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LIGHT WATER BREEDER REACTOR CORE EVALUATION OPERATIONS AT THE EXPENDED CORE FACILITY

(LWBR Development Program)

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FOREWORD

The Shippingport Atomic Power Station located in Shippingport, Pennsylvania was the first large-scale, central-station nuclear power plant in the United States and the first plant of such size in the world operated solely to produce electric power. This program was started in 1953 to confirm the practical application of nuclear power for large-scale electric power generation. It has provided much of the technology being used for design and operation of the commercial, central-station nuclear power plants now in use.

Subsequent to development and successful operation of the pressurized Water Reactor in the Atomic Energy Commission (now Department of Energy, DOE) owned reactor plant at the Shippingport Atomic Power Station, the Atomic Energy Commission in 1965 undertook a research and development program to design and build a Light Water Breeder core for operation in the Shippingport Station.

The objective of the Light Water Breeder Reactor (LWBR) program has been to develop a technology that would significantly improve the utilization of the nation's nuclear fuel resources employing the well-established water reactor technology. To achieve this objective, work has been directed toward analysis, design, component tests, and fabrication of the water-cooled, thorium oxide-uranium oxide fuel cycle breeder reactor for installation and operation at the Shippingport Station. The LWBR core started operation in the Shippingport Station in the Fall of 1977 and finished routine power operation on October 1, 1982. After an End-of-Life core testing, the core was removed and the spent fuel shipped to the Naval Reactors Expended Core Facility for detailed examination to verify core performance including an evaluation of breeding characteristics.

In 1976, with fabrication of the Shippingport LWBR core nearing completion, the Energy Research and Development Administration, now DOE, established the Advanced Water Breeder Applications (AWBA) program to develop and disseminate technical information which would assist U.S. industry in evaluating the LWBR concept for commercial-scale applications. The AWBA program, which was concluded in September 1982, explored some of the problems that would be faced by industry in adopting technology confirmed in the LWBR program. Information developed includes concepts for commercial-scale prebreeder cores which would produce uranium-233 for light water breeder cores while producing electric power, improvements for breeder cores based on the technology developed to fabricate and operate the Shippingport LWBR core, and other information and technology to aid in evaluating commercial-scale application of the LWBR concept.

All three development programs (Pressurized Water Reactor, Light Water Breeder Reactor, and Advanced Water Breeder Applications) have been conducted under the technical direction of the Office of the Deputy Assistant Secretary for Naval Reactors of DOE.

Technical information developed under the Shippingport, LWBR, and AWBA programs has been and will continue to be published in technical memoranda, one of which is this present report.

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LIST OF ACRONYMS

ACE	-	Anti-Contamination Enclosure
ANL	-	Argonne National Laboratories
ANL-E	-	Argonne National Laboratories - East (Argonne, Illinois)
ANL-W	-	Argonne National Laboratories - West (Idaho Falls)
B	-	Blanket Module
CC	-	Cassette Carrier
CCTV	-	Closed Circuit Television
COS	-	Cut Off System
CPIS	-	Crane Position Indicating System
ECF	-	Expended Core Facility
EDCOT	-	Eddy Current Oxide Thickness
EFPH	-	Effective Full Power Hours
EOL	-	End-of-Life
HDRF	-	Holddown and Rotation Fixture
HG	-	Horizontal Grapple
ICPP	-	Idaho Chemical Processing Plant
LCS	-	Liner Closure Station
LWBR	-	Light Water Breeder Reactor
MDA	-	Module Disassembly Apparatus
MTC	-	Module Transfer Cage
MVS	-	Module Visual Station
PBC	-	Peach Bottom Cask
PIFAG	-	Production Irradiation Fuel Assay Gage
POB	-	Proof of Breeding
R	-	Reflector
REX	-	Rod Examination Gage
RRS	-	Rod Removal System
S	-	Seed Module
SAPS	-	Shippingport Atomic Power Station
UF	-	Utility Fixture
VDS	-	Vertical Disassembly Stand
VIG	-	Vertical Inspection Gage
VIGIP	-	Vertical Inspection Gage Instrumentation Package

This report presents an overview of the processes and equipment used to receive, examine, and store the Light Water Breeder Reactor (LWBR) fuel modules once they had been partially disassembled and shipped to the Expended Core Facility (ECF) in Idaho for storage in an underwater facility. At ECF, the 39 fuel modules underwent further disassembly to provide fuel rods for nondestructive testing to establish the core's breeding efficiency and to provide core components for examinations to assess their performance characteristics. Thirteen of the modules were examined visually with underwater cameras. Ten of the 13 plus two additional modules were disassembled to permit removal of individual fuel rods. A total of 1,075 rods were removed from these 12 modules; 524 were examined at ECF, 34 were examined at Argonne National Laboratories (ANL), and the remainder of the rods were removed to allow internal examination of the modules. Additionally, a number of component pieces and fasteners were removed from the modules and examined. At the conclusion of the program, all modules and rods were shipped to the Idaho Chemical Processing Plant (ICPP) for long-term underground storage.

LIGHT WATER BREEDER REACTOR CORE EVALUATION OPERATIONS AT THE EXPENDED CORE FACILITY

(LWBR Development Program)

SECTION 1 - INTRODUCTION

The Light Water Breeder Reactor (LWBR) core, installed and operated in the Shippingport Atomic Power Station (SAPS), accumulated 29,047 effective full power hours (EFPH), far beyond the original design value of 18,000 EFPH. After plant shutdown, the core was removed and partially disassembled, and the spent fuel was shipped to the Naval Reactors Expended Core Facility (ECF) for detailed examination. Assessment was made of core component performance, including an evaluation of breeding characteristics. Upon completion of the end-of-life (EOL) examination program, all spent LWBR fuel was transported to the Idaho Chemical Processing Plant (ICPP) for long-term underground storage.

This report describes the ECF operations involved in receiving, handling, storing, examining, disassembling, and shipment for long-term storage of the LWBR core fuel modules, fuel rods, and related nonfuel reactor components.

1.1 - LIGHT WATER BREEDER REACTOR PROGRAM AND OBJECTIVES

The LWBR program was established in 1965 with the design objective of developing a practical, self-sustaining breeder reactor, cooled and moderated with light water, and fueled with Uranium-233 and thorium. The fuel system used for the LWBR was based on the generation of fissile Uranium-233 from thorium, a relatively abundant, naturally-occurring, fertile material. The LWBR core was designed to demonstrate conventional pressurized water reactor plant operational capability while simultaneously producing more fissile fuel than was consumed. The design of the LWBR core is described in detail in Reference 1.

1.2 - LIGHT WATER BREEDER REACTOR FUEL ASSEMBLIES

The LWBR core consisted of 39 fuel modules: 12 seed, 12 blanket, and 15 reflector modules. A module type was characterized by its cross-sectional geometry, as shown in Figure 1. The seed modules were designed to be moved vertically through hexagonal guidetubes in the blanket modules thus controlling core reactivity and eliminating the need for poison control rods. The reflector modules were positioned around the core perimeter to reduce neutron leakage from the core, thereby increasing thorium conversion (breeding). Each fuel module contained a Zircaloy shell as a structural member. This shell encased the exterior of the seed and reflector fuel modules but was located on the inside of the blanket modules as a guidetube for the moveable seeds. Each fuel module contained a lattice of fuel rods arranged on a triangular pitch. The fuel rods were supported vertically in the fuel modules by the module baseplates and laterally by the grid support system. The individual fuel rods, an example of which is shown in Figure 2, were Zircaloy tubes filled with oxide fuel pellets with a plenum space and helical coil spring at the top end.

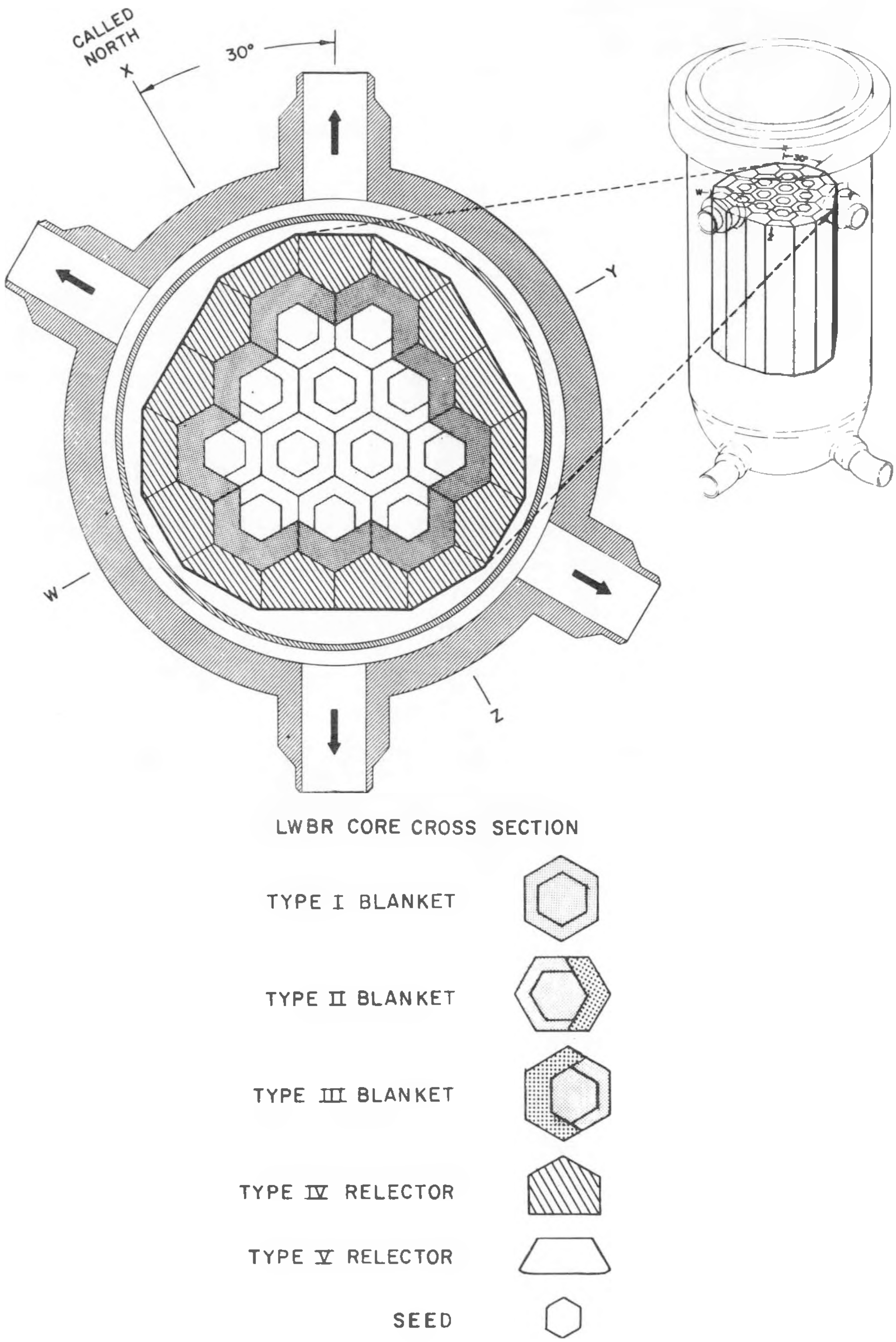
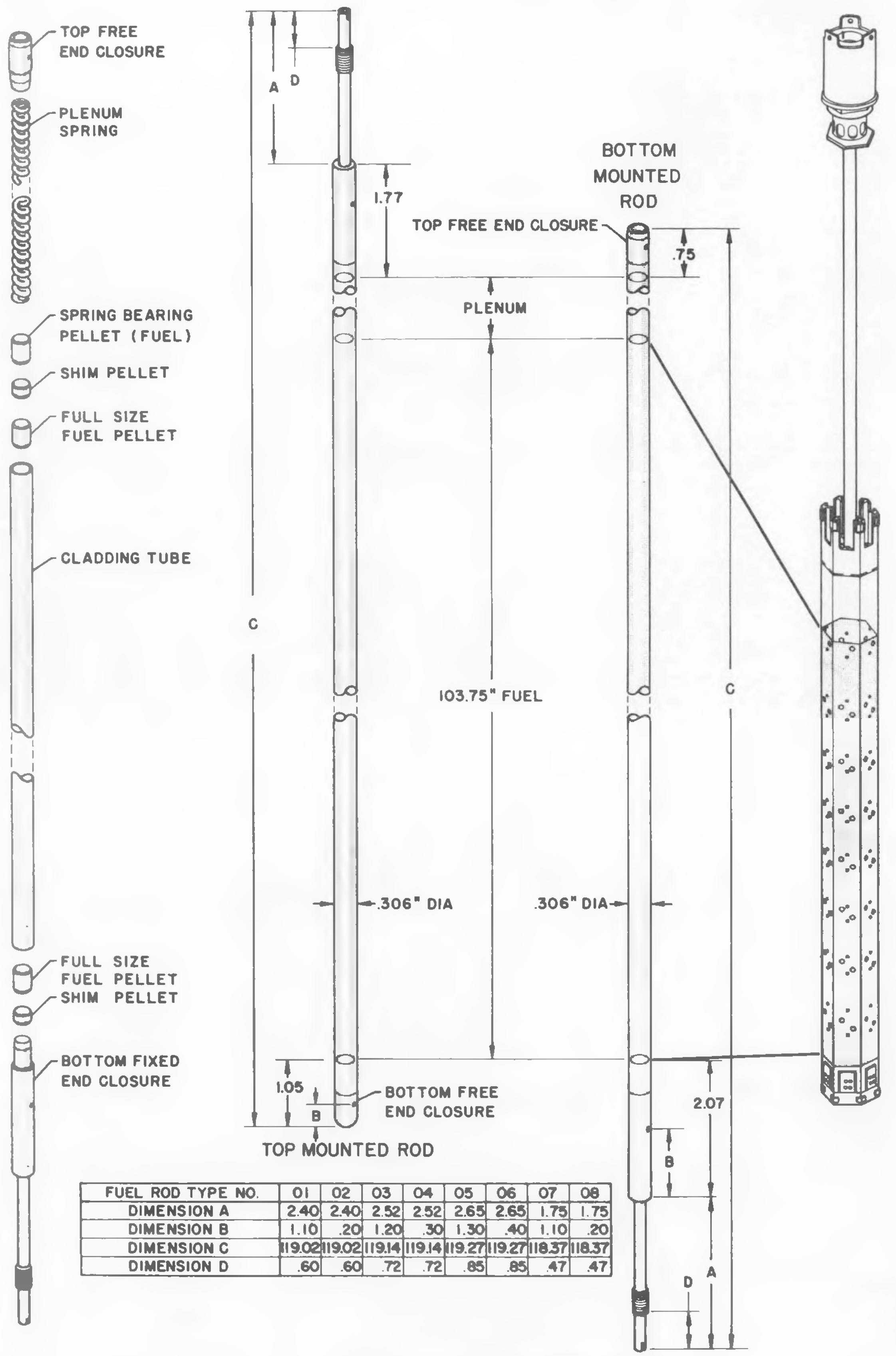


Figure 1. LWBR Fuel Module Cross-Sectional Views



FUEL ROD TYPE NO.	01	02	03	04	05	06	07	08
DIMENSION A	2.40	2.40	2.52	2.52	2.65	2.65	1.75	1.75
DIMENSION B	1.10	.20	1.20	.30	1.30	.40	1.10	.20
DIMENSION C	119.02	119.02	119.14	119.14	119.27	119.27	118.37	118.37
DIMENSION D	.60	.60	.72	.72	.85	.85	.47	.47

Figure 2. LWBR Seed Module Fuel Rods

1.3 - LIGHT WATER BREEDER REACTOR OPERATION, DISASSEMBLY, AND TRANSPORT TO THE EXPENDED CORE FACILITY

The LWBR core started power operation at SAPS on September 7, 1977, and concluded routine power generation on October 1, 1982. The LWBR fuel modules were partially disassembled at Shippingport to reduce each module to a length suitable for shipment to ECF in an M-130 shipping container. Three M-130 shipping containers were modified to accommodate the three fuel module types: seed, blanket, and reflector.

Disassembly of the fuel modules prior to shipping included removing the support shaft and other structural hardware from the seed modules; the support tube, seal block assembly, the guide tube extension, and stub tube assembly from the blanket modules; and the seal block from the reflector modules (see Reference 2). A shipping plate was then installed on each module to provide structural support during shipping. Figures 3 through 5 show details of typical seed, blanket, and reflector modules as received at ECF. The lift adapter, which accommodated a specialized lifting grapple, was installed at ECF.

1.4 - END-OF-LIFE EXAMINATION PROGRAM

The LWBR core EOL examination program included examination of modules as received at ECF, examination during disassembly, and individual component examinations after disassembly. The examinations were performed to provide sufficient information to verify that components performed as designed, to verify the acceptability of major design procedures, and to provide technology for future core design.

Examinations were performed at ECF on 15 of the 39 total modules in the LWBR core. The modules examined consisted of five seed, six blanket, and four reflector modules. Examination of one seed and two blanket modules was limited to detailed visual examination of the outside features of the module. The remaining 12 modules (four seed, four blanket, and four reflector) were disassembled sufficiently to permit removal of selected individual fuel rods. A total of 1,075 rods were removed from the disassembled modules: 524

of these rods were examined for proof-of-breeding (POB); 19 were nondestructively analyzed; 17 were destructively assayed; 12 were destructively examined; and five were examined for crud characteristics.

Additionally, extensive disassembly operations were performed on one module of each type to provide access to the internal structure for examination. Half of the external structural shell was removed from the reflector module and all of the shell from the seed module. The internal fuel rod spacing was measured as rods were removed from the modules, and various internal structural members were examined. Grid sections were removed from the seed module for detailed hot cell examination. Cursory visual examination of the seed and reflector shell sections, top and bottom cover plates, and the blanket shear keys, struts, support posts, and base plates were conducted. Visual and metallographic examinations were performed on fasteners from all three module types.

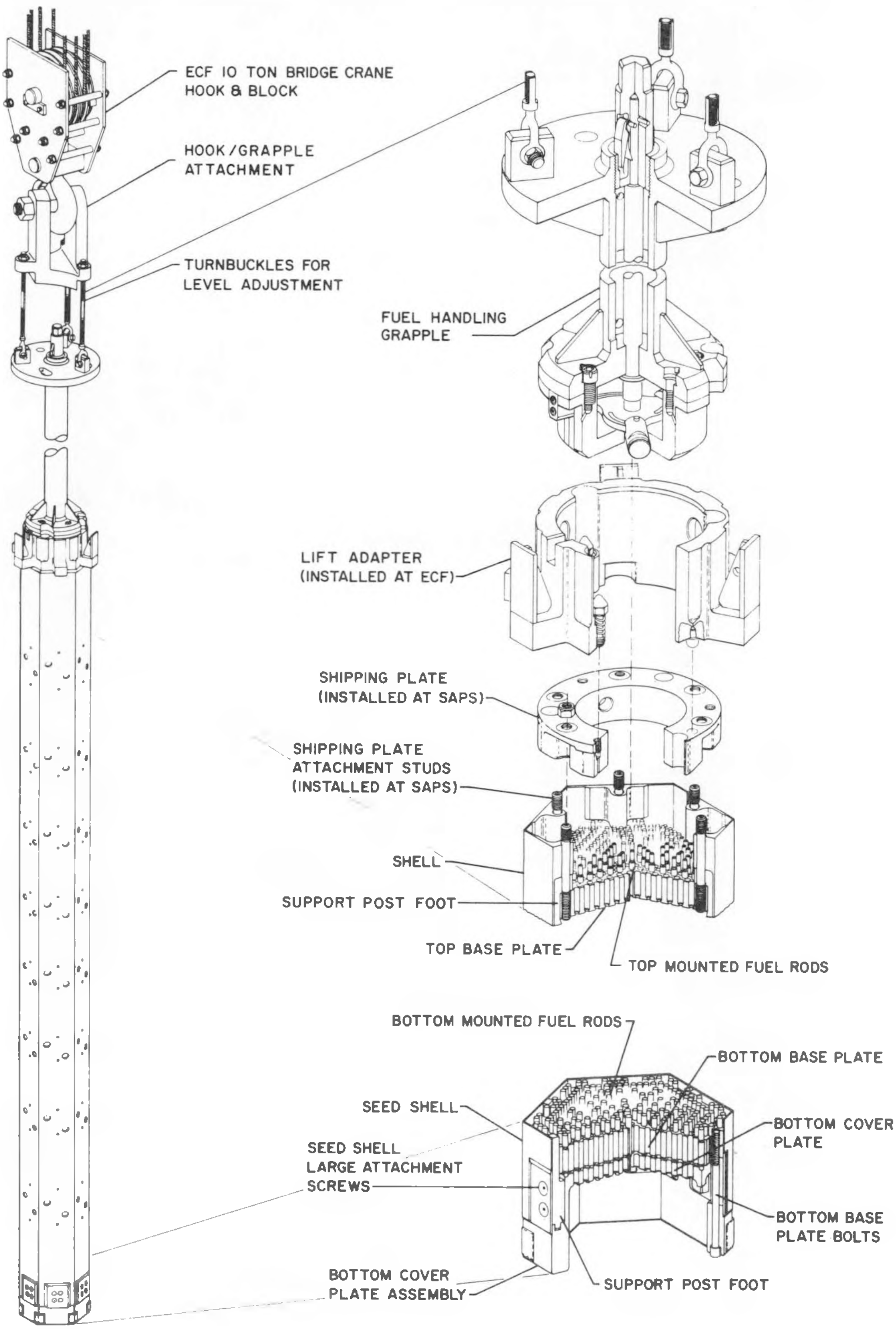


Figure 3. LWBR Seed Module as Received at ECF

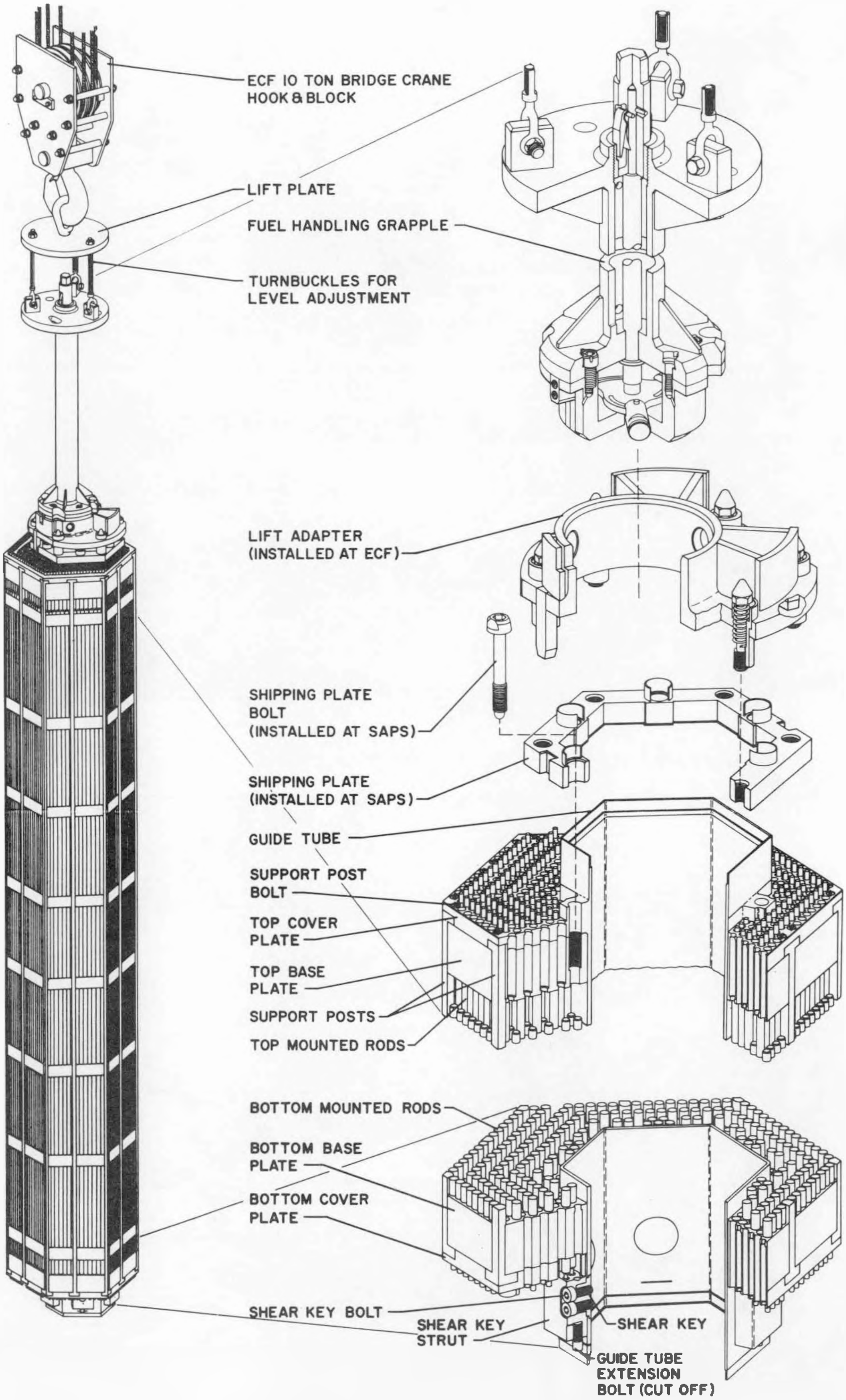


Figure 4. LWBR Blanket Module as Received at ECF

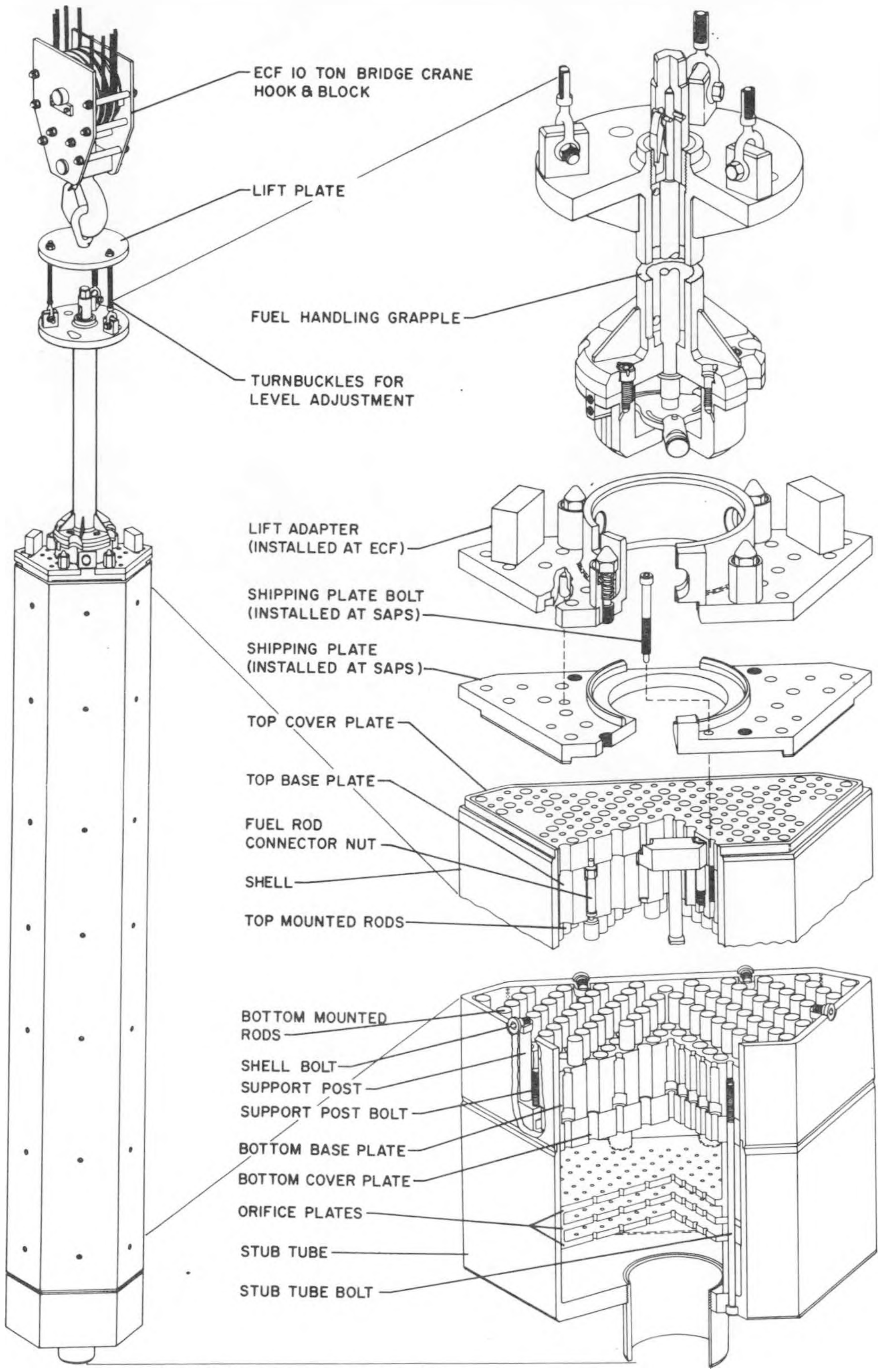


Figure 5. LWBR Type IV Reflector Module as Received at ECF

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SECTION 2 - THE EXPENDED CORE FACILITY

The Expended Core Facility (ECF), at the Naval Reactors Facility (NRF) in Idaho, is a large building consisting of a water pit area, a hot cell area, a mechanism refurbishment area, craft working areas, storage areas, and office areas.

