodium is completed, open LIC penetration hatch and lower test-train grapple to the loop.
- (14) Shut down loop pump.
- (15) Unbolt test-train closure.
- (16) Attach hoist grapple to test train.
- (17) Hoist test train to desired elevation. Monitor the load applied to the test train.
- (18) Clamp test train with support fixture.

5. Disassembly of Test Train

During the handling of the test train, great care must be exercised so that experimental information is not disturbed. Chunks of fuel and sodium

may be spread all around the cell if care is not taken when transferring the test train.

- (1) Position the test-train cutter in proper location.
- (2) Cut the test train in half.
- (3) Clamp the top section of the test train.
- (4) Hoist the top section of the test train up until it clears the support fixture.
- (5) Attach the E/M manipulator to the top section of the test train.
- (6) Lower the top section of the test train to the cell floor using the E/M manipulator and hoist.
- (7) Release the hoist grapple.
- (8) Retract test-train hoist cable and grapple into LIC and close hatch.
- (9) Attach lifting fixture to experiment section of test train.
- (10) Grapple the test-train lifting fixture with E/M manipulators.
- (11) Release clamps of test-train support fixture.
- (12) Hoist the test train free of the loop.
- (13) Transfer the lower end of the test train to the working elevation of the master-slave manipulator.
- (14) Place a cap over the lower end of the test train to catch debris that may be dislodged during handling.
- (15) Transfer test-train experiment section and flow divider to upright support fixture.
- (16) Release grapple.
- (17) Attach grapple to the experiment section.
- (18) Withdraw the experiment section from the flow-divider section.
- (19) Visually inspect the exterior surface of the experiment section. The scanning periscope will primarily be used. If unusual phenomena are evident, the inspection may be continued on the stereomicroscope.
- (20) Photograph the experiment section as required during

disassembly and inspection.

(21) Wipe any excess sodium from the exterior surface of the experiment section.

(22) Perform a diametral survey of the experiment section. (Locations and number of measurements will be selected at a later date.)

(23) Transfer the experiment section to the general machining station. NOTE: The experiment section of the test train may be disassembled at either the general machining station or the vertical subassembly dismantler. This presentation discusses disassembly at the general machining station.

(24) Clamp the experiment section in a support-tilting fixture.

(25) Lower the experiment section to a horizontal position.

(26) Transfer the experiment section and fixture to the milling machine.

(27) Clamp the test section and fixture on the milling-machine bed.

(28) The experiment section is to be adjusted so that the front side of the T-bar grids are up.

(29) Adjust the fixtures and experiment section as required so that the milling operation will not damage the informational features of the experiment section.

(30) Mill the upper corner of the vertical flat facing the window, completely cutting through the hex can. The cutting operation should be continually monitored by viewing through a scanning periscope.

(31) Cut the full length of the experiment-section hex tube.

(32) Rotate the experiment section and fixtures 180° , clamping and adjusting as required to the mill table.

(33) Mill the upper corner of the vertical flat facing the window. Cut the entire length of the experiment-section hex tube. NOTE: The above two cuts will release two flats with the exception of the ends. The long length of the cuts may set up vibration during cutting, which could modify test results. The application of clamps along the sections being cut

may be required to prevent damage.

(34) Cut across the top flats at both ends of the experiment section. The actual location of the cuts has not been determined at this time.

(35) Remove the two flats that are on the top side of the experiment section.

(36) Place clamps around the experiment section to hold the fuel elements in place.

(37) Remove the experiment section and fixture from the milling-machine bed.

(38) Visually inspect the experiment section, utilizing the scanning periscopes to look down between the rows of fuel elements. NOTE: The actual mechanics of the examination will vary and will be dependent upon the results of the visual observation. Additional machining may be required to complete the disassembly.

(39) Transfer the experiment section and fixture to a general workstation.

(40) Start to remove the fuel elements, cutting instrumentation leads at the top end as required.

(41) Place the fuel elements in appropriate storage containers. It should be reemphasized that photographs will be taken during all phases of this disassembly and examination.

(42) Sodium will be wiped from the fuel elements as required.

(43) Fuel-element debris will be collected and placed in suitable containers.

(44) All materials will be removed from the test section for identification and possible examination.

6. Sodium Collection

The loop heater has been keeping the loop's sodium coolant in a liquid state until sodium removal can begin. The removal is accomplished as follows:

(1) Transfer the removal and collection system to the

loop-disassembly area.

- (2) Start the trace heaters for the sodium-collection system.
- (3) Bring the sodium-collection system up to 500°F.
- (4) Start inserting the sodium-removal piping into the loop. The piping will be in several sections, which must be assembled as it is lowered into the loop.
- (5) Lower the piping until it is completely inserted in the loop.
- (6) Seal the loop's top closure.
- (7) Monitor thermocouples to assure that the loop and sodium-collection system are up to temperature.
- (8) Push out the sodium with argon gas. The sodium will flow through a screening and filter unit and into a storage container.
- (9) Shut down the argon pressurizing gas after all possible sodium is obtained. Some sodium will remain in the bottom of the loop. The actual amount will be determined after designs are finalized. Some of the sodium in the vertical section of piping will fall back into the loop.
- (10) Shut down the loop heater.
- (11) Shut down trace heating on sodium removal piping.
- (12) Remove piping from loop.
- (13) Store the sodium-collection system containing the sodium until a convenient time for further processing.