The total water pit complex ranges in depth from 20 to 45 feet, and it holds approximately three million gallons of water. The water is continuously circulated through underwater filters to maintain low radioactive contamination levels.

The ECF hot cell area is connected to the water pits by three underwater transfer canals. Examinations of specific, small, dry samples of fuel are performed in the hot cells, which consist of a series of 13 cells, each equipped with at least one pair of slave manipulator arms. The transfer canals are equipped with transfer carts and elevators to move the samples between the water pits and the hot cells.

A large craft production area is located at the west end of the building. In addition to the labor support equipment and welding area, M-130 containers are received and unloaded in this area. Decontamination of larger pieces of equipment is performed in an isolated shop located in the area.

Four overhead cranes and five bridge cranes service the water pit area, and one overhead crane is established above the hot cell area.

2.1 - THE EXPENDED CORE FACILITY WATER PITS

The LWBR end-of-life (EOL) core evaluation program included module receipt, storage, disassembly, rod removal, module and rod examinations, and shipment to long-term storage. The EOL evaluation was performed in an area of the water pits approximately 105 feet long, 40 feet wide, and 35 feet deep (see Figure 6). Removable watertight gates separate and isolate the large facility into smaller water pit areas. Personnel walkways traverse the top of the water pits to allow vertical access to the equipment within. The "beach" is the area adjacent to the water pits and is used for water pit related work.

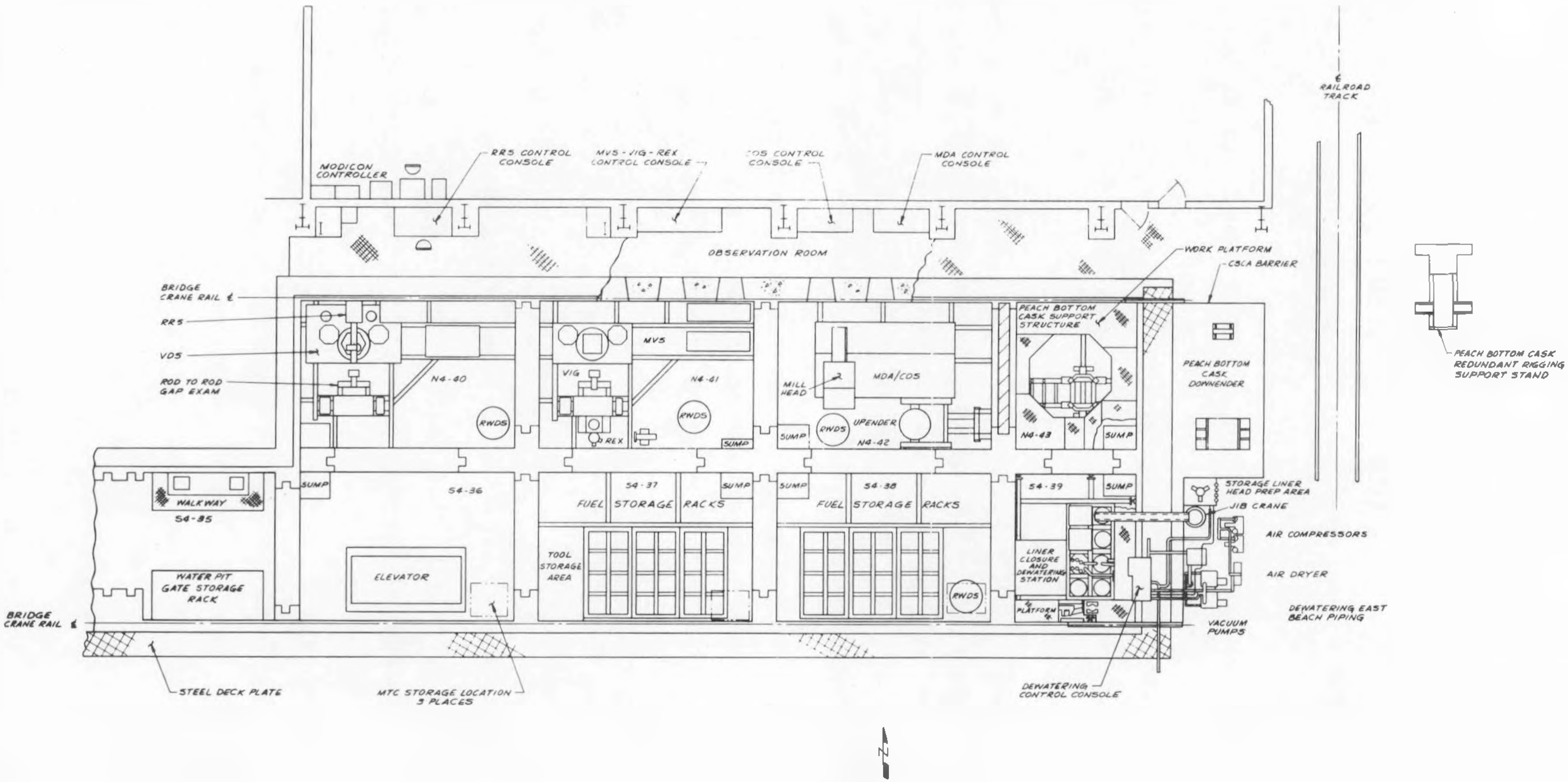

Figure 6. Area of ECF Used for LWBR Program

The observation room runs the length of the four north pits as shown in Figure 6. This narrow room is located one floor elevation below the beach and adjacent to the pits. A 3-foot thick wall with leaded glass windows separates the observation room from the water. The module disassembly apparatus (MDA) and the rod examination gage (REX) were situated in the water pits so that direct observation of the work in progress could be made through the windows. Remote slave manipulator arms were available in the observation room to perform underwater work for both stations. Control equipment for both of these stations was situated in the observation room. Additionally, the pit used for both defueling and module preparations for long-term storage activities had one window used occasionally for observation.

The laydown area, called the east beach, provides an area for railcars and tractor trailers to enter the ECF water pit building high bay and be positioned adjacent to the water pits, thus simplifying shipping and receiving operations. The east beach area was also used to store, assemble, and test equipment prior to water pit installation, as well as to provide an area to train technicians on equipment and techniques before actual water pit work was begun. Storage for LWBR equipment awaiting checkout and installation was available in the ECF south bay, which was adjacent to, but isolated from, the ECF high bay.

High-capacity building cranes and lower-capacity water pit bridge cranes serviced this area. Assigned to the LWBR program during normal operations was an overhead building crane, which had a 125-ton capacity main hoist and a 25-ton capacity auxiliary hoist. This crane was used primarily to transfer the M-130 and Peach Bottom casks between the railcar and the water pit and to install major pieces of examination equipment. Two water pit bridge cranes, each with a 10-ton capacity, were used for module and component transfers within the water pits. The two bridge cranes were equipped with a crane position indicating system (CPIS) which consisted of closed circuit television (CCTV) cameras, video monitors, video switches, measuring tapes, and an absolute encoder to measure and display the crane hook position in three axes. This system provided an accurate method of positioning the bridge crane during fuel moves.

2.2 - EXPENDED CORE FACILITY HOT CELLS

The hot cell gallery, shown in Figure 7, is a series of totally enclosed and shielded dry test areas with windows and slave manipulators allowing remote operator interface. The hot cells are located in a large room adjacent to, but isolated from, the water pit area. Three underwater transfer canals, each with a conveyance platform and an elevator, connect the hot cells to the water pits for fuel, component, or hardware transfer. A hot cell area and one of the water pit-to-hot cell transfer systems was dedicated to the production irradiated fuel assay gage (PIFAG). The PIFAG performed the nondestructive assay of the fuel rods to determine the EOL fissile fuel content. LWBR fuel rods removed from the modules were transferred underwater to the transfer canal, conveyed through the canal, raised into the PIFAG hot cells, and nondestructively assayed. This area was also used to dry-load rods into sealed inner containers for shipment to other facilities for additional analysis. Refer to Section 3.12 for more information on the PIFAG.

Figure 7. ECF Hot Cells

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SECTION 3 - LIGHT WATER BREEDER REACTOR OPERATIONS

3.1 - MANAGEMENT

The Light Water Breeder Reactor (LWBR) Engineering Program at the Expended Core Facility (ECF) was divided into two groups: LWBR Fuel Receipt and Disassembly; and LWBR Core Examination. The first group of engineers was responsible for receiving, unloading, and storing fuel from the M-130s, disassembly of select modules, and final shipment of the modules and individual fuel rods from ECF to long-term storage. The second group was responsible for the rod examination operations on the rod examination gage (REX) and the production irradiated fuel assay gage (PIFAG), shipment of individual fuel rods to the Argonne National Laboratory (ANL) for examination, and examination of component parts from the reactor. Engineering duties included writing work requests, performing equipment design and checkout, executing job follow and supervision, and resolving problems as necessary.

3.2 - WORK CONTROLS

The LWBR ECF technical work efforts and examinations were directed by a system of work requests: a site work request; a Naval Reactors Facility (NRF) work request; or a route card. All types of work requests consist of a series of steps detailing the work to be performed. A site work request is limited to minor equipment and facility repairs. It is not used for work on equipment or systems that require limitations or outages, that directly effect defueling equipment, or that require radiological control actions and approvals. An NRF work request is used to cover more extensive work but may not be used for core, crud, irradiations, fuel handling or examination, M-130 defueling, fuel storage, or M-130 maintenance work. A route card, however, is not limited in the work which it can direct. The route card requires any combination of technician and craft effort to complete the job, and it typically contains a greater number of explicit steps to complete, safely and correctly, the requested work without further instructions from the follow engineer.

A procedure, similar in format to a route card, is a work document which is written and approved to detail a repetitive job effort; however, it may not be used independently of a route card. For each repetition of such a job effort, a route card specifies the individual job and refers to the applicable steps in the procedure. Without a route card, the steps in a procedure cannot be worked.

All forms of work requests and procedures must be reviewed and approved by the engineering management supervisor, Radiological Controls, Quality Assurance (if applicable), and ECF operations management before the package is issued. Work is followed precisely as stated and changed only with a formal change notice.

3.3 - EQUIPMENT CHECKOUT

The major systems of equipment used to examine the LWBR core were designed at the Bettis Atomic Power Laboratory (Bettis) and shipped to ECF unassembled. These systems, such as the module disassembly apparatus (MDA) and the rod removal system (RRS), were assembled in their respective ECF water pits before the pits were filled with water. Each of these systems was checked out and operated, as fully as possible, while dry then again when the pit was filled with uncontaminated water. This provided the opportunity to operate the equipment and discover potential problem areas which were corrected before the systems were submerged in contaminated water. The REX was assembled and checked out on the beach area prior to being installed in the water pits.

3.4 - TRAINING AND QUALIFICATIONS

All water pit and hot cell technicians who worked on LWBR fuels were trained on the equipment and familiarized with the procedures prior to working on any of the systems. Training, conducted primarily by the engineers, included live or videotaped lectures and hands-on operation of equipment under qualified supervision. Before being allowed to operate any system of equipment without supervision, each LWBR technician had to pass an oral examination on the system and the expected sequence of events as well as demonstrate a proficiency of operation on the equipment.

3.5 - RADIOLOGICAL CONTROLS

NRF Radiological Controls is committed to the practice of ensuring that the work on radioactive materials is performed in a manner that provides the maximum possible protection to personnel from the effects of radiation. Surface contamination levels are maintained at less than 450 $\mu\mu$Ci/100 cm^2 beta-gamma and no detectable alpha in all areas not requiring radiological controls. Radiological Controls conducts formal training courses for all NRF departments in the required theoretical fundamentals, individual responsibilities, and practical abilities considered necessary for personnel before they are permitted to work on or around radioactive materials.

Anti-contamination clothing is required to be used in designated areas where contamination levels exceed, or may exceed, 450 $\mu\mu$Ci/100 cm^2 beta-gamma and no detectable alpha. This clothing consists of coveralls, hood, gloves, booties, and respirator and is used to keep personnel from spreading radioactive contamination outside of the designated area and to keep the wearer free from contamination. The extent of anti-contamination clothing required is dependent on the the contamination levels. Radiation levels are monitored and the practices of increasing the distance from and the shielding of radiation hot-spots, as well as decreasing stay time in the radiation area, are used to minimize personnel exposure.

LWBR engineering personnel and radiological controls evaluation engineers studied and discussed each evolution of the LWBR program prior to the work being performed. Potential radiological problems were evaluated, methods devised, and procedures written to minimize personnel exposure. The LWBR engineers were trained and qualified in the radiological controls needed for evaluating and writing radiological control steps in route cards and procedures. All route cards and procedures were reviewed and approved by the radiological controls engineers before being issued. Additionally, potential problems were minimized by using mockup equipment and pre-job training evolutions.

Prior to the receipt of the LWBR fuel, a new underwater filter system was installed in the water pit area. This filter system used a resin base to filter radioactive contaminants from the water. It was successful in maintaining the water pit radioactive contamination level to less than 1×10^{-7} μCi/ml.

All tools and equipment which were raised out of the water were surveyed for radiological contamination. Either the items were immediately placed into a containment bag or, if possible, they were washed and dried to obtain contamination levels of less than 10,000 μμCi/100 cm^2 beta-gamma and no detectable alpha. These items were not necessarily bagged but were worked on or stored only in a designated contamination area. Containment bags were commonly made of yellow herculite or polyvinylchloride and were used to completely seal an item to prevent the spread of contamination.

Before all casks were shipped from ECF, the cask and truck underwent extensive radiological and contamination surveys. If a cask had been loaded or unloaded in the water, a survey was done on the cask prior to immersing it in the water and upon taking it out. All casks were surveyed prior to removing them from a designated contamination area and installing them on the truck. All accessible areas on the cask and truck were required to be less than 450 μμCi/100 cm^2 beta-gamma and no detectable alpha for loose contamination and 100 counts per minute for fixed contamination. Areas experiencing levels above these were decontaminated, as necessary, to meet the NRF requirements for shipping.

The radiological controls established for the LWBR program were more than adequate. The radiation levels in all the evolutions of the program were lower than expected, no abnormal conditions occurred, and no major radiological control exposure problems were encountered.

3.6 - FUEL RECEIPT

The 39 LWBR fuel modules were shipped to ECF from the Shippingport Atomic Power Station (SAPS) in three internally-modified M-130 shipping containers. The basic M-130 container is a right circular cylinder approximately 84 inches in outside diameter and 158 inches in overall height. The container is mounted on a railcar and shipped in the upright position. The container walls consist of a finned, 1-inch thick outer steel shell, a 10-inch center shell of lead shielding, and a 1-inch thick inner steel shell. The inner shell has an inside diameter of 55 inches. Internal modifications included installing uniquely designed module holders within the inner shell to accommodate the different module types. Modified containers M-130-6, M-130-7, and M-130-4 carried six seed modules, four reflector modules, and three blanket modules, respectively. In all, a total of 10 shipments were made: two seed, four reflector, and four blanket shipments. Table 1 details the modules received in each shipment. Because only three modules remained for the last reflector shipment, the open container space was used to transport various nonfuel components from the reactor for subsequent examination.

Defueling each M-130 container included receipt, unloading, and return operations. A detailed description of the equipment and processes necessary to perform these operations follows.

3.6.1 - M-130 Receipt

Upon arrival at ECF, the railcar-mounted M-130 container, shown in Figures 8 and 9, was brought into the ECF high bay. The energy absorber was removed from the top of the container. This energy absorber, made of redwood and stainless steel, was a special drop accident protector. The container was then transferred by overhead crane from the railcar to the floor east of the water pit where it was stationed in the center of an M-130 work platform, shown in Figure 10. This platform provided a working area set at a convenient height near the top of the M-130.

The M-130 was then connected to the support system, illustrated in Figure 11. The support system was an intricate system comprised of three filters, a pump, a heat dissipation unit, a pressure monitoring system, and associated piping. Its purpose was to fill and flush the M-130 with recycled water prior to submersion in the water pit and to drain the container when it was removed from the water. Recycled water is pit water which has been cycled through the underwater radioactive collection filters to remove radioactive contaminants. Additionally, the support system controlled the rate of cooldown of the container during the fill and flush cycle.

Table 1 - LWBR Modules Received at ECF

Shipment	Container	Module Core Position	Module Serial Number
1	M-130-7	RIV-1	L-RA01-06
		RIV-3	L-RA01-10
		RV-1	L-RB01-07
		RV-4	L-RB01-08
2	M-130-4	BI-1	L-GR01-01
		BII-1	L-GS01-01
		BIII-6	L-GT01-06
3	M-130-7	RIV-6	L-RA01-04
		RIV-7	L-RA01-05
		RV-5	L-RB01-03
		RV-6	L-RB01-05
4	M-130-4	BI-3	L-GR01-03
		BII-3	L-GS01-02
		BIII-3	L-GT01-03
5	M-130-6	SI-2	L-BB01-05
		SII-1	L-BB01-09
		SII-3	L-BB01-13
		SIII-1	L-BB01-07
		SIII-2	L-BB01-08
		SIII-5	L-BB01-14
6	M-130-4	BI-2	L-GR01-02
		BII-2	L-GS01-03
		BIII-4	L-GT01-04
7	M-130-7	RIV-2	L-RA01-02
		RIV-5	L-RA01-07
		RIV-8	L-RA01-08
		RV-2	L-RB01-04

Table 1 (Cont)

Shipment	Container	Module Core Position	Module Serial Number
8	M-130-6	SI-1	L-BB01-04
		SI-3	L-BB01-06
		SII-2	L-BB01-10
		SIII-3	L-BB01-12
		SIII-4	L-BB01-11
		SIII-6	L-BB01-16
9	M-130-4	BIII-1	L-GT01-01
		BIII-2	L-GT01-02
		BIII-5	L-GT01-05
10	M-130-7	RIV-4	L-RA01-09
		RIV-9	L-RA01-03
		RV-3	L-RB01-06

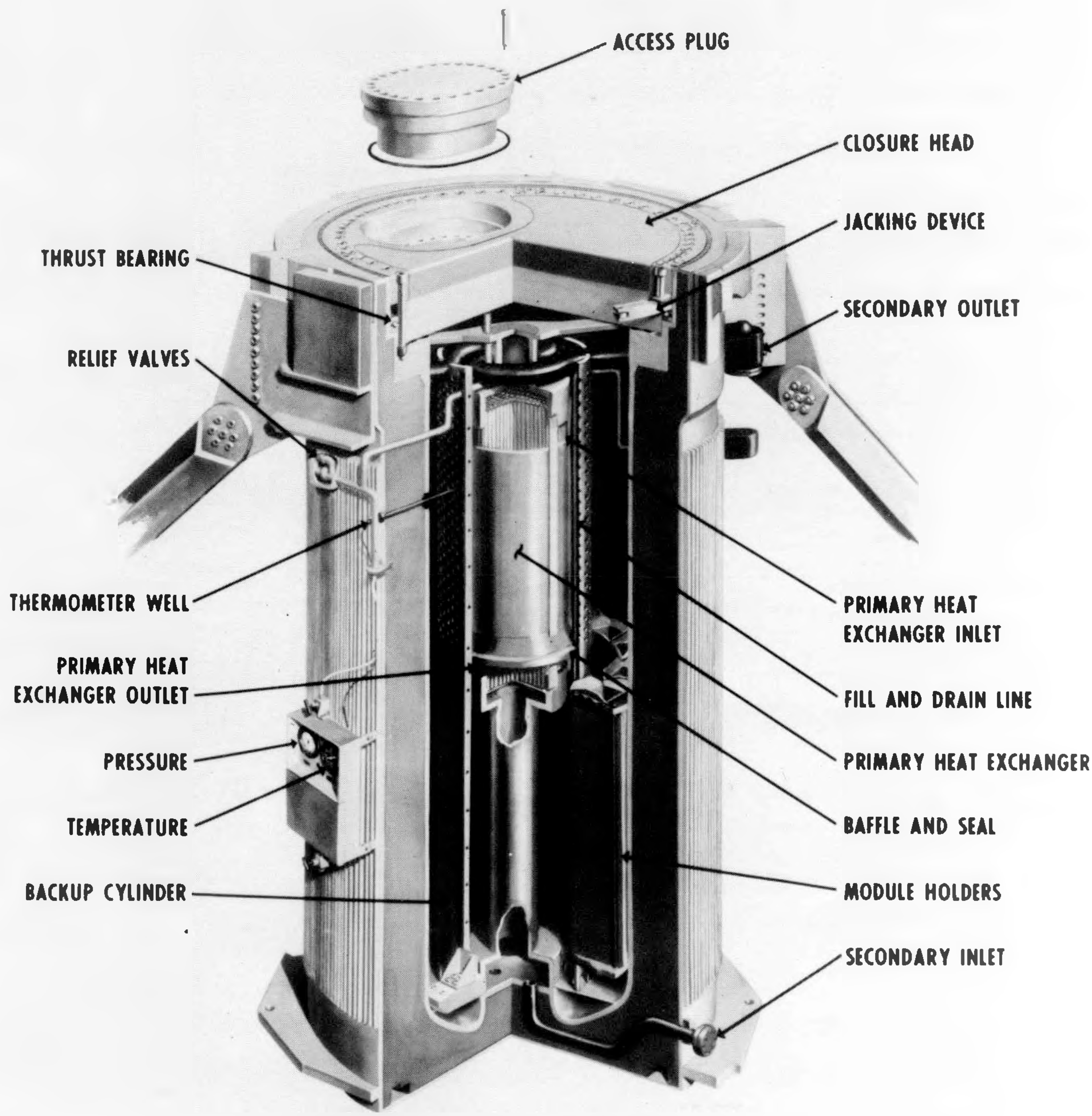

Figure 8. M-130 Standardized Spent-Fuel Shipping Container

Figure 9. M-130 Container Railcar Shipment

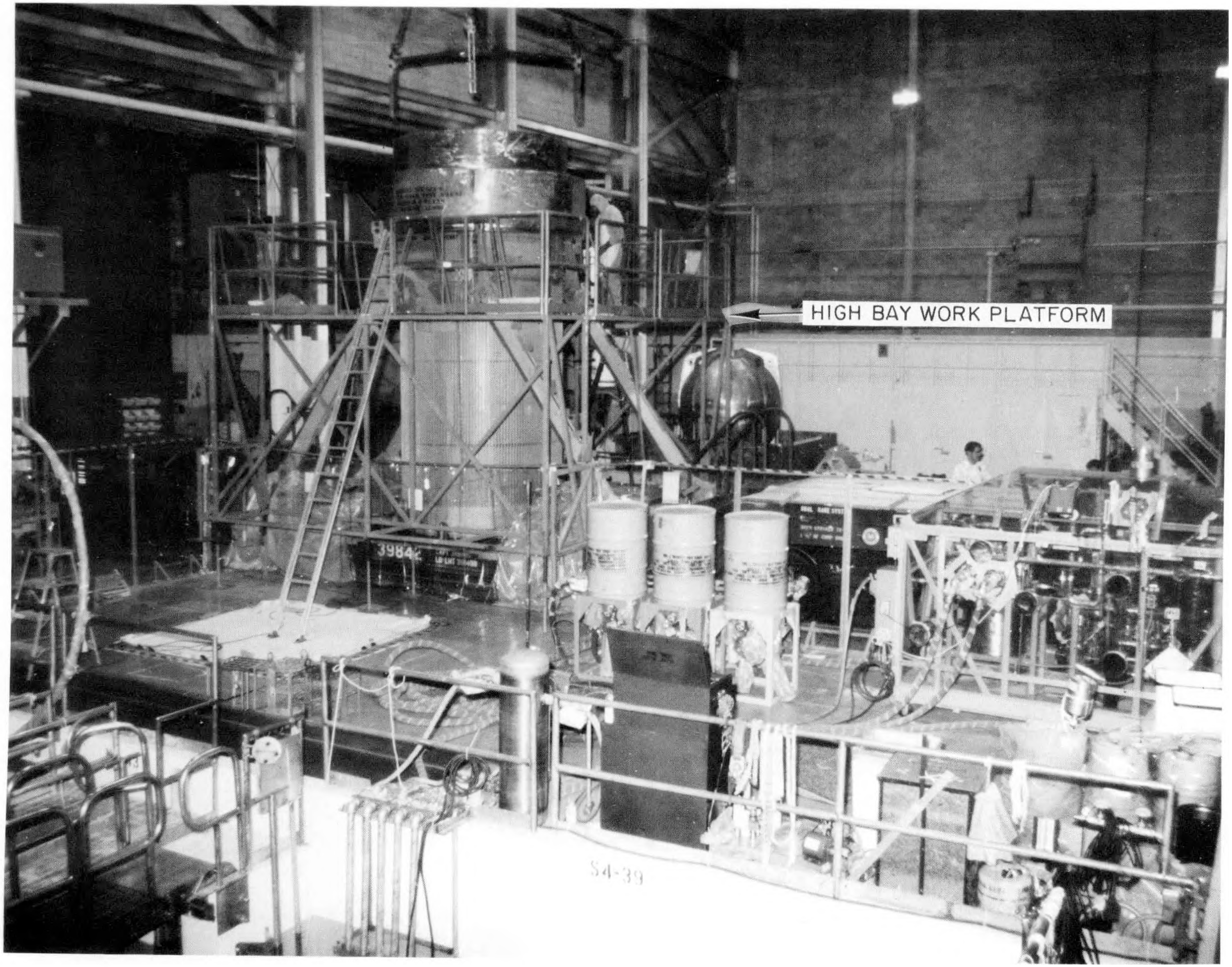

Figure 10. M-130 Preparation

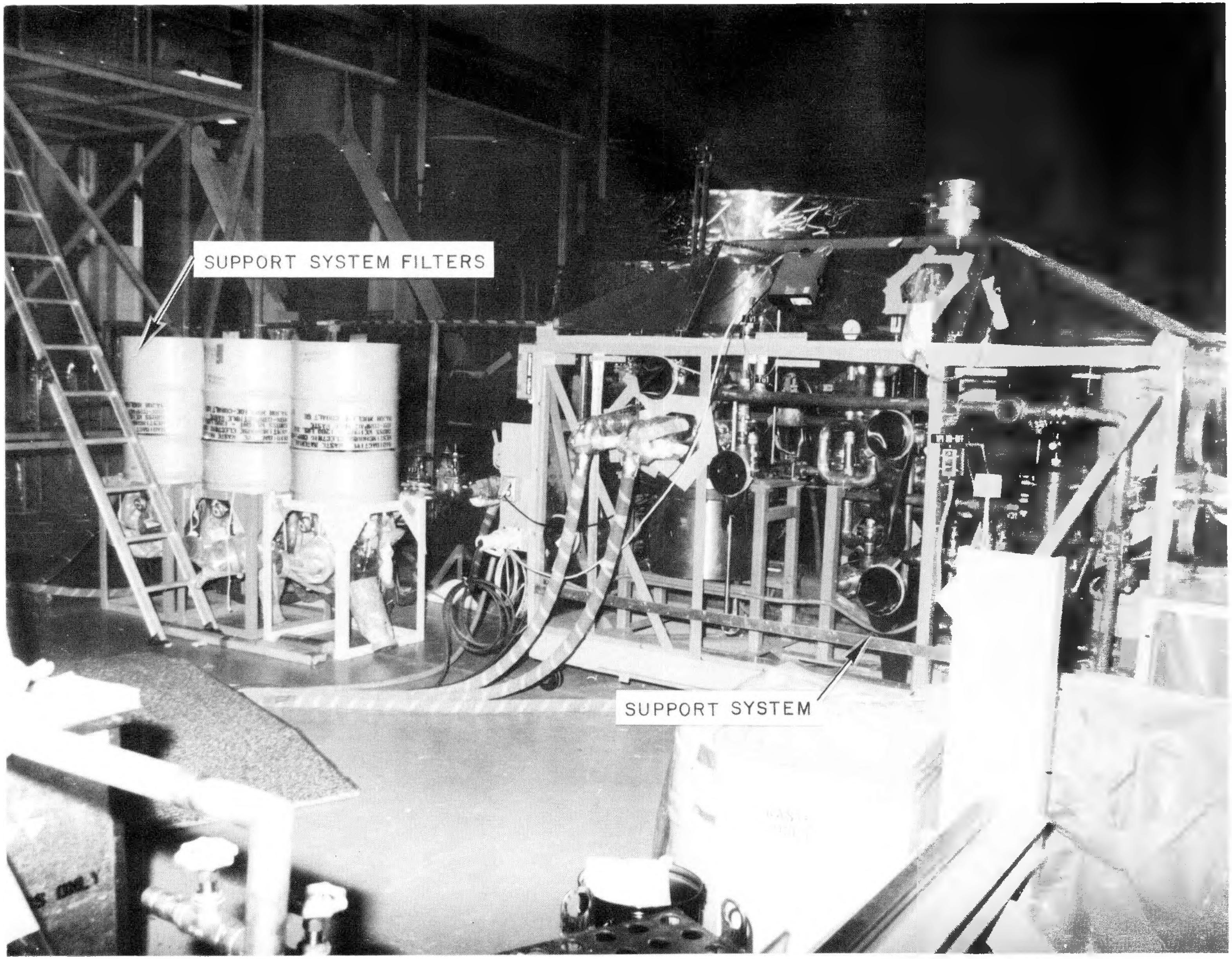

Figure 11. LWBR M-130 Support System

After opening both the M-130 container vent and drain penetrations, the support system vent and drain lines were coupled into the M-130 internal circulation system as shown in Figure 12. Cooldown and fill consisted of pumping water into the container at a controlled rate to condense any steam. When the container was filled, water was circulated through it for approximately 24 hours to reduce the water temperature to less than 100 F. The water was then pumped through the underwater radioactive waste collection filters. Temperature and pressure readings were continuously monitored, and the water was periodically sampled to measure the level of radioactivity. When the temperature was less than 100 F, the pressure less than 10 psig, and the level of radioactivity less than 1×10^{-6} μCi/ml, the M-130 was placed in the water pit.

3.6.2 - Immersion of the M-130 in the Water Pit

During the fill and flush operation and before the container was submerged in the water pit for fuel module removal, 17 of 56 bolts were removed from the closure head. Fourteen bolts were removed to allow installation of the three closure head lift brackets. The remaining three bolts were removed to permit installation of three closure head alignment pins. These pins facilitated alignment of the closure head when it was reinstalled underwater upon completion of fuel removal. Since the remaining 39 bolts were to be untorqued underwater by the use of a 27-foot long probe pole, the torque on these bolts was reduced before the container was put into the water. Three of 12 radial shims were removed to allow installation of the lift brackets on the closure head. These shims had been inserted between the closure head and the container at SAPS to prevent closure head motion in the event of a drop accident during transport. Lift plates and trunnions, bolted to the container, enabled the overhead crane to place it on the 35-foot deep water pit floor.

A large seal ring was mounted and bolted onto the top outer edge of the M-130. This ring, the two anti-contamination bags, and various hoses, quick disconnects, and flow meters, provided the M-130 anti-contamination enclosure (ACE) system. Although the recycled water in the ECF water pits commonly is maintained at a low level of radioactivity, the outside surface of the M-130

Figure 12. LWBR M-130 Support System Operations

container was covered before being submerged in order to avoid potential contamination of the container's external surfaces. Decontamination efforts on the finned outer shell would have been time-consuming and labor-intensive because it was painted carbon steel and had surface irregularities.

The ACE ring sealed the top outer edge and provided a surface to which the anti-contamination bags were secured. Two anti-contamination bags were used for each defueling: the inner bag was made of clear polyvinylchloride and the outer of opaque yellow herculite. Figure 13 shows both the seal ring and the ACE bags on an M-130. The M-130 was lifted off the floor with the overhead crane, the bags, which were staged with the inner bag inside the outer, were slid under the container and raised up the outside. Each bag was independently sealed and clamped to the seal ring.

The seal ring allowed access to the modules inside the M-130 once the closure head was removed, but the bags and seal ring prevented the potentially contaminated water pit water from coming into contact with the container's outer surfaces. A vent pipe had been built into the seal ring, and an inlet pipe was installed through and sealed to specially constructed sleeves at the bottom of both bags. Before submersion, an inlet line was connected to the inlet pipe and the vent line to the vent pipe. Thus, clean water (i.e., demineralized water which had never been in the ECF water pits) could be introduced through the vent line into the inside of the inner bag, circulated around the container, and discharged into the water pits through the drain line. As the M-130 was submerged, clean water was pumped into the inner bag; when it was fully submerged, water was continuously circulated and vented. This system worked successfully for all 10 M-130 shipments, including one in which the ACE bags separated from the seal ring surface leaving a visible gap of approximately 3 feet. In this case, the circulating water flow was increased to ensure a continuous exit of clean water from the breach. The total time required from beginning preparations on the container until it was placed on the water pit floor was an average of 13 shifts.

3.6.3 - M-130 Defueling

Long-handled, remotely-operated tools performed underwater defueling op-

Figure 13. LWBR M-130 Underwater Tooling and Closure Head Removal

erations. Figure 13 illustrates a tool used in LWBR defueling efforts. The tools were approximately 27 feet long and weighed as much as 300 pounds. Each of the heavier tools was lifted and moved by the water pit bridge cranes or the facility overhead crane. A tool was put in place and held vertically by the crane while one or two technicians standing over the water on the walkways operated the tool. Lighter, hollow stainless steel probe poles were handled directly by the technicians to perform the more common remote tasks. Some of these probe poles were fitted with a 90-degree offset, and others were fitted with socket adapters or special ends, such as allen keys or tongs. Job requirements determined pole selection.

Once the container was seated on the water pit floor and the ACE water circulation system had stabilized, the nine radial shims remaining around the closure head were removed with the probe-offset. Underwater tooling was then used to remove the remaining 39 closure head bolts. First the closure head bolt torque tool was used to break the torque on the bolts. Then a smaller unthreading tool was used to free the bolts. A third tool was used to grip the bolts so that they could be lifted and placed in a holding rack mounted on the top of the closure head.

Using the overhead crane, equipped with specially-designed rigging, the closure head was lifted off the container and placed on a holding rack. Access was now provided to the modules stored therein. Figures 13 and 14 show the closure head removal process. However, before the modules could be removed, the module restraining mechanisms had to be loosened or removed with the use of remote tools. These restraints were installed and tightened at SAPS before the M-130 was closed and shipped to ECF. The primary purpose of the restraints was to prevent seed and blanket rods from rupturing should a vertical drop accident occur while in-transit. Restraints for the seed modules were made from stainless steel honeycomb crush block material. One restraint simply rested on top of the second, but the second was secured against the module with two screws (see Figure 15) which had to be released before the restraint could be withdrawn. Blanket modules were held in place with a stainless steel ring made of crush blocks and springs resting on top of

Figure 14. M-130 Closure Head Removal

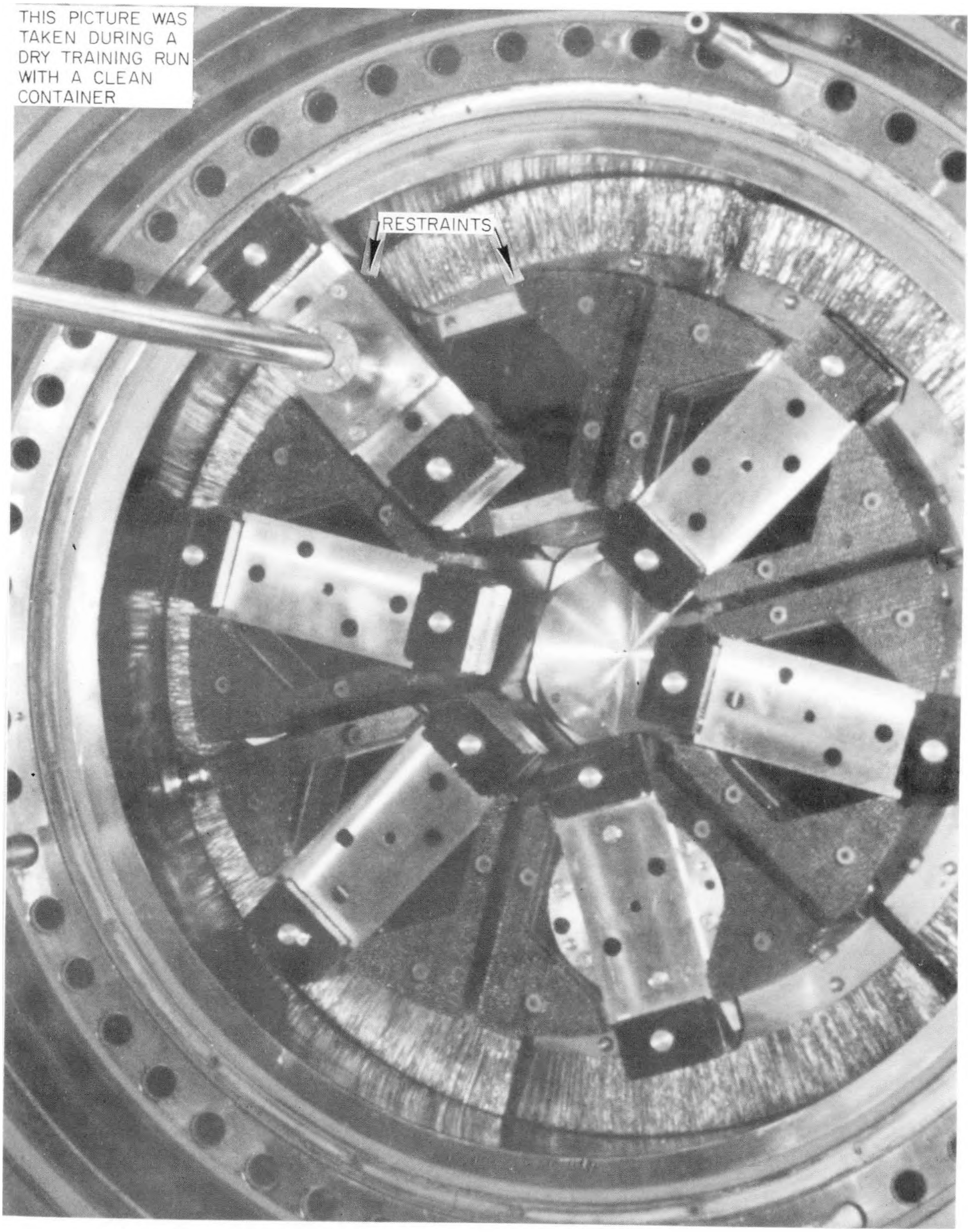

Figure 15. M-130 Seed Module Restraints

each module. After these restraints were removed with a specially-designed tool, a blanket plug, approximately 10.5-feet long with a 9-inch hexagonal cross section, had to be removed from the center of each blanket module. This plug was inserted in the middle of each blanket module prior to shipment to ensure that a seed module could not be placed inside the blanket module. An underwater tool carried by the overhead crane locked onto and lifted the plug out of the module. Each of the three plugs was stored in tubes on a holding table in the water pits.

The reflector modules were secured in position in the container with a holddown spring made of crush block material. These were removed, stored, and returned to SAPS in the M-130 for subsequent reuse.

After the above operations were performed, the torque on the shipping plate bolts was checked to ensure no bolts had loosened in transit. A shipping plate had been bolted onto each module at SAPS to provide structural support during shipping. Special adapter plates, which were designed to facilitate lifting the modules, were installed on each module shipping plate. These lift adapter plates, each built and designated for a specific module, allowed the handling of all modules with the same grapple. Refer to Figures 3 through 5 for illustrations of the shipping plate, lift adapter, and grapple.

After the lift adapter plates were in place on either the blanket or reflector modules, a centrally-positioned lateral restraint mechanism within the M-130, which securely held all modules in place, was loosened via an underwater tool. Once the restraints were released, the modules could be removed from the M-130 and transferred to the storage racks. Fuel storage racks provided temporary storage locations for the LWBR fuel modules.

A grapple system, shown in Figures 16 and 17, transferred all vertically-oriented fuel modules to various work stations within the ECF. The grapple was suspended from the bridge crane and latched onto the installed lift adapter plate. Three lift pins were radially driven outward into the corresponding adapter lift plate holes. These pins had an outer lip which prevented pin withdrawal under load.

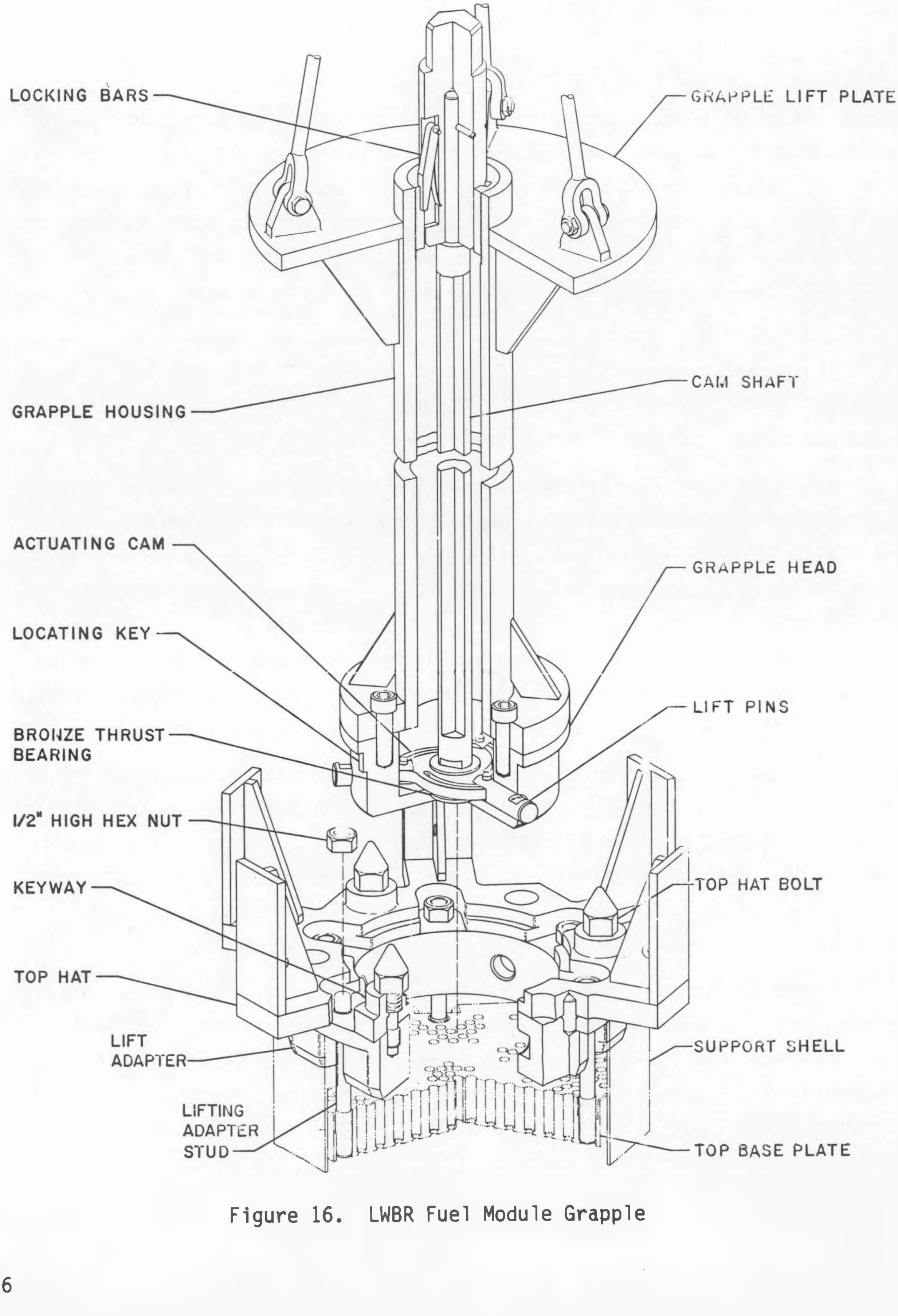

Figure 16. LWBR Fuel Module Grapple

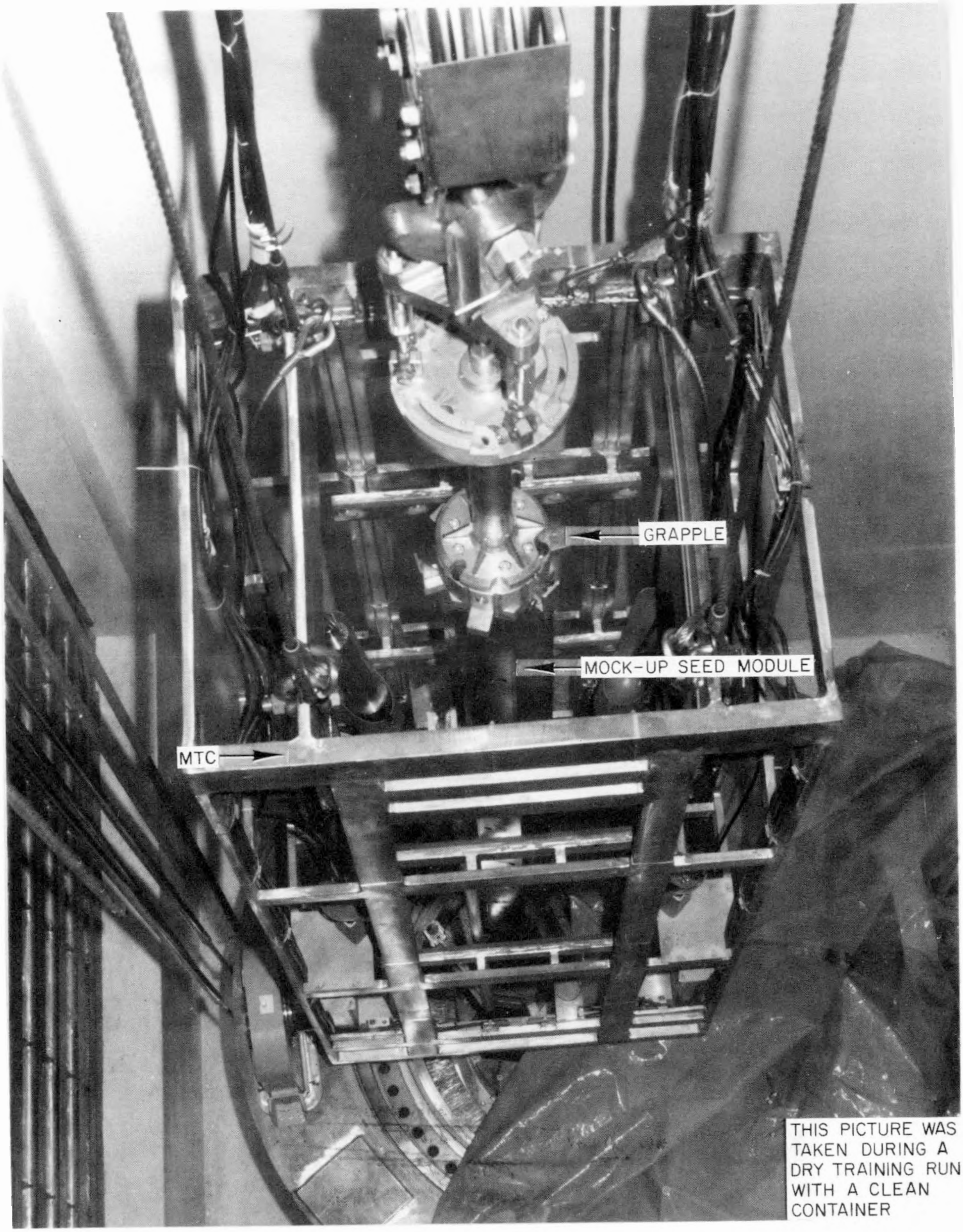

Figure 17. LWBR Module Transfer Cage and Fuel Module Grapple

3.6.4 - The Module Transfer Cage

The module grapple was located inside a special drop protection device called the module transfer cage (MTC), which was suspended from the bridge crane independent of the grapple. The MTC was used for all transfers of vertically-oriented LWBR fuel assemblies. It was specifically designed to catch the fuel module if the grapple should fail. Suspending the MTC from the bridge crane trolley ensured an adequate distance between the LWBR fuel module inside the MTC and other fuels outside during transfer operations. Two MTCs were available in the LWBR program; however, only one was used. Either MTC had the capability to be suspended from and conveyed by either of the two ECF water pit bridge cranes.

The MTC, shown in Figure 17, was an open, stainless steel framework, approximately 4 feet square and 12 feet tall. It was hung from the bridge crane trolley by stainless steel wire ropes and turnbuckles at a fixed elevation above the storage and disassembly stands. It was open at the top and had hydraulically operated doors at the bottom through which the fuel was raised and lowered.

The module grapple, attached to the bridge crane hoist, was lowered through the open MTC doors, secured onto a fuel module adapter plate by the grapple operating tool, and raised back into the MTC. The fuel module elevation above the MTC doors was controlled by a limit switch on the bridge crane. After the MTC doors were closed and locked, the module was transferred within the water pit. Once at its destination, the doors were unlocked and opened allowing the bridge crane hoist to lower the module. The grapple operating tool, secured within the MTC, unlocked the grapple. Typically, one module was transferred per shift.

When the MTC was installed on the bridge crane, several electrical interlocks were activated which limited bridge and trolley motion, hoist speed, and the hoist upper limit. The lift capacity of the hoist was also limited while the MTC was attached to the trolley. When not in use, the MTC was commonly stored on one of two storage racks attached to the south water pit wall.