7. Loop Disposal

Normal disposal will be performed by cutting the loop into sections small enough to be accommodated by the normal solid-waste-disposal system in the main cell. The loop sections must fit into a waste container approximately 11-1/2 in. in ID and 6 ft long. A plasma-jet torch, a traveling milling cutter, and a hacksaw will be used for the cutting.

- (1) Cut the secondary vessel just below the loop's top closure. The secondary vessel is supported by the tube heater.

- (2) Attach a grapple to the primary vessel, using the cell crane as a hoist (see Fig. 28).
- (3) Hoist the primary vessel to the desired elevation and clamp.
- (4) Section the primary vessel at the lower plenum of the heat exchanger (see Fig. 29).
- (5) Transfer the cut section to lay-down area.
- (6) Hoist the remaining section of primary vessel to desired elevation and clamp (see Fig. 30).
- (7) Section the primary vessel just below pump and move to lay-down area.
- (8) Move in-pile section of primary vessel to lay-down area.
- (9) Hoist secondary vessel to desired elevation and clamp.
- (10) Cut secondary vessel and move section to lay-down area (see Fig. 31).
- (11) Complete sectioning of the secondary vessel (see Fig. 32).
- (12) Gamma-scan each section of the primary vessel looking for fuel and large quantities of sodium.
- (13) Remove fuel and sodium from each loop section.
- (14) Cut the large sections of the primary and secondary vessels into pieces that will fit into the waste-disposal containers.
- (15) Transfer the loop pieces to the decon cell.
- (16) Load the loop pieces into waste containers.
- (17) Transfer the waste containers to the EBR-II waste-storage grounds.

8. Fuel-element Examination

The procedures for examining the fuel elements from the test section will not be detailed at this time. The following examination techniques will be available for use if desired.

- (1) Precision gamma scanner
- (2) Diameter survey

Fig. 28. Separation of Primary from Secondary Vessel

Fig. 29. Removal of Heat Exchanger

Fig. 30. Removal of Loop Pump

Fig. 31. First Stage in Sectioning of Secondary Vessel

Fig. 32. Second Stage in Sectioning of Secondary Vessel

- (3) Stereomacroscopic
- (4) Scanning periscope
- (5) Weight balances
- (6) Fission-gas collection equipment
- (7) Sectioning equipment
- (8) Specimen preparation (mounting and grinding)
- (9) Polishing
- (10) Metallurgical examination

9. Sodium Disposal

The method of sodium disposal is presently undetermined.

10. Fuel Disposal

The method of fuel disposal is presently undetermined.

11. Loop Dissection for Test-train Removal

If it becomes impossible to remove the test train from the loop's primary vessel, provision will be made to cut the in-pile section free just below the ALIP pump. Pressure-pulse information obtained during loop testing will provide data to be evaluated to determine method of loop disassembly.

- (1) Perform steps 1 through 16 of Section 4.a for disassembly of loop.
- (2) Attempt to hoist the test train.
- (3) Monitor the hoist load cell.
- (4) Stop hoist when load exceeds predetermined limit.
- (5) Disconnect hoist grapple from test train.
- (6) Shut down all heaters.
- (7) Allow the loop sodium to freeze.
- (8) Lower LIC grapple and attach to the loop.
- (9) Hoist loop to desired elevation for cutting. Cut will be just below the ALIP (see Fig. 33).

Fig. 33. Dissection of Loop if Test Train Cannot Be Removed Normally

- (10) Clamp loop with support structure.
- (11) Cut in-pile-tube section free from remainder of loop.
- (12) Release upper clamps.
- (13) Hoist loop a short distance.
- (14) Attach a sodium seal to the cut section of loop.
- (15) Hoist top end of loop into LIC as far as possible.
- (16) Attach a grapple and E/M manipulator to in-pile-tube section.
- (17) Elevate test-train support structure to upper limit.
- (18) Lower loop-disassembly machine to clear lower end of in-pile tube.
- (19) Swing in-pile-tube section toward center of cell with test-train support structure.
- (20) Lower upper body of loop back into loop-disassembly machine.
- (21) Release grapple and hoist back into LIC.
- (22) Transfer the in-pile-tube section to the general machining station.
- (23) Clamp the in-pile-tube section on the milling-machine bed.
- (24) Split the in-pile-tube section of the secondary vessel.
- (25) Remove the in-pile tube containing the test train from the milling machine.
- (26) Place in-pile tube in a heater.
- (27) Attach a sodium catch container over the open end of the in-pile tube.
- (28) Start the heater, sequentially heating from the cut end.
- (29) After all sodium is melted and poured into the catch containers, shut down the heater.
- (30) Transfer the in-pile tube to the milling machine.
- (31) Split the in-pile-tube primary vessel and remove the test train.
- (32) Split the flow divider and remove the experiment section.
- (33) Perform the experiment-section disassembly as outlined

in Section 5.

(34) Attach LIC grapple to loop.

(35) Hoist loop to desired elevation (lower end of loop pump at cutting location).

(36) Remove a section of the secondary vessel (the 5-1/2-in. to 18-in. transition).

(37) Place a sodium seal over the cut end of the primary vessel.

(38) Lower loop back into loop disassembly machine.

(39) Proceed with loop disassembly as outlined in Sections 4.b, 6, and 7.

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