3.6.5 - The Light Water Breeder Reactor Fuel Storage Racks

Two storage racks were installed in the water pits to accommodate the storage of the 39 modules (see Figure 18). The storage racks were the first stop for the fuel modules after removal from the M-130 containers. The storage racks provided radiologically safe, temporary storage for the LWBR modules. Each rack had 24 ports, and all 12 blanket modules were stored in one rack along with 12 reflector modules. This ensured that no seed modules were stored in the same rack with blanket modules. The 12 seed modules and the remaining 3 reflector modules were stored in the second rack. Seven of the nine remaining ports were used to store fuel rods in special rod storage liners after the rods had been removed from the modules. Figure 19 shows the fuel module storage locations within the storage racks. Prior to any module being placed inside, each port was equipped with a module-specific storage liner.

Storage liners were right circular cylinders, made of stainless steel, 25.5 inches in diameter and 158 inches in height. A storage liner was required for each of the 39 core modules, as well as seven additional storage liners for fuel rods removed from selected modules during the evaluation program. The liners, in conjunction with the storage racks, provided a temporary storage containment for the modules and removed rods. Six different types of storage liners were required to correspond to the six fuel module types (i.e., Blanket I, II, and III, Reflector IV and V, and Seed). Externally, the liner bodies were identical, but the module supports and crush blocks inside were unique for each type. Seed liners, with a rod storage insert, were used for the removed fuel rods. At the conclusion of the core evaluation program, the liners served as long-term fuel storage liners. Refer to Section 3.14 for more information on long-term fuel storage.

Installation guides, as shown in Figure 20, were required to load all modules into the fuel storage liners. Six guides were used, one for each of the six module types. A guide was positioned on the storage rack by aligning a key into a keyway, thus ensuring the proper positioning of the module.

Figure 18. LWBR Fuel Storage Racks

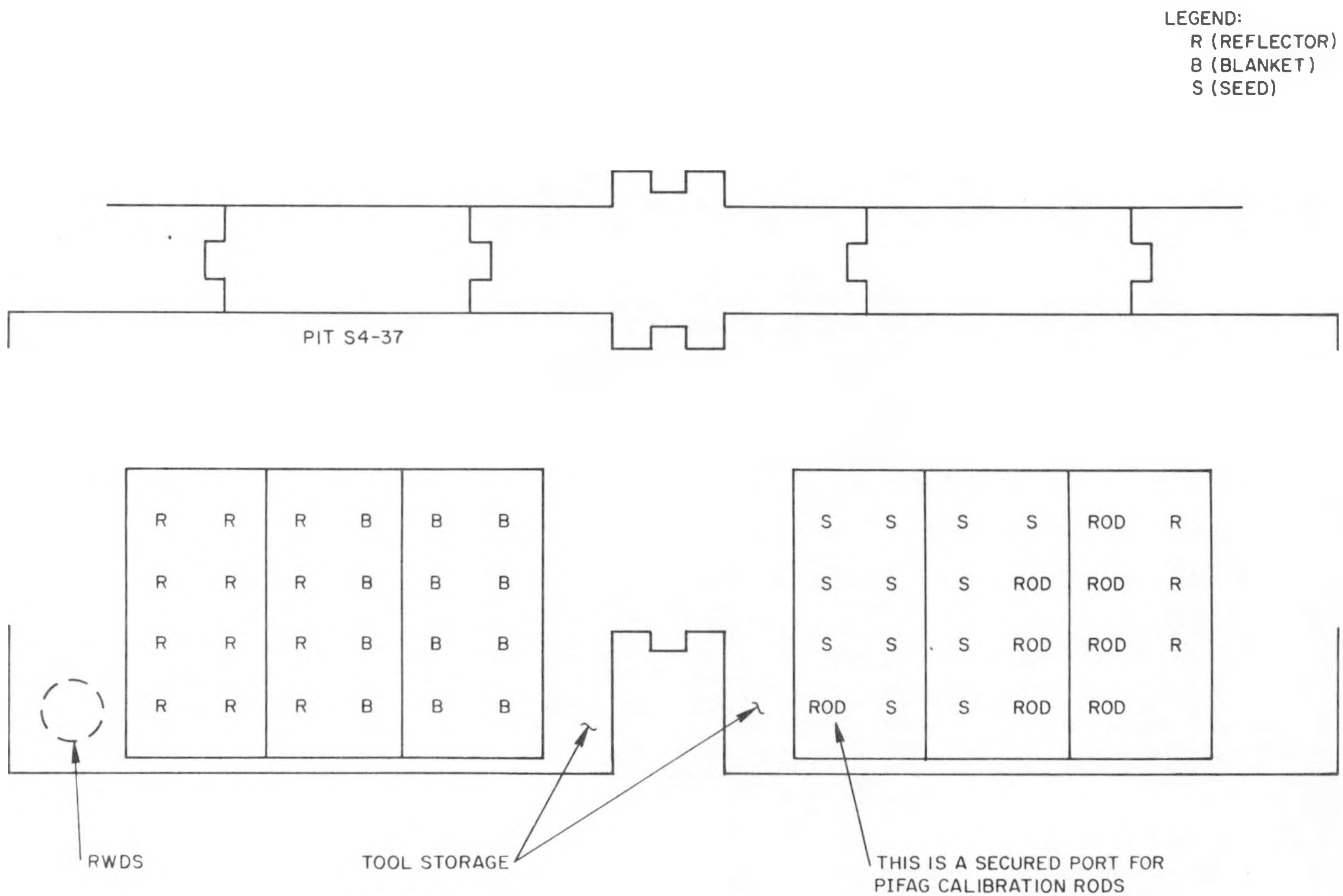

Figure 19. LWBR Fuel Storage Rack Configuration

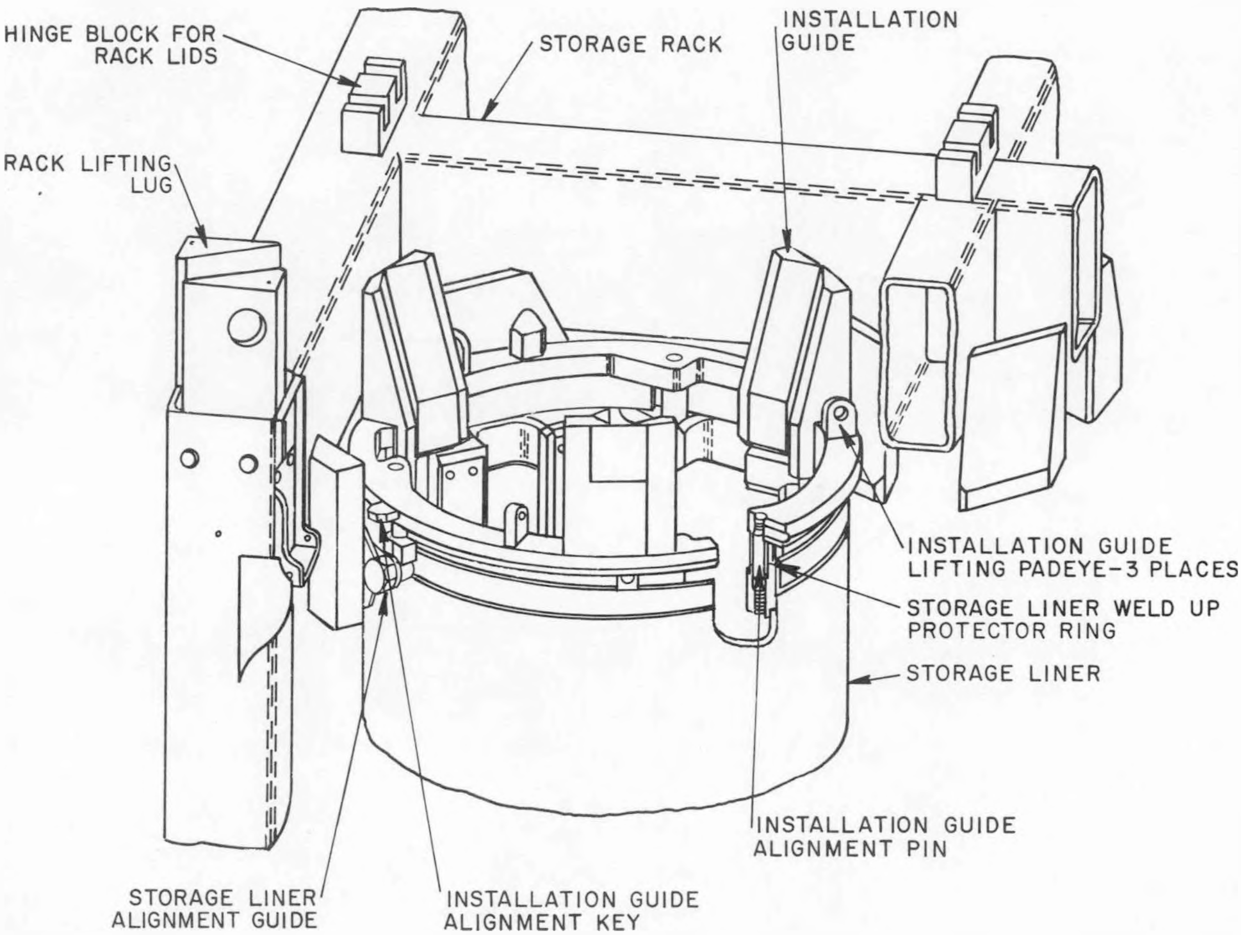

Figure 20. LWBR Module Installation Guide

3.6.6 - Preparation of the M-130s for Return Shipment

After the modules had been removed from the M-130 container, the module restraints and plugs were re-inserted and secured in the cask for use in subsequent shipments. The closure head was reinstalled and the container was raised from the water with the overhead crane. All underwater assembly operations were performed with the same tools as used for disassembly but in the reverse order. Water was drained from the interior of the container with the support system, described in Section 3.6.1. The lifting hardware and the containment equipment, installed before submersion, were removed and cleaned. The lubricated closure head bolts were installed, and the container was thoroughly surveyed for radioactive contamination and cleaned as necessary before it was reinstalled on the railcar. After the container was secured on the railcar, safety and radiological inspections were performed on both the car and container. Approximately 13 shifts were used in accomplishing the return shipment preparations.

3.7 - MODULE VISUAL STATION/VERTICAL INSPECTION GAGE

The module visual station (MVS) supported as-received fuel modules for visual and dimensional examinations of the module surfaces. Figure 21 shows the MVS as it was stationed in the water pit. A total of 13 modules were examined with the MVS: three reflector; five blanket; and five seed. Table 2 lists the specific modules that were examined at the MVS. Examinations were performed to gather evidence of cracks, marks, corrosion, and crud deposits as well as to measure module length and bow and rod-to-rod gaps. See Reference 3 for more detail on the MVS.

The MVS had three ports; the center port being the one that could hold a module. Only a module in the as-received condition (i.e., prior to having the ends cut off) could be inserted in this port. The module rested on a vertically-moving floater, which was a support designed to provide hydraulic drag and cushioning in the event of a module drop accident. The other two cavities were canisters which served as additional temporary storage ports for module and rod storage liners, rod caddies, or rod boxes, as discussed in Sections 3.6.5 and 3.11.

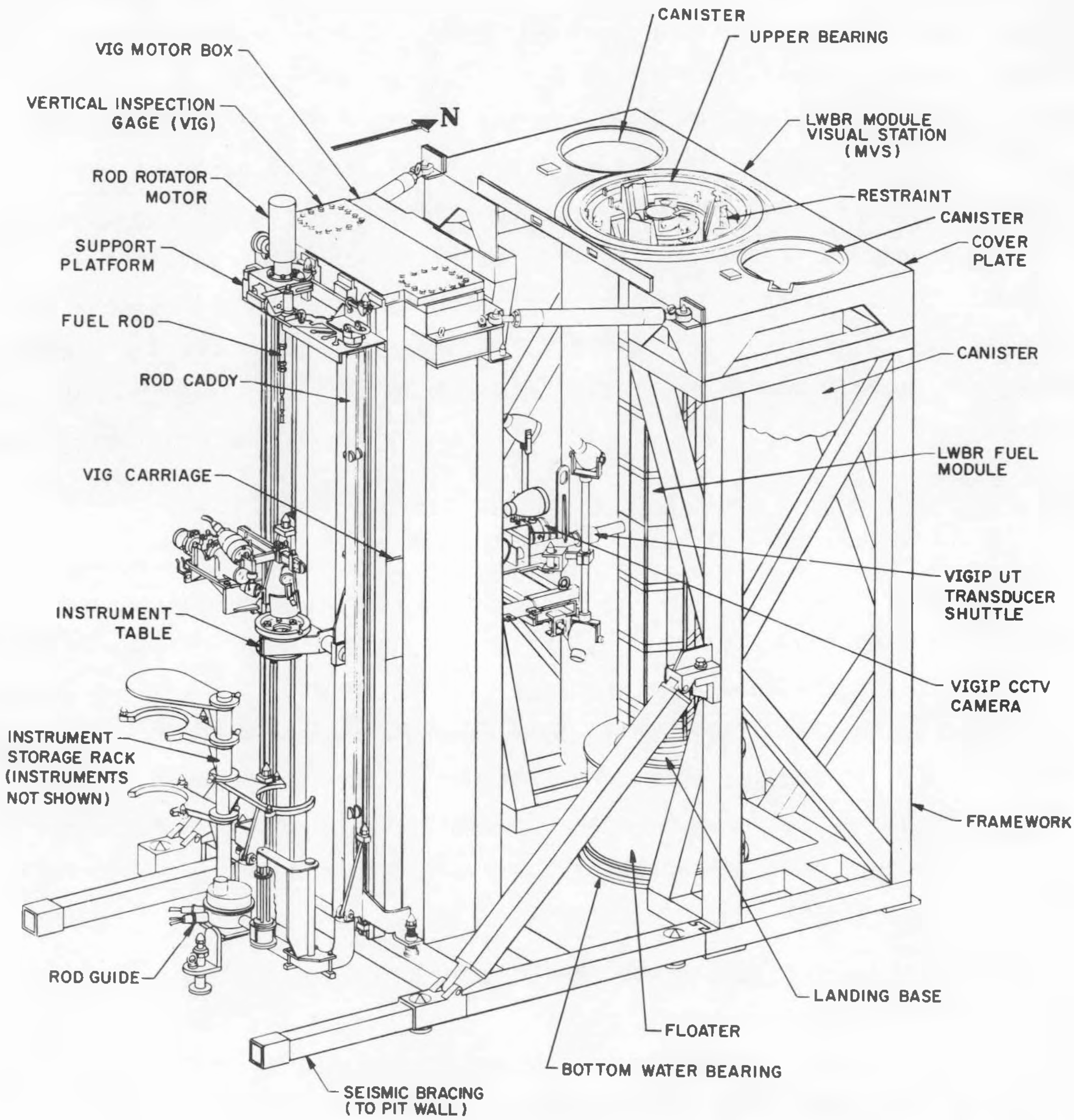

Figure 21. LWBR Module Visual Station and Rod Examination Equipment

Table 2 - LWBR Modules Examined/Disassembled at ECF

Module Core Position	Module Serial Number	Examination at MVS	Disassembly at MDA	Rod Pull at RRS
SI-1	L-BB01-04	Yes	Yes	33 POB 4 contingency 14 REX
SII-1	L-BB01-09	Yes	No	
SII-3	L-BB01-13	Yes	Yes	34 POB 4 contingency 8 REX 82 grid access
SIII-1	L-BB01-07	Yes	Yes	34 POB 4 contingency 5 REX
SIII-2	L-BB01-08	Yes	Yes	33 POB 3 contingency 3 REX
BI-1	L-GR01-01	Yes	No	
BI-3	L-GR01-03	Yes	Yes	36 POB 5 contingency 11 REX
BII-2	L-GS01-03	Yes	Yes	65 POB 9 contingency 12 REX

Table 2 (Cont)

Module Core Position	Module Serial Number	Examination at MVS	Disassembly at MDA	Rod Pull at RRS
BIII-2	L-GT01-02	Yes	Yes	75 POB 10 contingency 10 REX 296 rod gap and grid access
BIII-3	L-GT01-03	Yes	No	
BIII-6	L-GT01-06	No	Yes	75 POB 9 contingency
RIV-3	L-RA01-10	No	Yes	28 POB 5 contingency 1 REX
RIV-4	L-RA01-09	Yes	Yes	29 POB 5 contingency 5 REX 38 rod gap
RIV-9	L-RA01-03	Yes	Yes	48 POB 8 contingency 1 REX
RV-4	L-RB01-08	Yes	Yes	34 POB 3 contingency

Before a module was installed into the MVS center port, preparations to receive the module had to be completed on the MVS. Visual confirmation was required to ensure that a module was not already in the center port. A cover was placed over either of the two side canisters if fuel was stored there in cassettes, rod boxes, or rod caddies. Next, a landing adapter which corresponded to the module type to be received was placed on the floater. A compatible module restraint, which held the module securely in place during MVS operations and served as a guide during module installation, was installed over the landing adapter. Both the landing adapter and the module restraint were transferred from storage to the MVS by the bridge crane. A technician using a probe-offset assisted in the placement and removal of the rigging. As a final step, the module restraint was rotated with a probe pole so that its orientation matched that of the incoming module.

The module was then lifted into the MTC from the storage racks, transferred to the MVS, and lowered into the center port. Once in position, the module was rotated manually using a probe with a socket for examination.

After the module was installed in the MVS, a visual examination was done to determine module length by sighting on specific reference points. Rod-to-rod gap measurements were done on blanket modules immediately following the visual examination because these modules had no external shell surrounding the rods. Module bow measurements were performed next in the MVS sequence, and, in many cases, this was the last required examination. However, special examinations, such as wear pad or guide post visuals or repetitions of any of the above mentioned tests, were performed last.

The various examinations of the modules were accomplished with the vertical inspection gage (VIG) and appropriate instruments. The VIG provided a precisely-controlled underwater moving platform with one axis of motion in the vertical direction. An instrument package, called the vertical inspection gage instrumentation package (VIGIP), was attached to the VIG elevator platform. This package contained a CCTV, five lights, and an ultrasonic proximity probe for the examinations. All VIGIP operations were controlled by a technician from a console in the observation room.

At the conclusion of all module examinations at the MVS, the module was raised into the MTC and transferred back to the storage racks.

3.8 - MODULE DISASSEMBLY APPARATUS

The module disassembly apparatus (MDA) was a large, underwater milling machine capable of supporting an entire module and using two different working heads: the band saw and the millhead. The band saw, referred to as the cut off system (COS), was used to cut through the baseplates of the LWBR modules, severing structural components which, when removed, allowed fuel rod extraction. The millhead performed drilling, shell slitting, and milling operations on selected modules, so that shell sections and various pieces of hardware from the module could be obtained for visual and metallographic examination. Figure 22 shows the MDA with the milling head attached. See Reference 3 for more detailed information.

Top and bottom ends of 12 modules were cut off by the COS to gain access to the fuel rods for rod pull operations. Modules disassembled at the MDA by the COS are listed in Table 2. Two of the modules, a reflector and a seed, were further disassembled by the millhead. One-half of the shell was removed from the reflector module to allow rod-to-rod gap visual examinations, and the shell half was visually examined for evidence of wear and corrosion. The shell from the seed module was split in half, removed, and both sides examined visually. Removal of the shell provided access to portions of the grids. Seed module grid sectioning occurred after the necessary fuel rods had been extracted. Two sections of the seed grid were cut out, visually examined, dimensionally measured, and the spring stress relaxation force measured. One section, which was cut into smaller sections, was shipped to Argonne National Laboratories-West (ANL-W) for metallography tests.

All operational work on the MDA equipment was done over the water pit with hook and lanyards or with probe poles equipped with specialized ends such as offsets or deep-well sockets. To assist in viewing the work in progress, underwater cameras were positioned at the work area, and lights were set up as

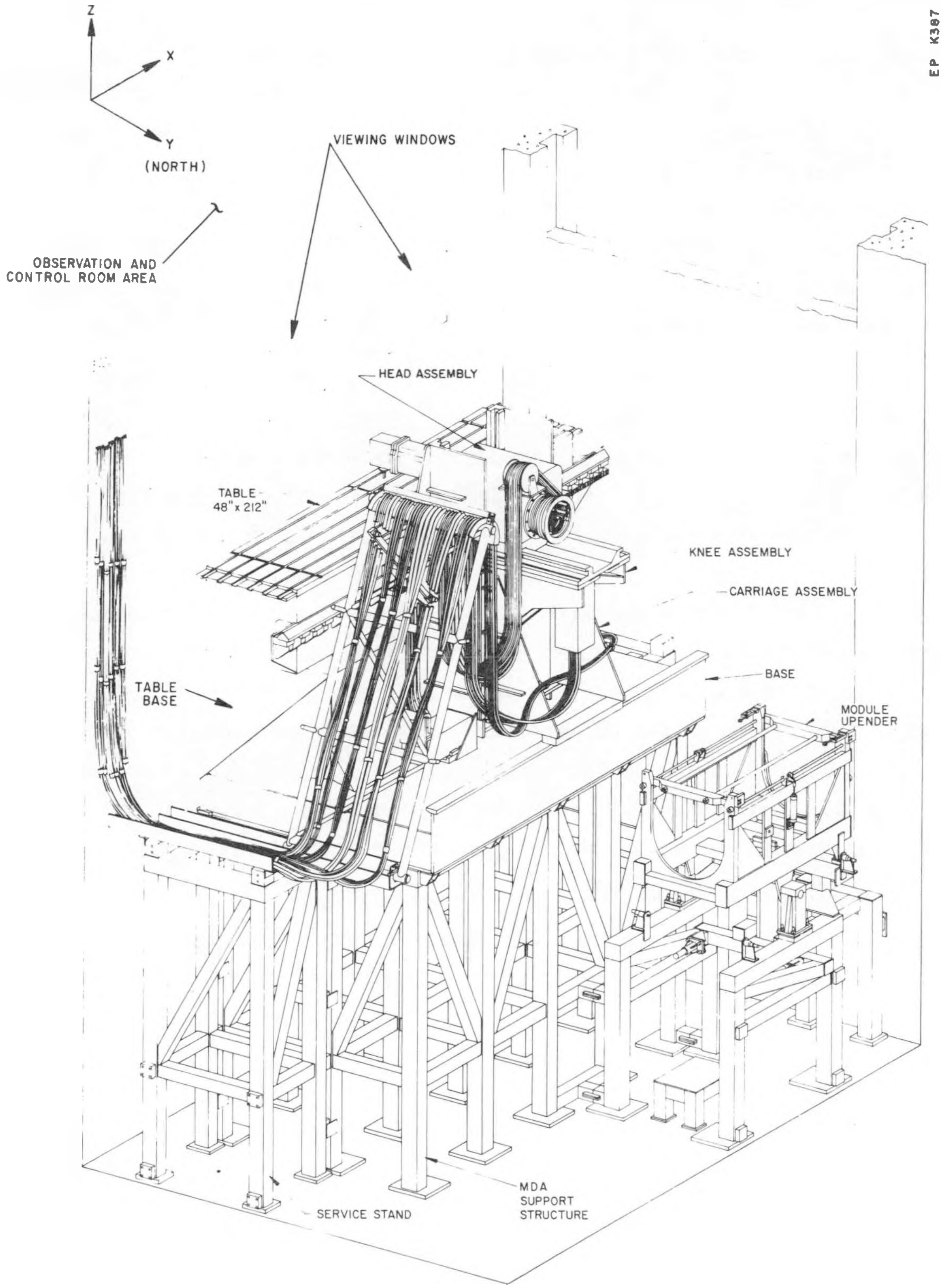

Figure 22. LWBR Module Disassembly Apparatus

needed. One or more CCTV monitors were normally stationed at the MDA console located in the observation room. When necessary, another monitor was positioned on the water pit beach so that the technician performing the work could view the operation. The MDA was stationed next to three observation room windows through which a technician could watch the actual machining operations while operating the MDA control console. Continuous communication was maintained between the technicians in the observation room and those over the water pits with an intercom system.

Conversion of the MDA to the cut-off or the millhead configuration was done prior to moving any fuel into the MDA water pit. Both the overhead and bridge cranes were required to exchange the millhead and the cut-off head. Each head had a network of electric and pneumatic cables connecting them to their respective control consoles. All cables had to be lifted and moved as the heads were exchanged; this was done with probe poles or lanyards for the lighter groups of cables and with a bridge crane hoist for the heavier sets. These conversions included operational checkouts of the hydraulic, electrical, and pneumatic systems and required approximately six shifts of effort. A new blade was installed on the COS prior to each module cut and during the cut as required. The new blade was pre-mounted on an aluminum framework, lowered into the water, and transferred onto the COS remotely. Tools for the millhead were exchanged as necessary depending on the required operation.

The module utility fixture (UF), shown on Figure 23, was a large, module-handling fixture which supported the module during MDA operations. Two UFs, identical except for the internal support structure, were employed: one for the reflector modules and one for both the seed and the blanket modules. When not in use, both utility fixtures were stored vertically in a storage rack in the water pit. Either the overhead crane or the bridge crane was used to transfer the UF required for the next module machining operations from the storage rack to the upender. The upender, shown in Figure 24, was located in the same water pit as the MDA and was used to rotate the module from the vertical to the horizontal or the reverse. To install the UF in the upender, a hydraulic gate was opened, the UF was set in place, and the gate was closed and locked.

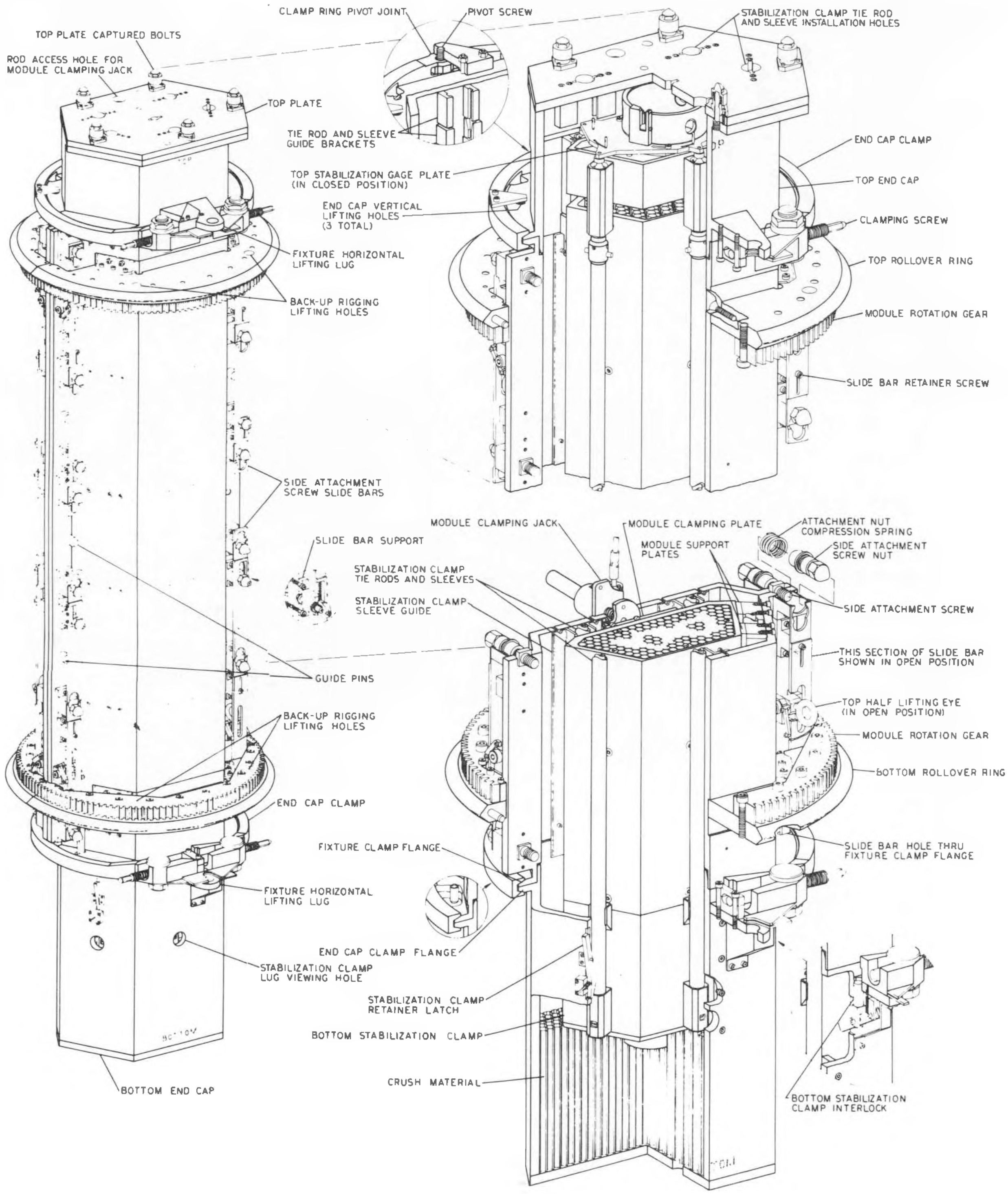

Figure 23. LWBR Module Utility Fixture

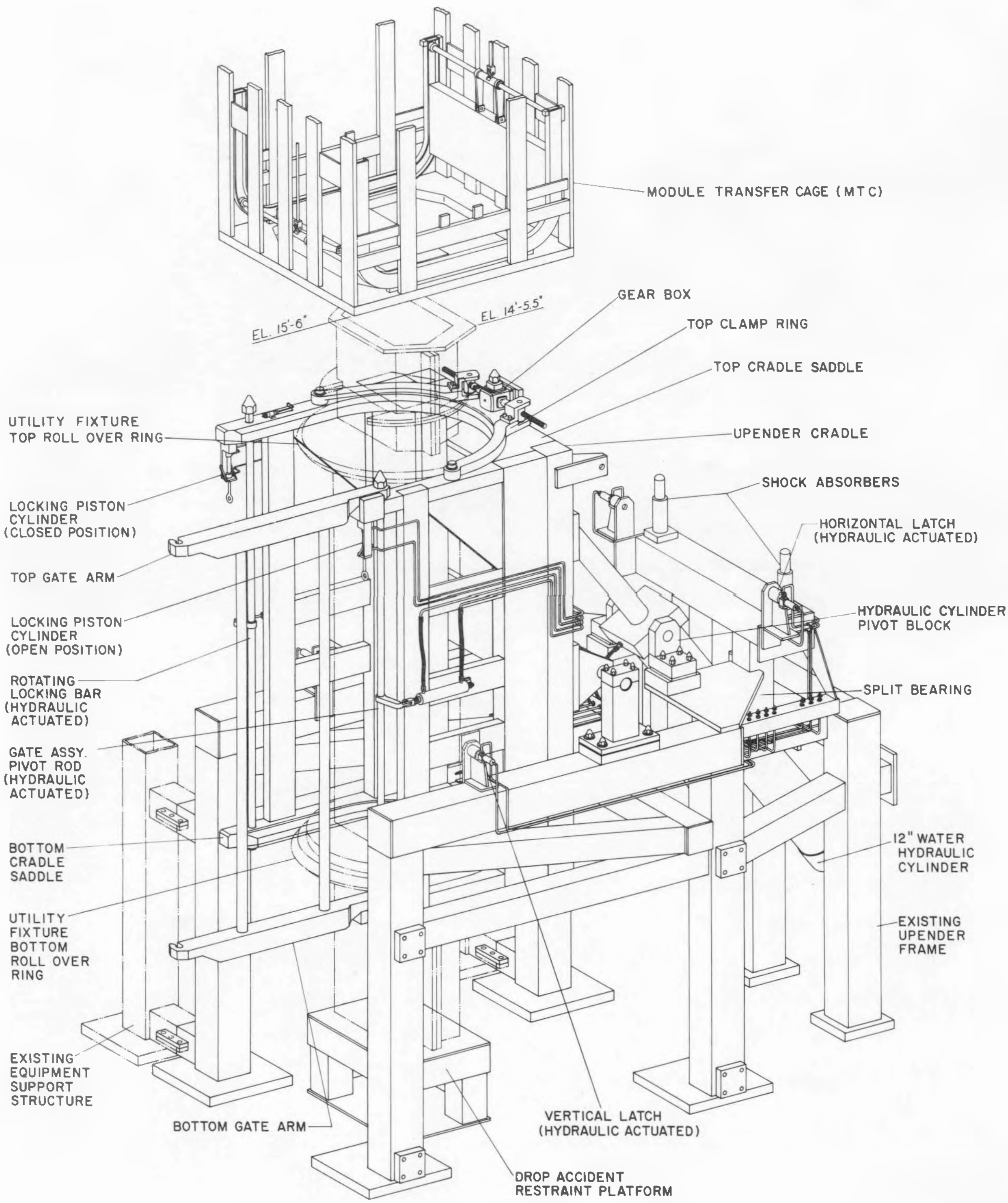

Figure 24. LWBR Module Upender Assembly

Prior to installing a module in the utility fixture, the internal configuration of the UF had to be changed to accommodate the scheduled module. Changing the internal configuration included adjusting end cap guides, removing or installing the main body inserts which supported and guided a module along the length of each side, and installing top end cap guides. Once the UF was reconfigured, the module was discharged from the MTC vertically into the UF, and the UF top end plate was set on the UF top end cap and secured in place.

The upender was then rotated to the horizontal position. The horizontal grapple (HG) was used in conjunction with a bridge crane to transfer the module-loaded UF. This grapple was a large, horizontal beam fitted with a lug on the top surface which could be adjusted axially to provide a level lift of the UF, as shown in Figure 25. Adjustments, made by a technician with a probe pole, were necessary since only two UFs were in use for the six module types. The horizontal UF containing the module was installed in the holddown and rotation fixture (HDRF) which was mounted on the bed of the MDA. The HDRF, as shown in Figures 26 and 27, was able to raise and lower the UF as well as rotate the UF about its longitudinal axis to position the module in the desired orientation for machining. The only allowable horizontal module moves were between the upender and the MDA operating table, and the HG was required to make the transfer. All other module moves were vertical.

Once the module was in place, the HG was released and was stored on a rack mounted in the adjacent water pit. The UF was disassembled to allow access to the module. For cut-off operations, the two end caps were removed; for shell milling, the UF was separated longitudinally. Times for the cutting and milling operations varied depending on the type of machining required. Top and bottom COS module end cuts took approximately 18 to 22 hours per cut to complete. Remnants from both the top and bottom ends of modules SII-3, RIV-4, and BIII-2 were retained for further visual examinations.

After the module ends were severed, the UF was positioned for installation of the bottom and top UF end caps. During COS operations, the bottom stabilization clamp was staged inside the unattached bottom UF end cap. The

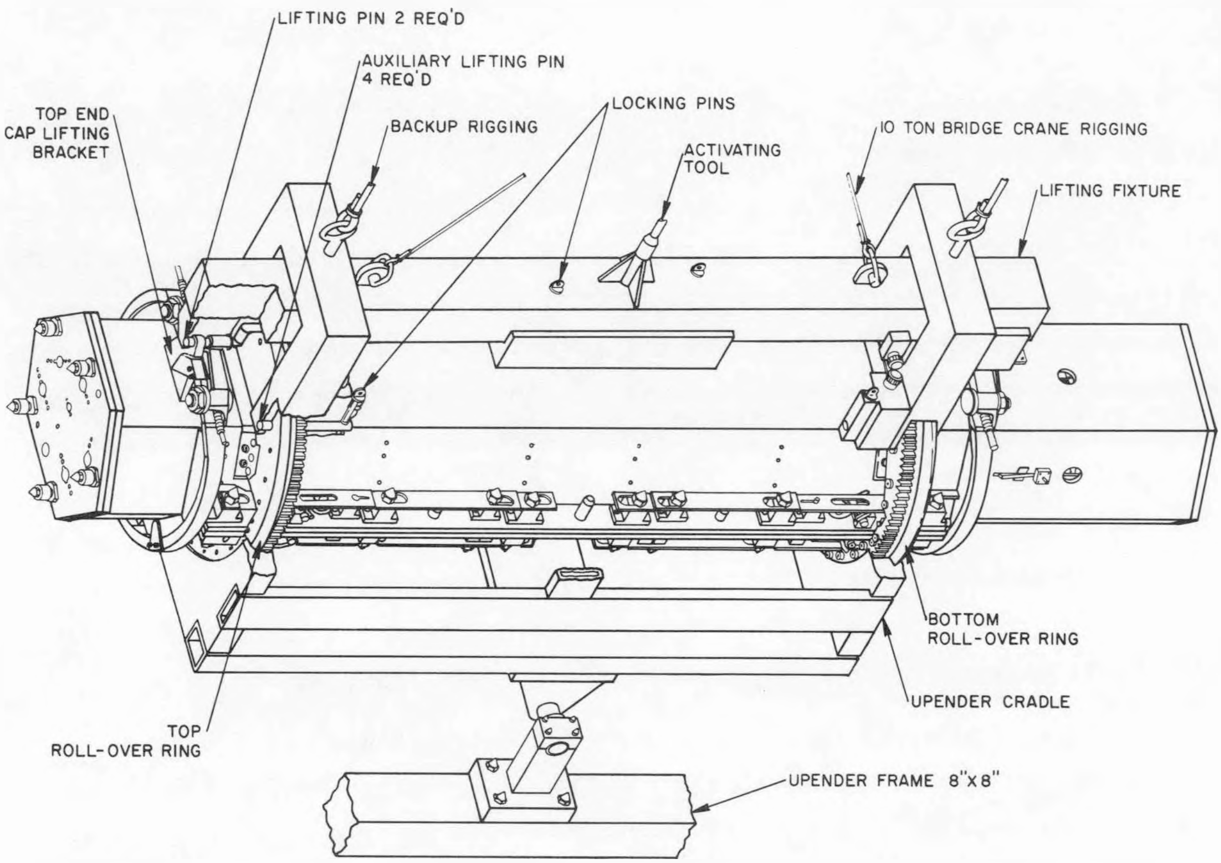

Figure 25. LWBR Module Utility Fixture Horizontal Grapple

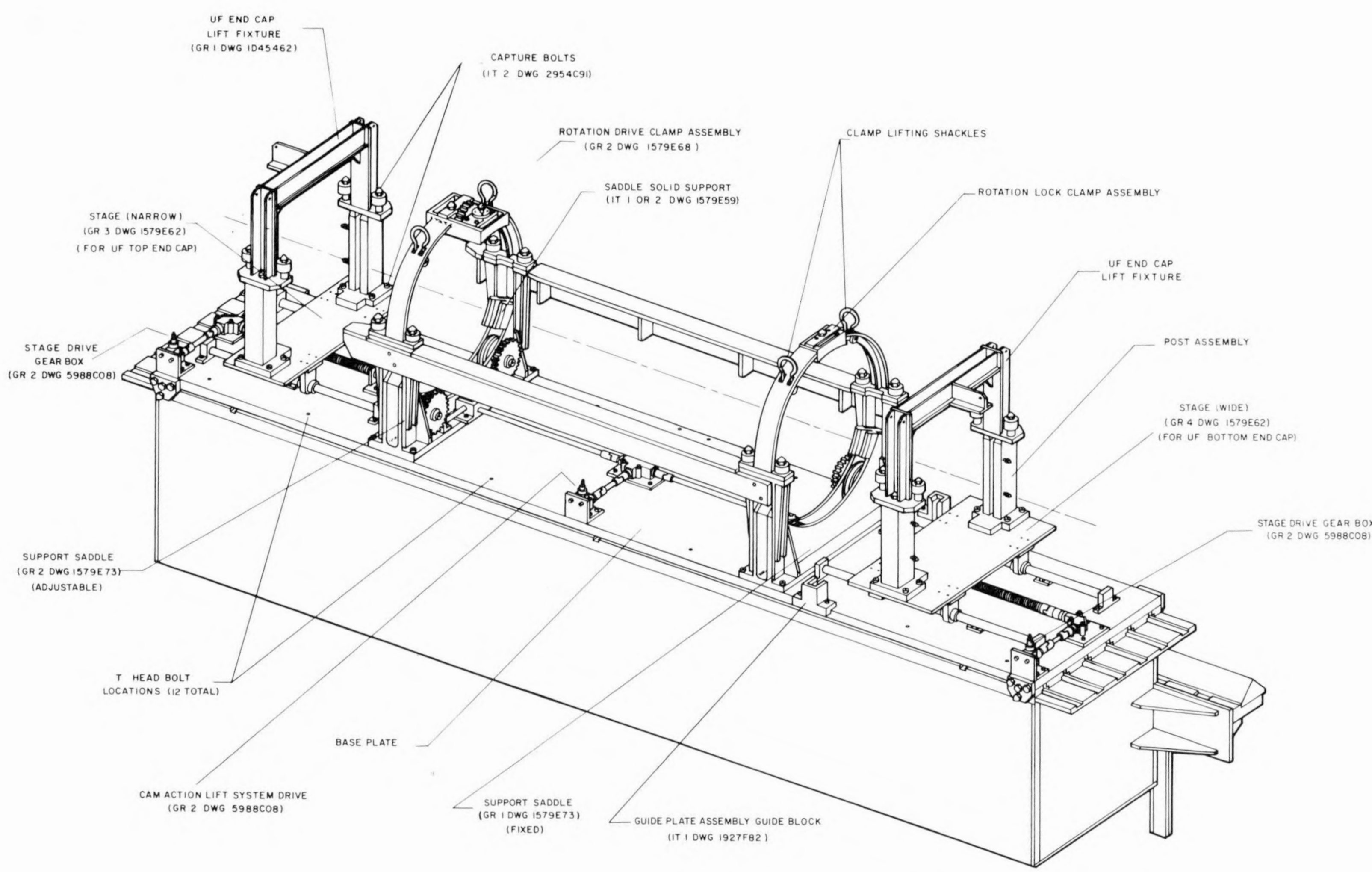

Figure 26. LWBR Module Utility Fixture Holddown and Rotation System

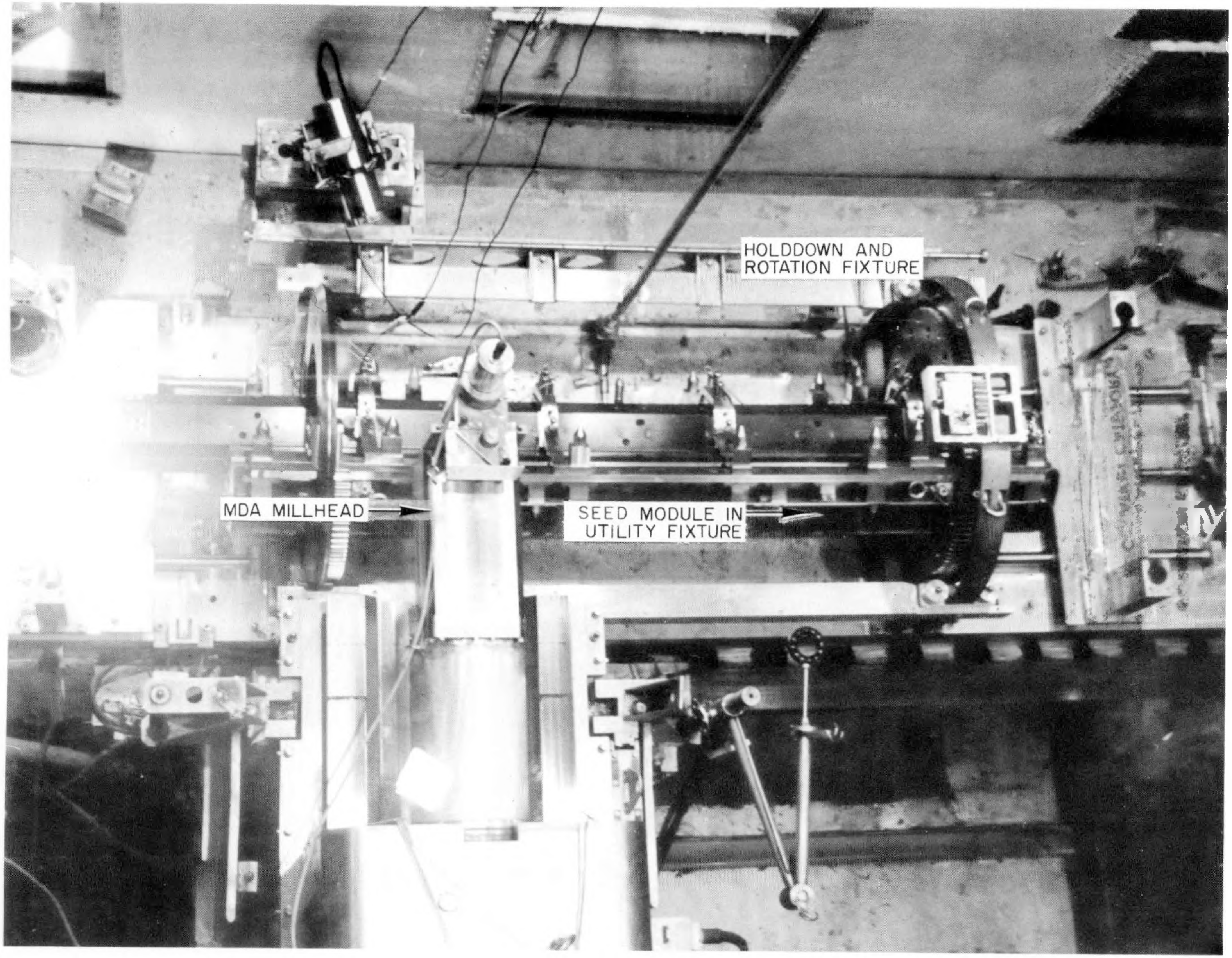

Figure 27. LWBR Holddown and Rotation Fixture in Operation

stabilization clamp consisted of an assembly of tie rods, compression sleeves, and top and bottom clamps which secured the module after the structural members were severed by COS operations. Figure 28 depicts a typical stabilization clamp. When the UF bottom end cap was installed on the module, the stabilization clamp automatically was set in place. With the UF top end cap installed, the HG lifted and transferred horizontally the UF from the HDRF on the MDA table to the upender. The upender was then rotated to the vertical position. The UF top end plate was removed from this end cap; tie rods and compression sleeves were installed along each side of the module into the bottom stabilization clamp. The top stabilization clamp was installed, and the tie rods bolted to it. Lifted vertically out of the UF, then into the MTC, the module was transferred either to storage or directly to the RRS for rod pull operations.

3.9 - VERTICAL DISASSEMBLY STAND/ROD REMOVAL SYSTEM

The vertical disassembly stand (VDS) held the modules securely during rod removal operations. The VDS, operationally similar to the MVS, was designed to accommodate modules with both ends cut off and fitted with stabilization clamps. During rod removal, which was performed at the rod removal system (RRS), modules and auxiliary equipment, including rod storage liners and rod cassettes, were positioned at the VDS. A cassette, which held a maximum of four fuel rods, was a strongback designed to handle rods safely and to interface with the PIFAG for individual fuel rod assay examination. (Refer to Sections 3.11 and 3.12 for a description of the rod cassettes and the PIFAG, respectively.) The RRS was located directly above the VDS as shown in Figures 29 and 30 (see Reference 4).

Only stabilization-clamped modules were inserted into the VDS; these modules were transferred either from storage or directly from the COS. Prior to module insertion in the VDS, a clamping ring was installed over the module port. The purpose of the ring was to secure the module in place during VDS/RRS operations. When not in use, clamping rings were stored vertically on a hanger in the water pit; a different type of clamping ring was used for each type of module. The bridge crane hook lifted and transferred each clamping

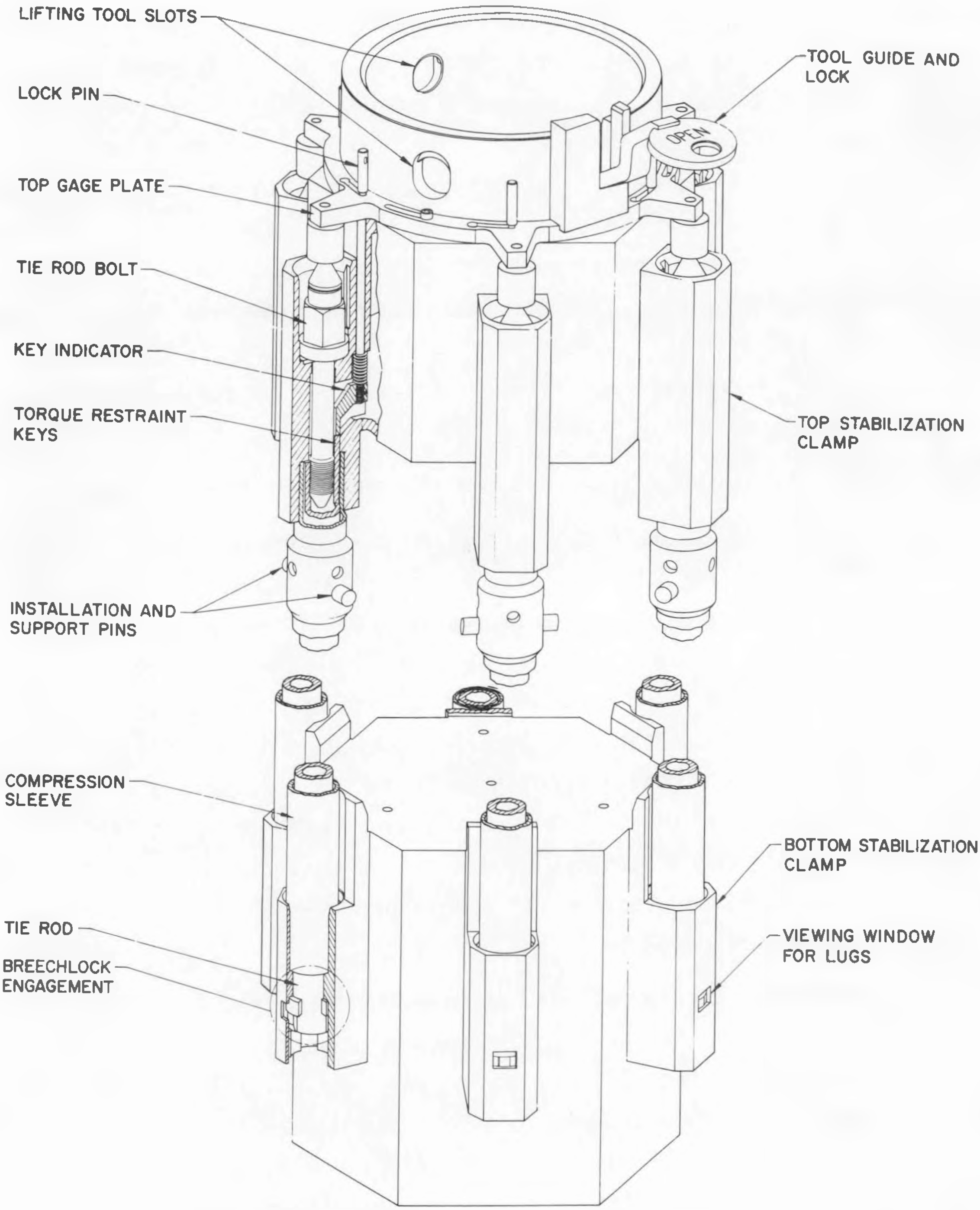

Figure 28. LWBR Seed Module Stabilization Clamp Assembly

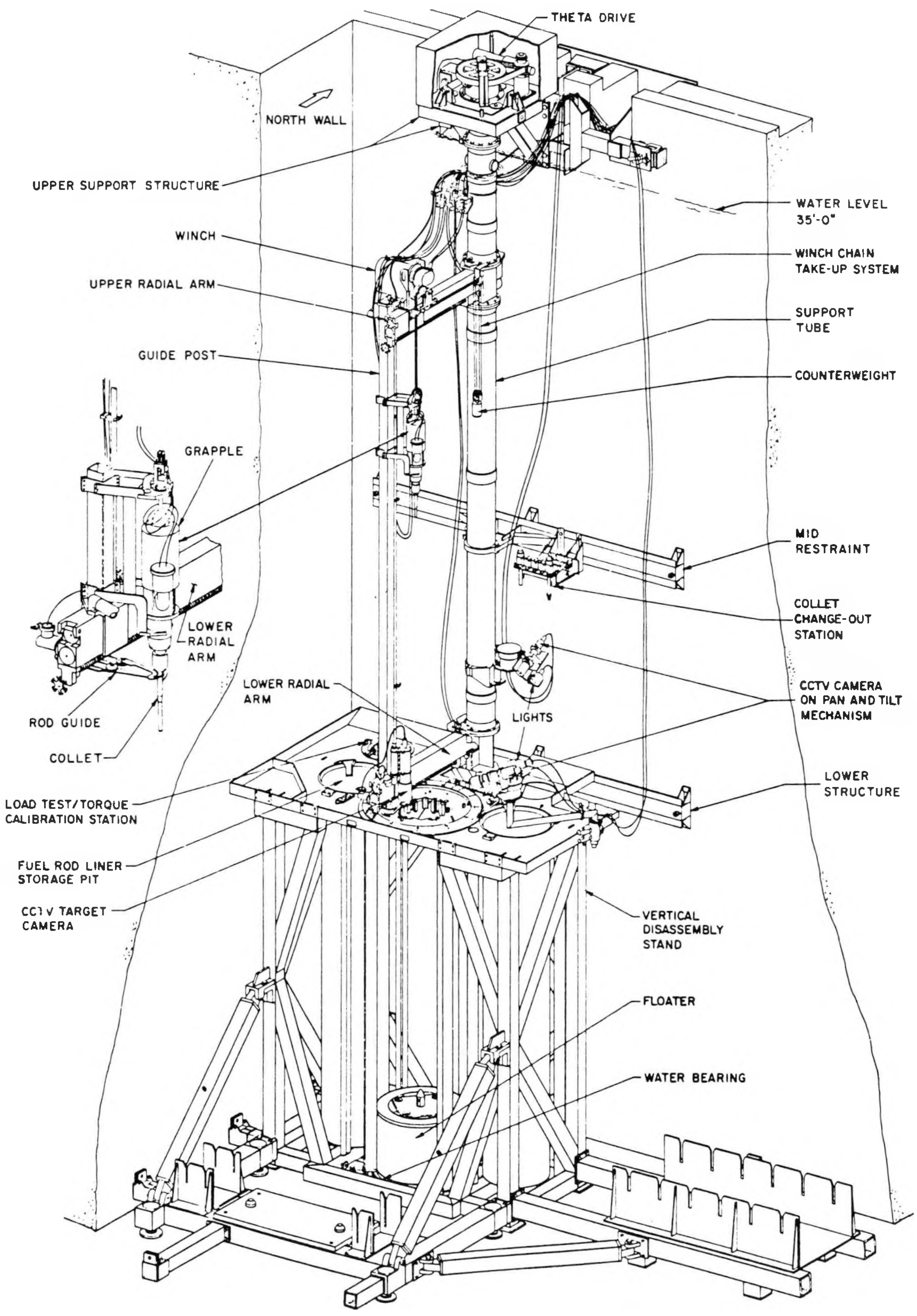

Figure 29. LWBR Rod Removal System and Vertical Disassembly Stand

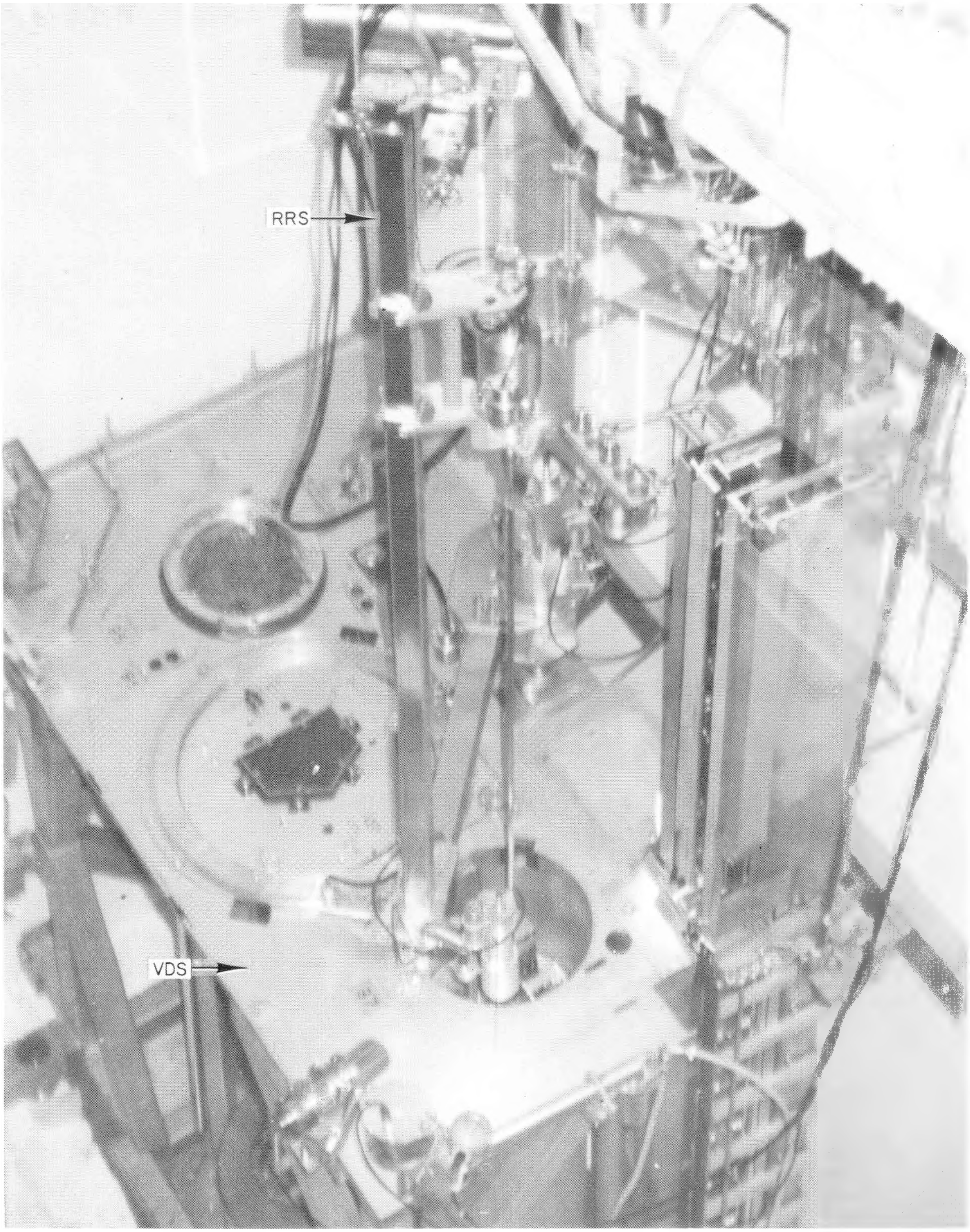

Figure 30. LWBR Rod Removal System and Vertical
Disassembly Stand in Operation

ring from storage to the VDS, and a technician, using a probe-offset, assisted in the placement of the ring and removal of the rigging. An installation guide, which was used to guide the module into the port and was designed to correspond to the module type, was installed on top of the clamping ring. This guide was moved and installed in like manner to the clamping ring (i.e., the bridge crane hook was used to move it, and a technician helped with the installation). The rigging was not removed from the installation guide, but the three slings were laid radially away from the ring. As a final step, the clamping ring and installation guide were rotated by a technician with a probe pole to match the orientation of the incoming module.

For blanket and reflector modules, the next operation at the VDS was to install a set of three jacking blocks called the top inner baseplate remnant removal tools. These jacking blocks were used to remove the top inner baseplate remnant from a module so that the rods could be accessed. The inner remnant was that portion of the baseplate left on the module after the end was severed at the COS. Probe poles with appropriately-sized sockets were used to transfer and install the jacking blocks. One technician was stationed at the television monitor in the RRS operator's console, shown in Figure 31, located on the beach adjacent to the VDS water pit. Another technician manipulated the probe poles over the module. The technician watching the work on television was able to verbally direct the actions of the technician over the water. After the jacking blocks were installed, they were manipulated with probe poles to accomplish uniform separation of the baseplate remnant from the module. A three-legged sling arrangement was used to remove the remnant.

Jacking blocks were not used on the seed module remnants because the module cross-sectional area was not large enough to accommodate the blocks. Rather, three equally-spaced flow holes were threaded with a probe pole fitted with a tap and T-handle. Three eyebolts were then installed in the tapped holes with a probe-offset, and a three-part sling arrangement lifted the remnant from the module. Top inner baseplate remnants from modules SII-3, RIV-4, and BIII-2 were set aside to be examined visually in the hot cells. All other inner remnants were scrapped after removal.

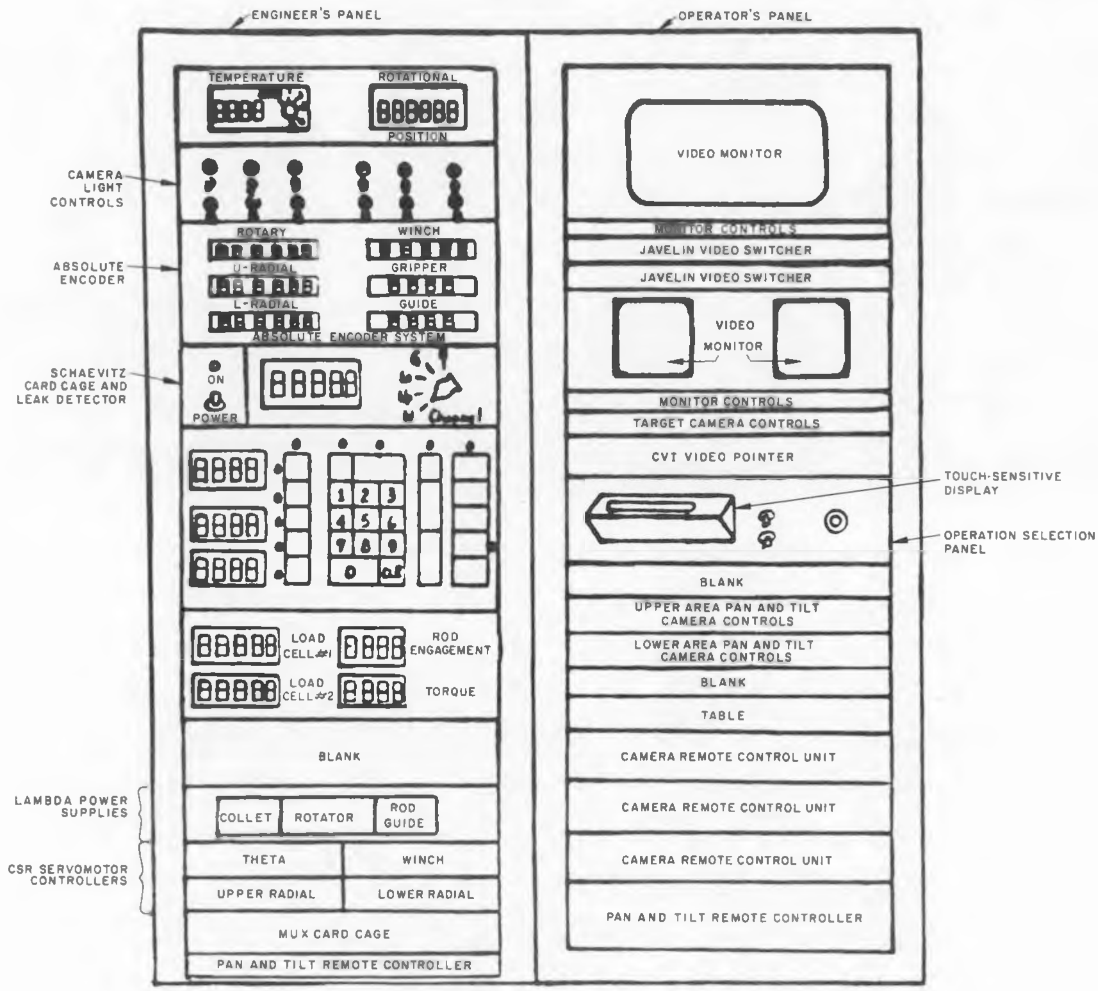

Figure 31. LWBR Rod Removal System Control Console

In preparation for rod pulling operations, a rod storage liner or a cassette, or both, had to be staged in the VDS. All moves of a rod storage liner, as with a module, required the MTC. The liner was grappled, lifted into the MTC, and lowered into the west port of the VDS. A key on the rod storage liner was aligned with a keyway in the port to achieve proper orientation.

Before a cassette was installed in the VDS, shrouds had to be inserted into each of the four ports. A shroud was an external casing for the fuel rod which provided PIFAG handling capabilities along with added protection. The cassette was rigged with a cassette grapple and raised to, but did not break, the surface of the water. Meanwhile, the shrouds were prepared at a workstation on the beach by a water pit technician. The shrouds were inspected for damage and manufacturing defects, were checked to ensure that they were the type required for the rods scheduled to be pulled (i.e., seed, blanket, or reflector), and were then trial fit with a spare PIFAG chain drive grapple. A plug was then placed into the bottom end of the shroud. This plug provided hydraulic braking for the fuel rod when it was ungrappled from the RRS grappler and allowed to drop the final two to four inches onto the plug. A funnel-shaped adapter was inserted on the top end of the shroud because of the minimal rod-to-shroud clearance. The shroud was then passed to the technician in the water pit area. This technician manually inserted each shroud into the cassette, and the cassette was transferred to and inserted in a VDS port.

Preparations for pulling rods from selected modules first required staging a proper set of collets in the collet changeout station. The technician working over the water used a probe-offset and a lanyard to interchange the collet sets from their storage tray to the changeout station located near the RRS. A different size collet was required for each type of rod.

Meanwhile, the technician working at the console on the beach was required to input information to the computer identifying: (1) the module; (2) the rod storage liner orientations; (3) the serial number of the fuel rod to be pulled; and (4) the disposition of the rod. The technician and computer then progressed through the sequence of rod pulling steps by a series of computer prompted questions and technician responses.

A video tape recording was taken of each fuel rod as it was pulled in order to assess the condition of the rod. When the fuel rod was completely removed, the technician verified the fuel rod serial number. A total of 1075 fuel rods were pulled from 12 modules. Of these fuel rods, 557 were decrudded, shrouded, and examined further; the others were stored.

The RRS was used to pull four categories of fuel rods. Upon completion of fuel rod pulling, the top stabilization clamp was reinstalled, and the module was transferred back to storage in the MTC. Table 2 lists the quantity of fuel rods pulled from each module and the category to which they belong. The four categories were:

1. Proof-of-Breeding (POB) rods -- 524 rods were removed from the module, decrudded, and inserted into the proper type shrouds. They were stored in cassettes until needed for nondestructive examination in the PIFAG (see Section 3.12). An additional 69 fuel rods were pulled for contingency.

2. Examination rods -- 70 rods were removed for additional rod examinations and 53 were examined: 19 were nondestructively examined at ECF; of the remaining 34, 17 were destructively assayed, 12 were destructively examined, and 5 were nondestructively examined for crud characterization at ANL. Sections 3.10 and 3.13 describe the examinations in more detail.

3. Grid access rods -- 82 rods were removed from the SII-3 module to provide access to a section of the seed module grids. These rods were stored in a rod storage liner (see Section 3.8).

4. Rod gap measurement rods -- these rods were removed to facilitate video taping of selected adjacent rods in order to measure the post-operational rod-to-rod distances, see the following paragraph. Rod gap visuals were performed as the 296 rods from the BIII-2 module, the 82 rods from SII-3, and the 38 rods from RIV-4 were removed.

Rod-to-rod gap visual examinations were done at the VDS with a video camera which was secured on a camera elevator platform. Camera lights were also stationed on the platform. The elevator, mounted on the south side of the VDS, operated on a vertical carriage. The force for vertical travel was provided by the bridge crane hook which was rigged to the elevator. Camera vertical height was printed out via a character generator on the television monitor. A water pit technician observed the television monitor on the beach and controlled the camera magnification, focus, iris, and light intensity while also controlling the elevation of the camera with the bridge crane controls. Video tape records were made of each rod-to-rod gap examination, and the modules were rotated, as necessary, to do visual examinations on other sides.

The RRS equipment was also used to transfer rods between cassettes, rod boxes, rod caddies, and rod storage liners. These transfers were made to accommodate the PIFAG and REX examination schedules.

3.10 - ROD EXAMINATION GAGE

The rod examination gage (REX) was an underwater, multigage, remotely-operated, and semi-automated system that performed nondestructive examinations on selected LWBR fuel rods. Refer to Figure 32 and Reference 5 for more detail. All rods examined at the REX were placed into rod caddies at the RRS, which had been prepared to receive the rod. To begin the preparation of a rod caddy, it was transferred vertically to the REX caddy worktable. The caddy could not be stationed vertically on the caddy worktable, because it would have broken the water surface in this position, and, therefore, had to be laid horizontally on the table. Underwater manipulator slave arms were used to open the caddy door and insert a proper size spacer for the designated seed, blanket, or reflector rod. This spacer was necessary to fill the unused space in the caddy since the caddy was longer than the rod. The caddy was then removed from the table and transferred to and inserted into a port of the VDS. The RRS was then used to insert the designated rod into the caddy.

After the rod was inserted in the caddy, the fuel rod and caddy were transferred to and placed horizontally on the caddy worktable. Using the

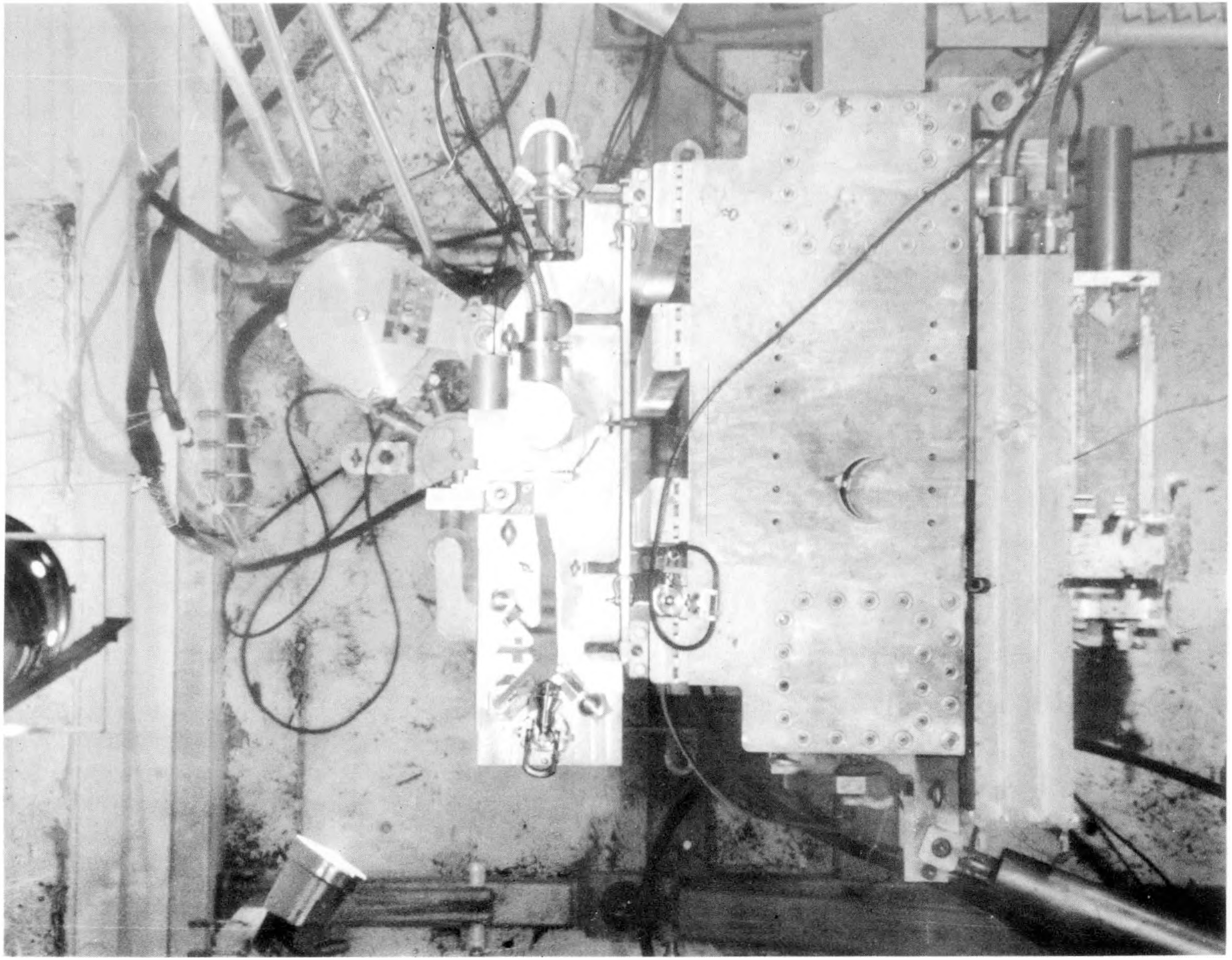

Figure 32. LWBR Rod Examination Gage

slave arms, the technician opened the caddy door to prepare the rod for the REX. A bottom-mounted rod required the installation of a dummy lifting stem, because the built-in stem was at the bottom end of the rod. The top end of such a rod was cleaned out with water by using a probe pole specially fitted with a water jet. A high pressure stream of water was directed into a threaded hole in the top end of the rod to dislodge metal filings from MDA machining or crud particles from the reactor water. A dummy stem was placed into a transfer container and lowered by lanyard to the caddy worktable. The technicians, using slave manipulators and a dummy stem installation tool, aligned the dummy stem and threaded it into the rod top end closure. Figure 33 depicts the installation of the dummy stem. A different installation tool was used for each type of rod (i.e., blanket, reflector, or seed), because each type of rod required a different size dummy stem. When the installation tool with the dummy stem installed was placed into the rod caddy, the stem was automatically centered on the rod. After the stem was threaded into the rod, the installation tool was removed. After installation of the dummy stem, the bottom-mounted rod could be handled as a top-mounted rod until the end of the REX examinations when the dummy stem was removed.

A drop protection wire was installed on all rods. This wire was to provide secondary drop protection for the rod should the collet fail to retain the rod securely. This wire and an appropriately-sized push nut were lowered to the caddy worktable in a container. The loop end of the wire was placed around the rod stem with the slave manipulators. The rod was then clamped in place in the caddy so that it could not turn or slide, and the push nut was installed with a special tool over the rod stem capturing the wire. The needle end of the drop protection wire was momentarily left loose until the collet was attached to the rod.

A collet, which held the rod securely in the vertical position when it was examined or moved, was installed on each rod (see Figure 34). Commonly, two or three collets of each type were stored on the caddy worktable. The type of collet required for the rod being examined was picked up with a slave manipulator and positioned on the end of the caddy. Positioning was critical

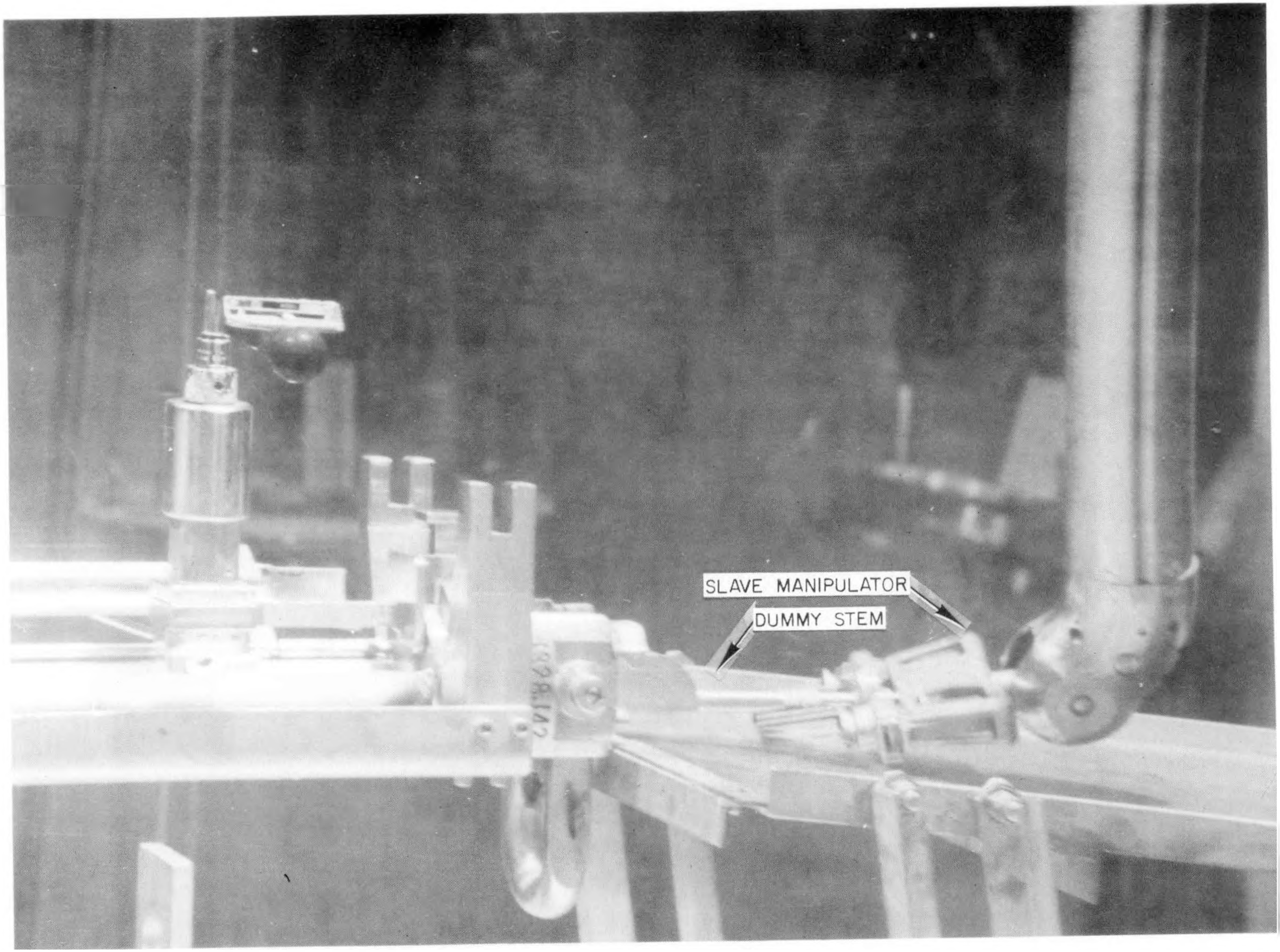

Figure 33. Installation of LWBR Rod Examination Gage Dummy Stem

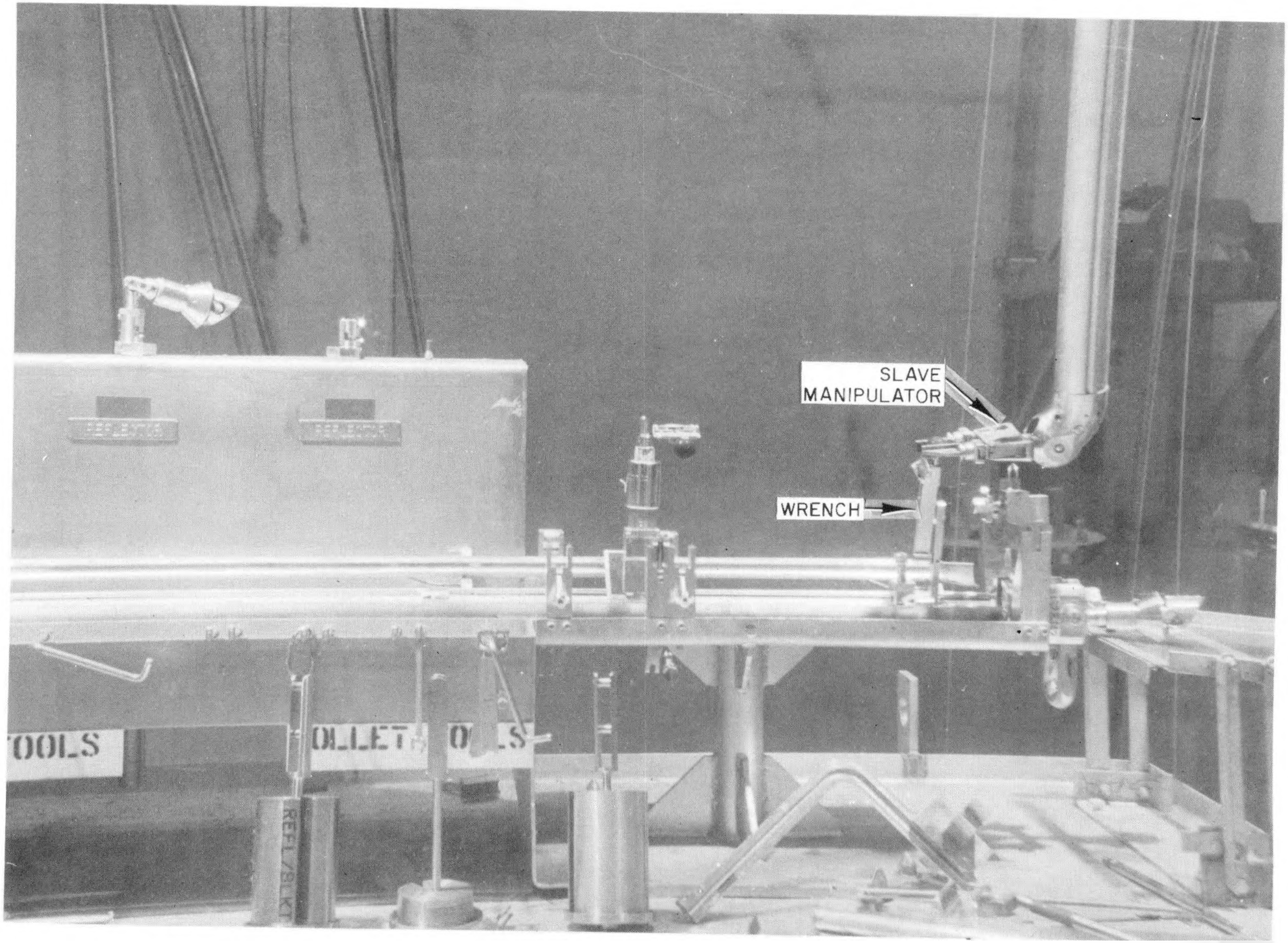

Figure 34. Installation of LWBR Rod Examination Gage Collet on Rod

because of the differing diameters of the three types of rods; centering was achieved with an asymmetrical hex head. When positioned correctly, the collet slid onto the rod stem when pushed with the slave manipulator. Then the collet was tightened securely on the rod end stem with slave-held wrenches.

Once the collet was secured on the rod, a load test was performed to verify adequacy of the connection. A load test fixture applied an axial tensile load on the collet. If the collet was improperly secured, the collet would slip off the rod end stem. After a successful test, the needle end of the drop protection wire was threaded through a slot on the collet. The last step was to free the rod from the caddy clamp, close the caddy door, and transfer the caddy and fuel rod to the REX. At the REX, the caddy was inserted vertically into the caddy port.

Before the rod could be transferred out of the caddy and into the rod examination port, the rod rotator motor had to be tilted out of the way. This was accomplished simply by turning a hex ball with a socket attached to a probe pole. The rod was moved to the examination port, and the rod rotator motor was tilted back into position. This same process was repeated each time any rod, including the standard calibration rods, was moved into or out of the examination port. Additionally, a water pit technician manipulating a probe pole moved the various instrument trays into or out of position or positioned the lights for the visual examinations. A second technician was stationed at the REX console which was located in the water pit observation room. All of the REX measurements were controlled at the control console.

All instruments were calibrated both before and after a fuel rod was examined. Successful calibration ensured that each instrument was operating within its specified parameters, thus guaranteeing the validity of the fuel rod measurements. Standard bars were manufactured of stainless steel with very precise length, diameter, and finish requirements. Four standard bars were required to calibrate the equipment for the seed, reflector, or either of the two types of blanket rods (i.e., standard or power-flattening).

The nondestructive examinations performed on the individual fuel rods included length, bow, diameter, ovality, wear mark depth and volume, and oxide thickness measurements, and visual and ultrasonic examinations. Length measurements were taken to determine the post-operational length of the rod. Camera crosshairs were centered at the top of the rod, and the camera was moved downward until the crosshairs centered at the bottom of the rod. The encoder on the camera measured the length of the fuel rod by subtracting the smallest elevation reading from the largest, to the nearest one mil. All measurements and visual examinations were recorded on video tape. During visual examinations, the rod was held stationary while the camera traveled the length of the rod, thus defects, wear marks, or unusual conditions in the rod could be detected. The rod diameter examination revealed minor variations in the rod diameter along its length. Orbital profilometry equipment measured rod ovality and wear marks; eddy current oxide thickness (EDCOT) equipment measured the thickness of the oxidized corrosion film on the rod cladding. Ultrasonic equipment was used to detect any cracks in the rod cladding. Table 3 lists the rods examined at the REX.

All data from the REX examinations were transmitted to the Bettis Atomic Power Laboratory (Bettis) in Pittsburgh for evaluation. When the data from the examinations were evaluated and determined to be acceptable by Bettis, the caddy was transferred back to the worktable. At the worktable, the secondary drop protection wire was removed; a wrench was used to loosen and remove the collet; and the push nut and wire loop were worked off with the slave manipulator fingers. For a bottom-mounted rod, the dummy stem was removed. The caddy door was then closed, and the caddy and fuel rod were lifted off the table and transferred to the RRS water pit. There, the fuel rod was removed from the caddy, and both were stored.

3.11 - ROD TRANSFERS

All rods which were removed from the fuel modules at the RRS were inserted into cassettes, rod boxes, rod caddies, or rod storage liners. A cassette, a rod caddy, and a rod storage liner are pictured in Figures 35, 36, and 37. The cassettes and rod boxes were protective strongbacks which carried a maximum of four of any type of LWBR rod and were used to store and transport rods between work stations. Cassettes carried only shrouded rods and were

Table 3 - LWBR Rods Examined

Module Core Position	Module Serial Number	Examined at REX	Examined at PIFAG	Examined at ANL
SI-1	L-BB01-04	6	33	5 POB 1 V 1 CC 4 NR and DE
SIII-2	L-BB01-08		33	
SII-3	L-BB01-13		34	
SIII-1	L-BB01-07		34	
BI-3	L-GR01-03	5	36	4 POB 1 V 1 CC 3 NR and DE
BII-2	L-GS01-03	5	24 41 PF	4 NR and DE
BIII-2	L-GT01-02		18 57 PF	

Table 3 (Cont)

Module Core Position	Module Serial Number	Examined at REX	Examined at PIFAG	Examined at ANL
BIII-6	L-GT01-06		18 57 PF	6 POB
RIV-3	L-RA01-10	1	28	2 POB 1 NR and DE
RIV-4	L-RA01-09	2	29	
RIV-9	L-RA01-03		48	1 CC
RV-4	L-RB01-08		34	

Legend: PF - Power Flattening
V - Visual
CC - Crud Characteristics
NR - Neutron Radiography
DE - Destructive Examination

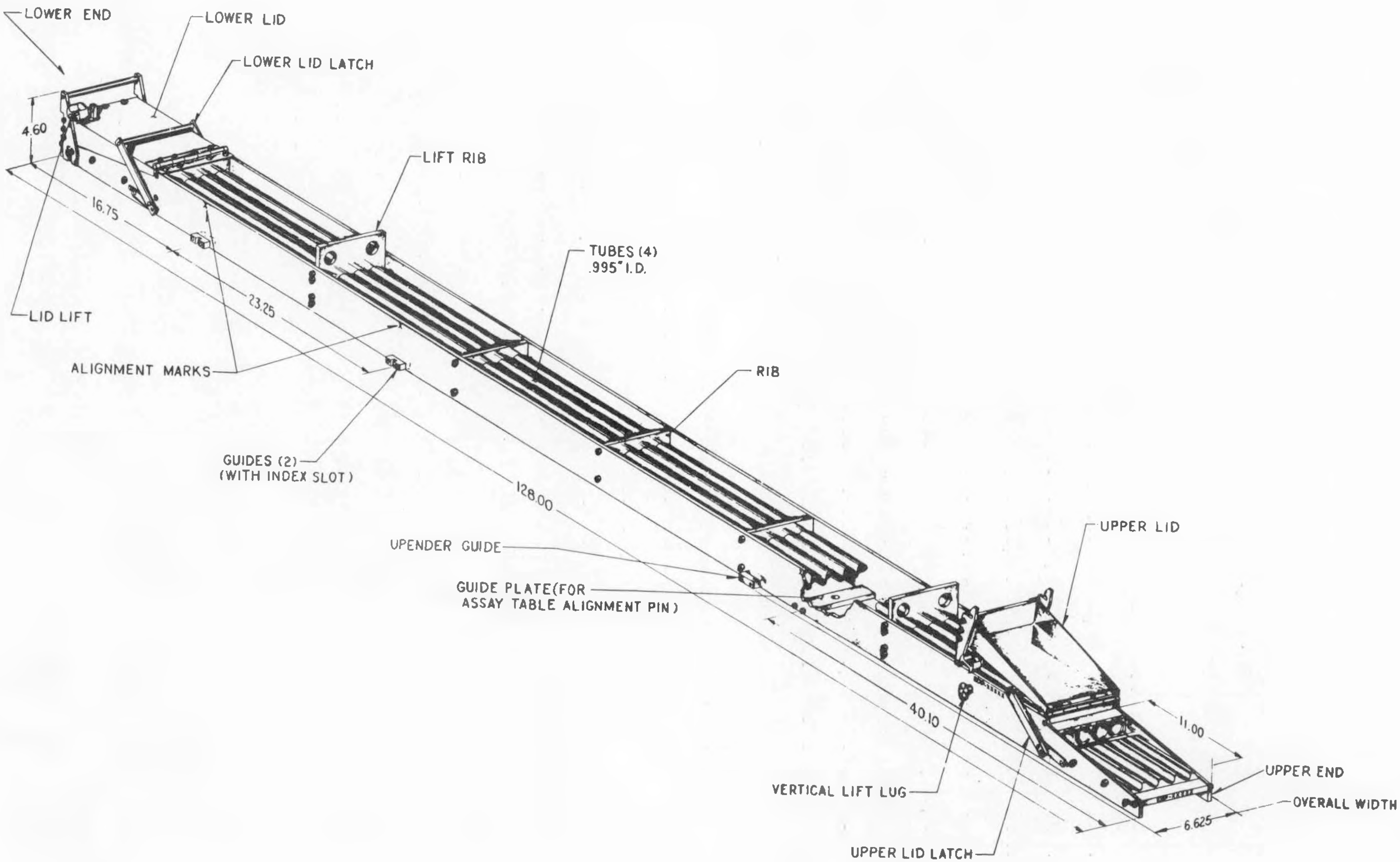

Figure 35. LWBR Fuel Rod Cassette

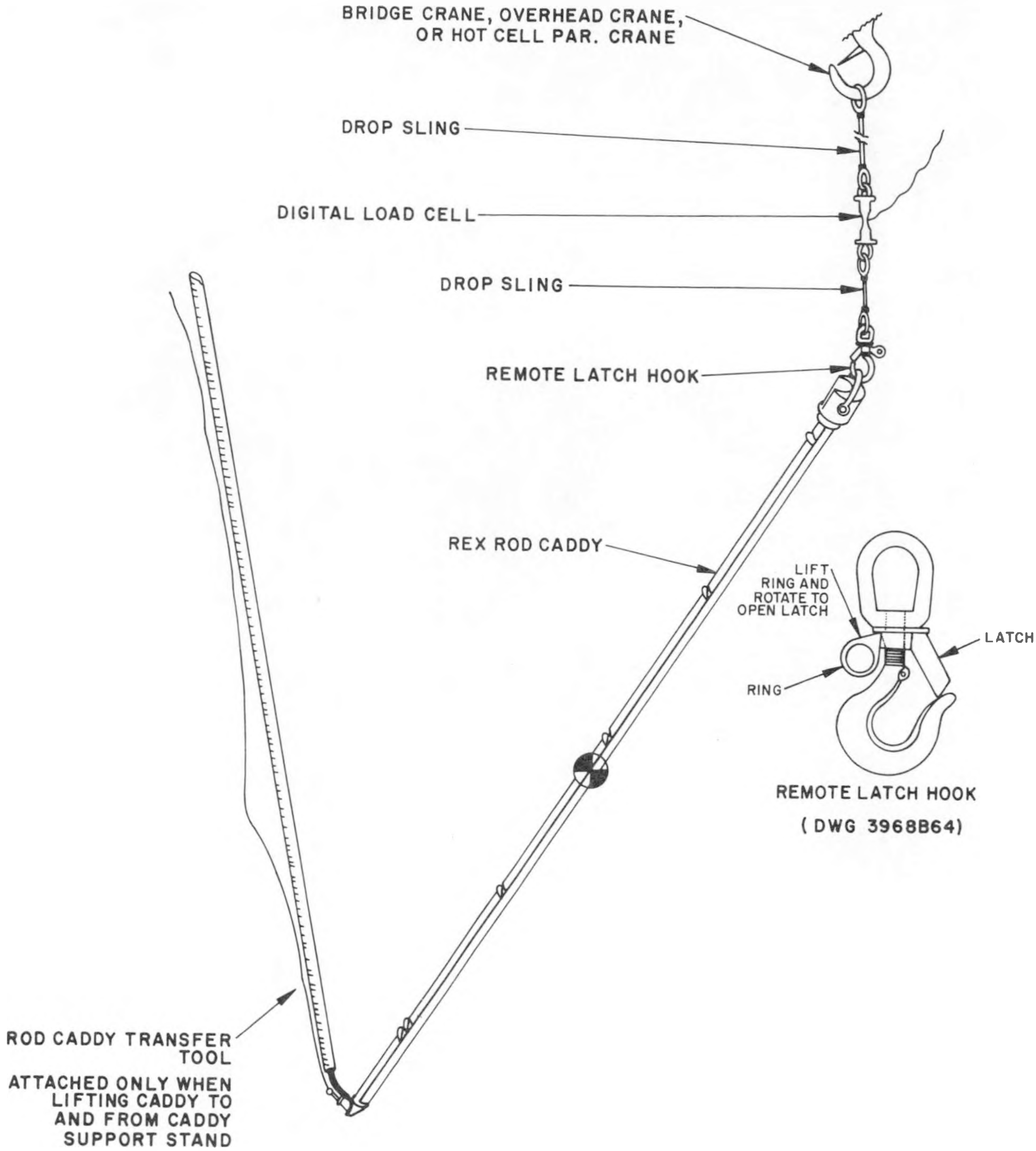

Figure 36. LWBR Rod Examination Gage Rod Caddy

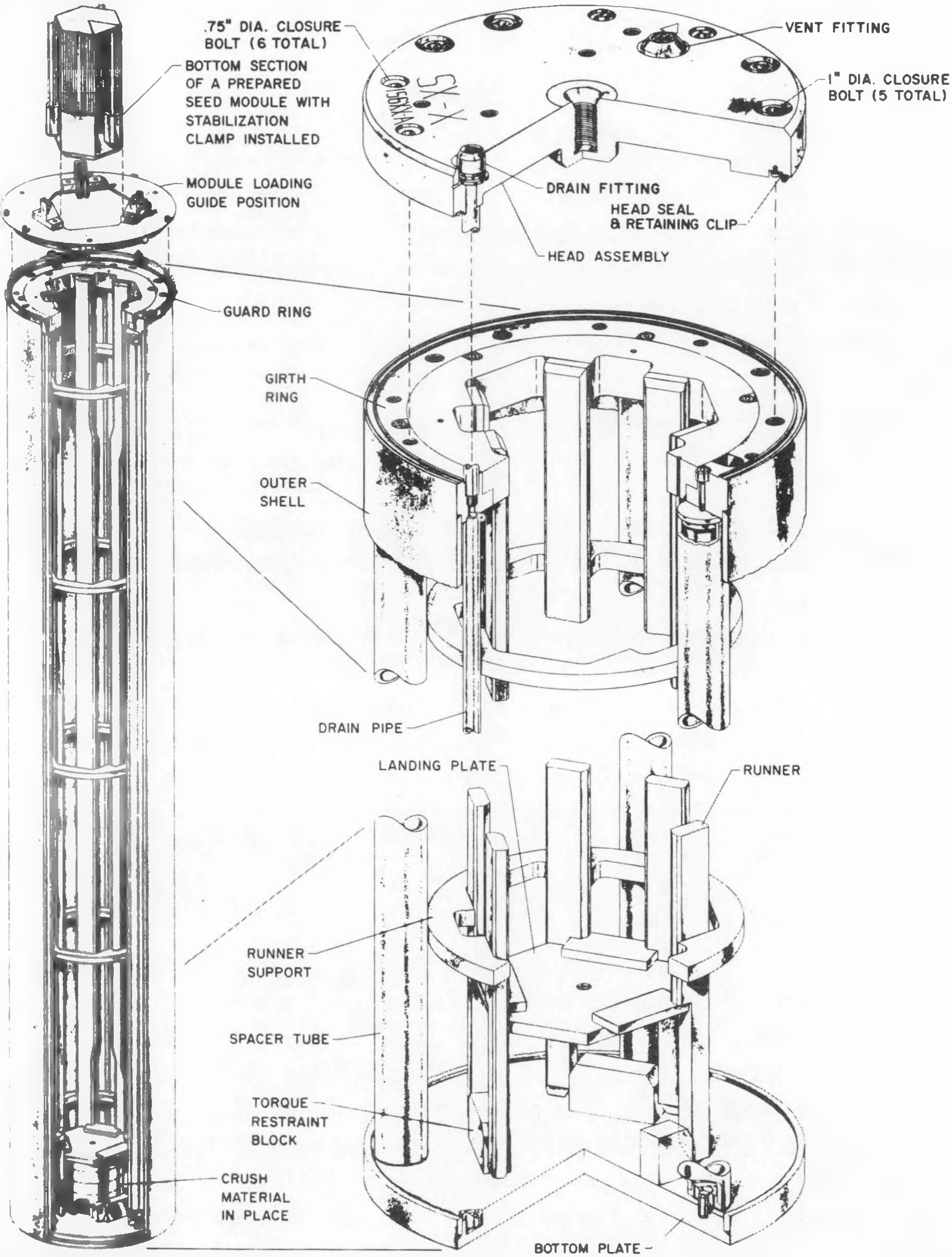

Figure 37. LWBR Module Storage Liner

designed to interface with the PIFAG rod drying system and the assay table. Details of the PIFAG are presented in Section 3.12. Rod boxes carried only unshrouded rods and were used primarily for transferring rods or as intermediate storage for REX examinations. Those rods which were designated for examination at the REX were placed into rod caddies which provided transfer support for single rods.

Both ends of a cassette opened in order to attach it to the PIFAG vacuum drying and chain drive systems, but in the water pit operations, only the top end was opened for rod transfers. The bottom door remained locked in place to prevent it from being inadvertently opened during water pit operations. Rod boxes were identical to rod cassettes except that they opened only at the top end and were not intended to interface with the PIFAG system. Water pit technicians opened and closed the cassettes and rod boxes underwater with the use of a probe-offset tool. Once rod operations were completed, the top end was closed, and a latch was locked in place. The cassette grapple was then attached to the cassette or rod box and transported in the ECF water pit by the bridge crane hoist. In the hot cells, the latches and ends were operated with the slave manipulators. Transfers of the rod boxes and cassettes in the hot cells were made with the hot cell hoist.

A rod caddy was equipped with a full length door, which when opened, allowed horizontal translation of a rod in the REX from a vertically-oriented caddy. Rod caddies were used to store rods awaiting REX examination and to transport these rods between the RRS and the REX. The top end of the caddy was constructed to facilitate installation of dummy stems for bottom mounted rods and collets for all rods. The bridge crane hoist was used for all rod caddy transfers.

Three rod storage liners were designed to store loose rods removed from various fuel modules with each of the three different fuel rod types being stored in its own liner. The liners were kept in designated ports in the fuel storage racks. Each was transported vertically in the MTC under the same restrictions which applied to module moves. At the end of the LWBR program, these liners were sealed and shipped to the Idaho Chemical Processing Plant (ICPP) (refer to Section 3.14).

The cassette carrier (CC) was a steel, protective overpack designed to hold and transport five cassettes or rod boxes at a time. Figure 38 illustrates the CC. The interior of the CC was designed with a turntable arrangement consisting of five cassette holder ports and a dummy cell which acted as a door closure. A cutout in the top and side of the CC provided access to the five ports. Water pit technicians rotated the interior carousel with a probe-socket to expose each of the ports to the opening. Numbers visible from the water surface indicated which cell was in the open port. This aided in the location identity of each cassette and rod box. Cassettes and rod boxes were lowered into the CC with the cassette grapple suspended from the bridge crane.

The CC was classified as a moving criticality zone, which allowed the CC to be transferred between water pit zones without fuel transfer paperwork. Loaded CCs were moved through the water pits by the bridge crane to the west end of the ECF water pits where individual cassettes were removed from the CC for transfer to the PIFAG hot cells. The CC successfully minimized the number of cassette transfers through the water pits and provided temporary storage for loaded cassettes.

The upender/transfer cart system supported and conveyed individual cassettes between the water pits and the hot cells through an underwater tunnel. In the water pits, cassettes were loaded vertically into the upender; two latches were closed and locked to secure the cassette in place. The cart, which was driven by an electrical motor, rode on two permanent tracks and carried the upender through the tunnel. At the hot cell side of the tunnel, the cart rode onto the tines of a lift elevator, which was then turned on and raised into the hot cell. Once in the hot cell, the upender was slowly rotated from the vertical to the horizontal, the latches released, and the cassette lifted out of the upender with the in-cell hoist. This operation was reversed when cassettes were moved from the hot cells to the water pits.

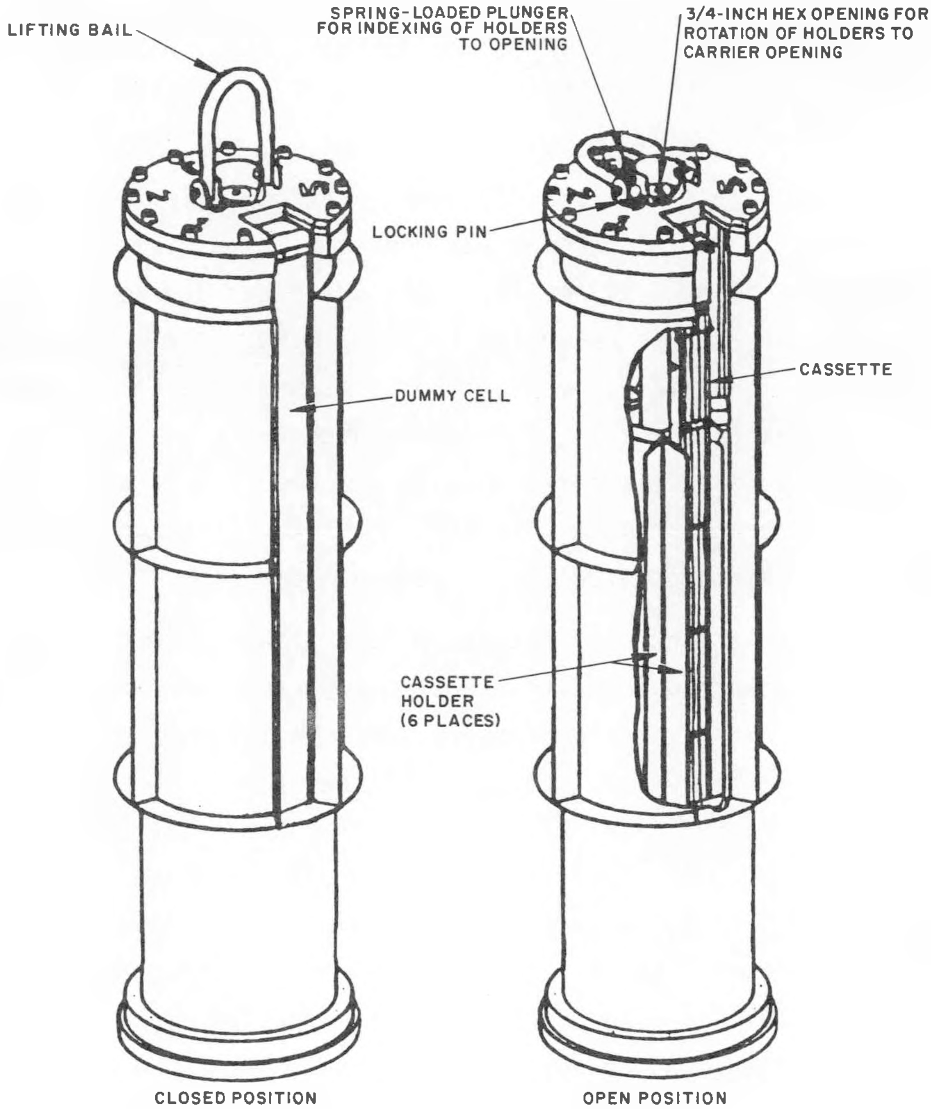

Figure 38. LWBR Cassette Carrier

3.12 - PRODUCTION IRRADIATED FUEL ASSAY GAGE

The production irradiated fuel assay gage (PIFAG) was a system developed to assay remotely and nondestructively a fuel rod by neutron interrogation to determine the end-of-life fissile fuel content of the rod. A schematic of the PIFAG is presented in Figure 39, with actual photographs featured in Figures 40 and 41. A detailed explanation of the complete system is given in Reference 6.

Both calibration rods and fuel rods were examined with the PIFAG. Unirradiated calibration rods, with known fuel content, were used to calibrate the PIFAG for assay operations. All calibration rods scheduled for PIFAG examination had to be transferred to cassettes from rod boxes because only cassettes could interface with the PIFAG. Calibration rods were stored in rod boxes to release all cassettes for handling rods designated for assay. Rod box-to-cassette transfers were made prior to moving the cassette through the transfer canal. These transfers were made with the use of the bridge crane which allowed the RRS to remain dedicated to rod removal operations.

All LWBR fuel rods that were scheduled for PIFAG examination were loaded into cassettes, transferred by CC to the transfer canal, and from there moved into the hot cells on the transfer system. Once in the PIFAG hot cell, the cassette was held in the vertical position in the upender for approximately one hour to drain. After that time, the upender rotated the cassette from vertical to horizontal. All upender moves were directed from a console outside the hot cell window by the PIFAG technician. The technicians lifted the cassette from the trough with the in-cell jib hoist and transferred it to the drying location on the assay table where slave manipulators attached vacuum dryer endcaps onto both ends of the cassette. When the temperature inside the cassette under controlled conditions equaled that of the ambient air, the rods were considered to be successfully dried. This operation took a minimum of six hours.

After the drying operation was successfully completed, the vacuum end caps were removed and the cassette was moved to one of three assay locations

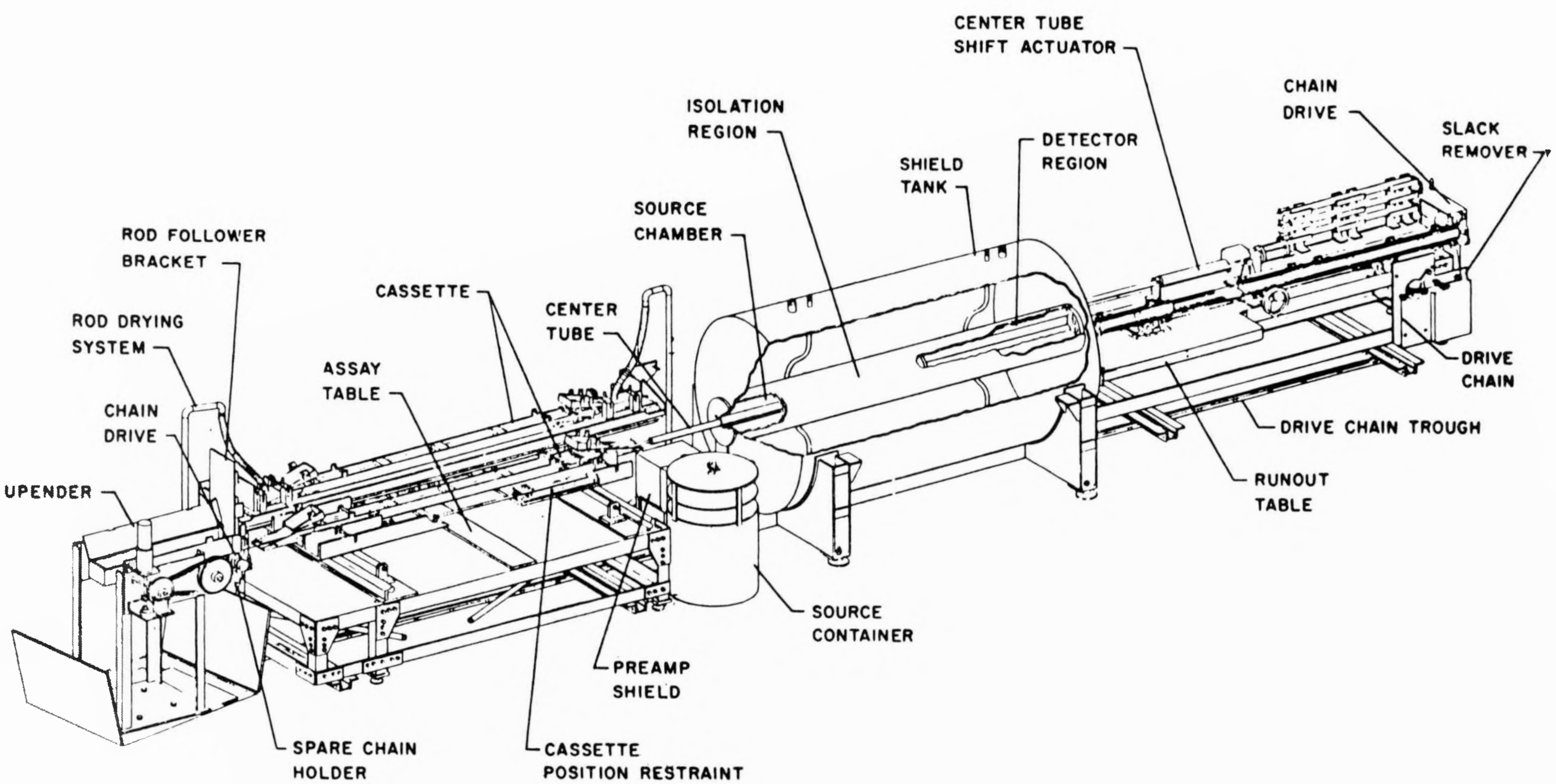

Figure 39. LWBR Production Irradiated Fuel Assay Gage System

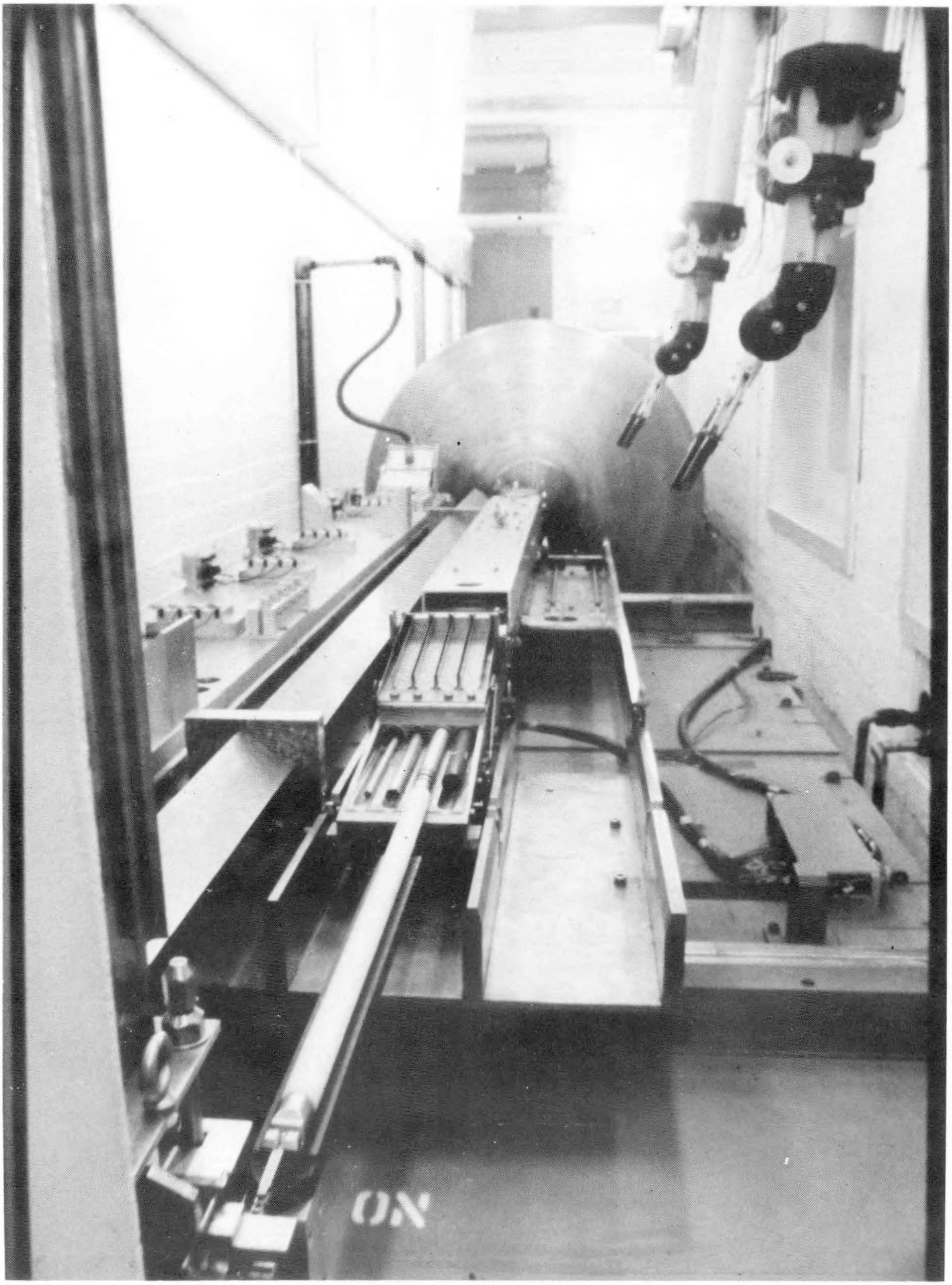

Figure 40. LWBR Production Irradiated Fuel Assay Gage in Operation

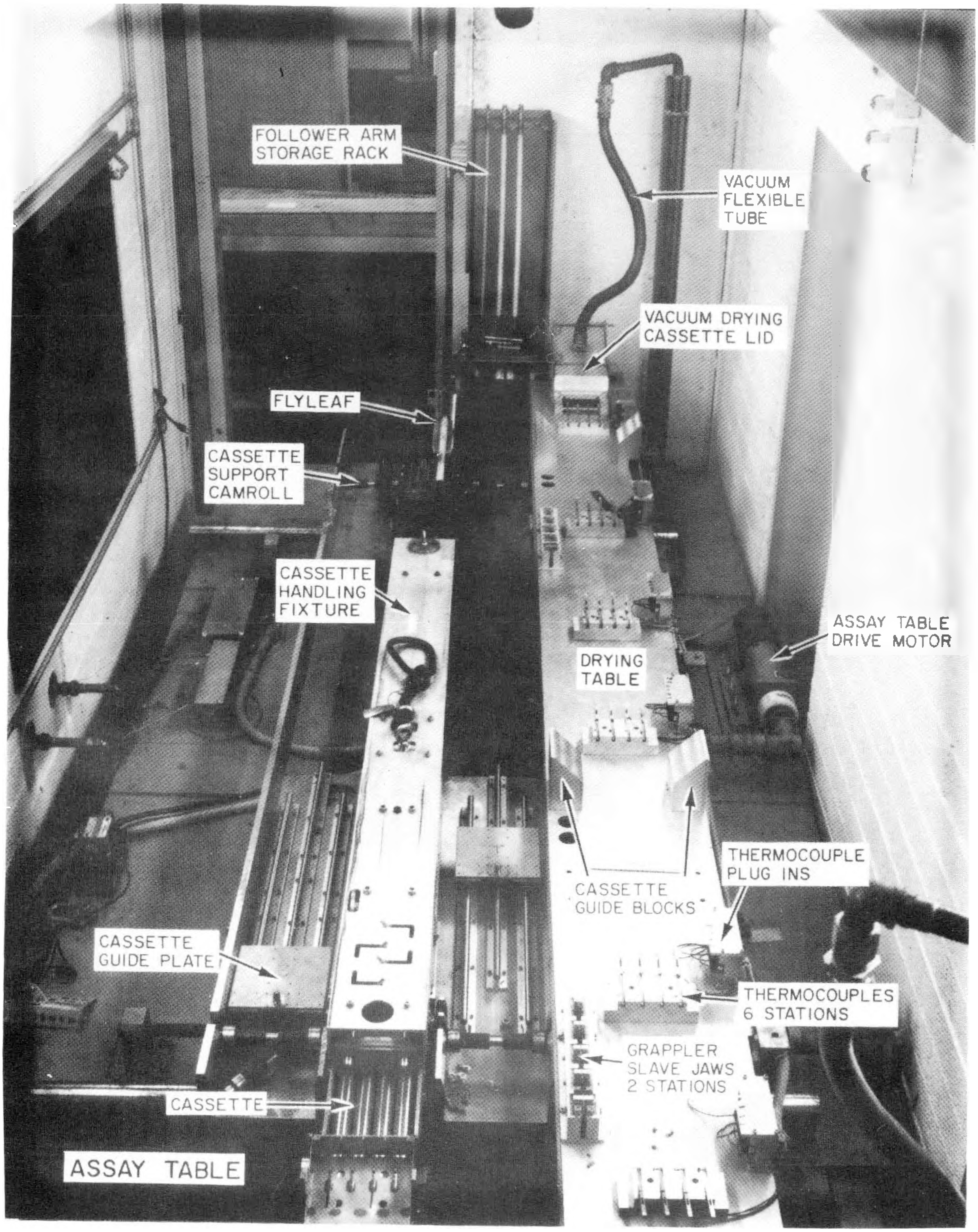

Figure 41. LWBR Production Irradiated Fuel Assay Gage Area

on the assay table. The selected rod was connected to the PIFAG rod drive system. Normally two cassettes of core rods were on the assay table during assay operations; the third position on the table held calibration rods. Assay was first completed on shrouded calibration rods to verify proper PIFAG operation. The computer was updated with the current information on the rod location before it was assayed. Upon completion of the assay, the rod was reinserted into the cassette, the assay table was repositioned, and another rod from the same cassette was examined. When all the rods which were to be examined in a cassette were completed, that cassette was removed from the PIFAG hot cell and another transferred in. Assay operations for one rod, including the calibration passes, averaged eight hours.

Two types of assays were done on the PIFAG. Thermal and epithermal interrogating neutron energy levels were obtained by translation of the PIFAG center tube to impose different materials between the neutron sources and the fuel rod. These two values were independently used to determine the fuel content in each rod. In addition to the above assays, a gamma scan, using an intrinsic germanium detector, and flux dip measurements, using four fission counters, were done on each rod to determine correction factors for the data. A total of 524 rods from the 12 proof-of-breeding (POB) modules were assayed. See Reference 6 for more detail. Table 3 gives a breakdown of the rods examined at the PIFAG.

In addition to the POB examinations done in the PIFAG cells, this area was used to prepare a limited number of rods for loading into shipping cask inner containers. These inner containers were transferred to the water pits and loaded into their corresponding shipping cask for transfer to ANL. The following section provides additional information on the ANL examinations.

Additionally, the PIFAG assay table area was used to transfer rods between cassettes and rod boxes, as time and resources permitted. Fuel rods were deshrouded, as necessary, in this area. A loaded cassette and an empty rod box were positioned on the assay table. The selected rod was eased out of its shroud by the slave manipulator fingers and slid into an intermediate center tube container stationed in the PIFAG shield tank. This was necessary because an unshrouded rod was never allowed to touch the external sides of a cassette, a rod box, or the shield tank. The table was then re-aligned so that the rod could be slid into the rod box port.

3.13 - OTHER EXAMINATIONS

Nondestructive and destructive examinations of fuel rods and structural components from the expended LWBR core were part of the LWBR core component end-of-life examination program. This work was contracted to ANL, with the work being done in their Idaho Falls (ANL-W) and Argonne, Illinois (ANL-E) laboratories. ANL was also responsible for the data reduction and issuance of data reports.

As shown in Table 3, a total of 34 rods were shipped to ANL for destructive or nondestructive analysis. Seventeen rods were POB rods that, after analysis at the PIFAG, were sent to Argonne for destructive assay. Assay data from all seventeen rods confirmed the PIFAG results. Twelve LWBR rods were sent to ANL for neutron radiography and destructive examination. After initial neutron radiography, the destructive examinations performed on the 12 rods included metallographic examination of cladding, pellets, welds, stems, springs, and support sleeves, hydrogen analyses of the cladding, energy dispersive X-ray analysis of the cladding, chemical analysis for cladding and fuel, fuel depletion analysis, fission gas analysis, and tensile tests of cladding. Additionally, five fuel rods were nondestructively examined at ANL. A visual examination only was done on two of these rods. The nondestructive tests done on the remaining three rods included a visual examination, crud thickness determination, a crud profile, and an incremental descale with chemical analysis for crud characterization.

All 34 rods that were shipped to ANL were transported by truck in a WAPD-40 cask. The WAPD-40, shown in Figure 42, is a steel-jacketed, lead-shielded cask which was used to ship irradiated fuel and structural materials from ECF to ANL. The shipped items were loaded into a watertight inner container in order to keep the cargo dry during underwater loading and unloading; and the inner container was placed into the WAPD-40. Interfacing hardware for

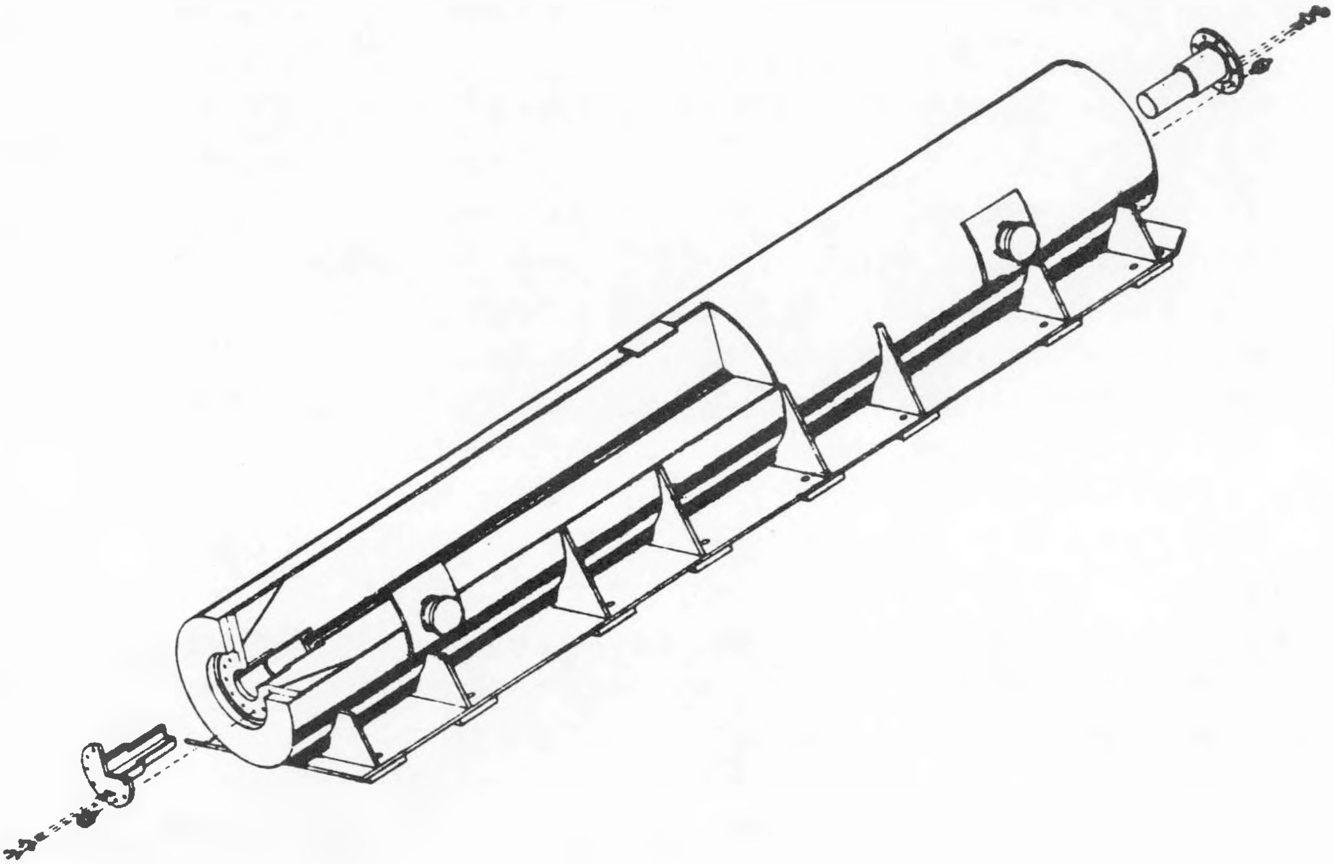

Figure 42. WAPD-40 Shipping Cask

discharging the WAPD-40 cask at the ANL-W neutron radiography and hot cell facility was designed and provided by ANL.

Selected components and hardware from various modules were removed and examined at ECF or sent to ANL for examination. Table 4 lists the items removed and retained for examination at ECF. Table 5 lists the parts sent to ANL and the modules from which they were removed. All items sent to ANL were loaded into a shipping cask inner container in the ECF hot cells, then the container was transferred to the water pits where it was loaded into an Argonne-owned cask. This cask was chosen because it was compatible with the Argonne hot cell unloading facility, and it could be loaded underwater at ECF.

3.14 - LONG-TERM FUEL STORAGE

Upon completion of the LWBR end-of-life (EOL) core evaluation program, all LWBR fuel had to be processed for long-term storage. LWBR fuel storage shipments included fuel modules, fuel rods, and miscellaneous specimens of cut fuel which were prepared, loaded, and transported to the Idaho Chemical Processing Plant (ICPP) in the Peach Bottom Cask (PBC). A total of 48 fuel storage shipments were made. The following components/materials comprised these shipments: 39 shipments of LWBR fuel modules; seven shipments of packaged fuel rods; one shipment of the spare LWBR seed module; and one shipment of miscellaneous fuel specimens. All fuel modules were shipped in module storage liners. Rods removed from modules as well as unirradiated PIFAG calibration rods were shipped in rod storage liners. The miscellaneous fuel specimens included pieces of fuel rods which had been destructively analyzed at ANL and irradiated and unirradiated fuel specimens from pre-LWBR test specimens. These specimens had been stored at ECF in various containers and were consolidated into one shipping and storage liner. See Reference 7 for more detail.

Preparations to ship a storage liner in the PBC included receiving the PBC and submerging it in the water pit, preparing and installing the storage liner into the PBC, removing the PBC from the water pit, and installing it on the truck.

Receipt operations for the PBC included radiological surveys of the cask and the truck, shown in Figure 43, when it was brought into the ECF high bay.

Table 4 - LWBR Component Examinations at ECF

Module	Component	Quantity	Examination
SI-1	Baseplate Bolt	6	Breakaway torque
SII-1	Support Shaft	1	Visual
	Buffer Cylinder	1	Visual
	Balance Piston	1	Visual
	Balance Piston Nut	1	Check torque
SII-3	Grid Section	1	Visual
	Shell Screw	3	Breakaway torque
	Baseplate Remnant	3	Visual
	Grid Bolt	4	Breakaway torque
	Shell	2 halves	Visual
BIII-2	Cover Plate Remnant	2	Visual
	Baseplate Remnant	3	Visual
	Shear Key	2	Visual
	Shear Key Strut	2	Visual
	Baseplate Bolt	1	Breakaway torque
	Support Post Bolt	6	Breakaway torque
RIV-4	Cover Plate Remnant	2	Visual
	Baseplate Remnant	3	Visual
	Filler Strip	2	Visual
	Shell	1 half	Visual

Table 5 - LWBR Component Samples Sent to ANL

Module	Component	Quantity
SI-1	Fuel Rod Nut Remnant	10
SII-1	Cover Plate Bolt Cover Plate Spacer	1 1
SII-3	Shell Screw Grid Bolt Grid Section	3 4 2 1/2" Rhombus, Subdivided
BI-3	Flux Thimble Section	2
BIII-2	Bottom Support Post Bolt Fuel Rod Nut Fuel Rod Washer	1 5 3
BIII-6	Baseplate Bolt	2
RIV-4	Fuel Rod Nut Support Post Bolt Shell Screw	3 1 2
RIV-7	Flux Thimble Section	12
---	BIF Tube Section	12

The cask was lifted off the truck in a horizontal position and placed in the downender on the beach area which is shown in Figure 44. The downender, a stationary piece of equipment, provided a pivot point for two of the four cask trunnions in order to rotate the cask from horizontal to vertical and back. At the downender, the vertical lift adapter was installed on the cask closure lid as shown in Figure 45. The overhead crane was then used to rotate the cask to the vertical position, and it was transferred to the water pit where it was stationed in a support stand. Underwater tools were used to remove the closure lid bolts, and the closure lid was lifted off with the bridge crane.

Liner preparations were made at the liner closure station (LCS), an underwater system containing six storage liner ports and the equipment to remove water from the storage liner and dry the interior. Figure 46 shows the LCS. Two of the LCS ports were reserved for closure head installation work, two for dewatering operations, and two for storage of prepared liners.

All module storage liners were equipped with sealable closure heads which were installed at the LCS head installation port. Prior to, or in conjunction with, moving the liner to the LCS, the liner closure head was prefitted with a large, metal O-ring while at a special workstation on the beach. Each of the closure head bolts was fitted with a metal O-ring; and all bolts, except one closure head bolt and the drain bolt, were preinstalled in the head. The vent fitting was also preinstalled in the head at this time. The liner containing a module selected for shipment was fitted with the MTC grapple lift adapter and moved from the storage racks to one of the head installation ports in the LCS. The lift adapter was removed, and the prepared closure head was transferred by a jib crane to the storage liner. Alignment pins were used to center the head on the liner and ensure alignment of the bolt holes. Handheld underwater tooling was used to tighten the bolts in the closure head. Another type of lift adapter was installed on the closure head for the remaining MTC transfers.

Next, the liner was lifted into the MTC, transferred to, and installed in one of the dewatering ports. Two tool assemblies, which had inner spindles to open the drain and vent fittings, were moved over the liner and connected to

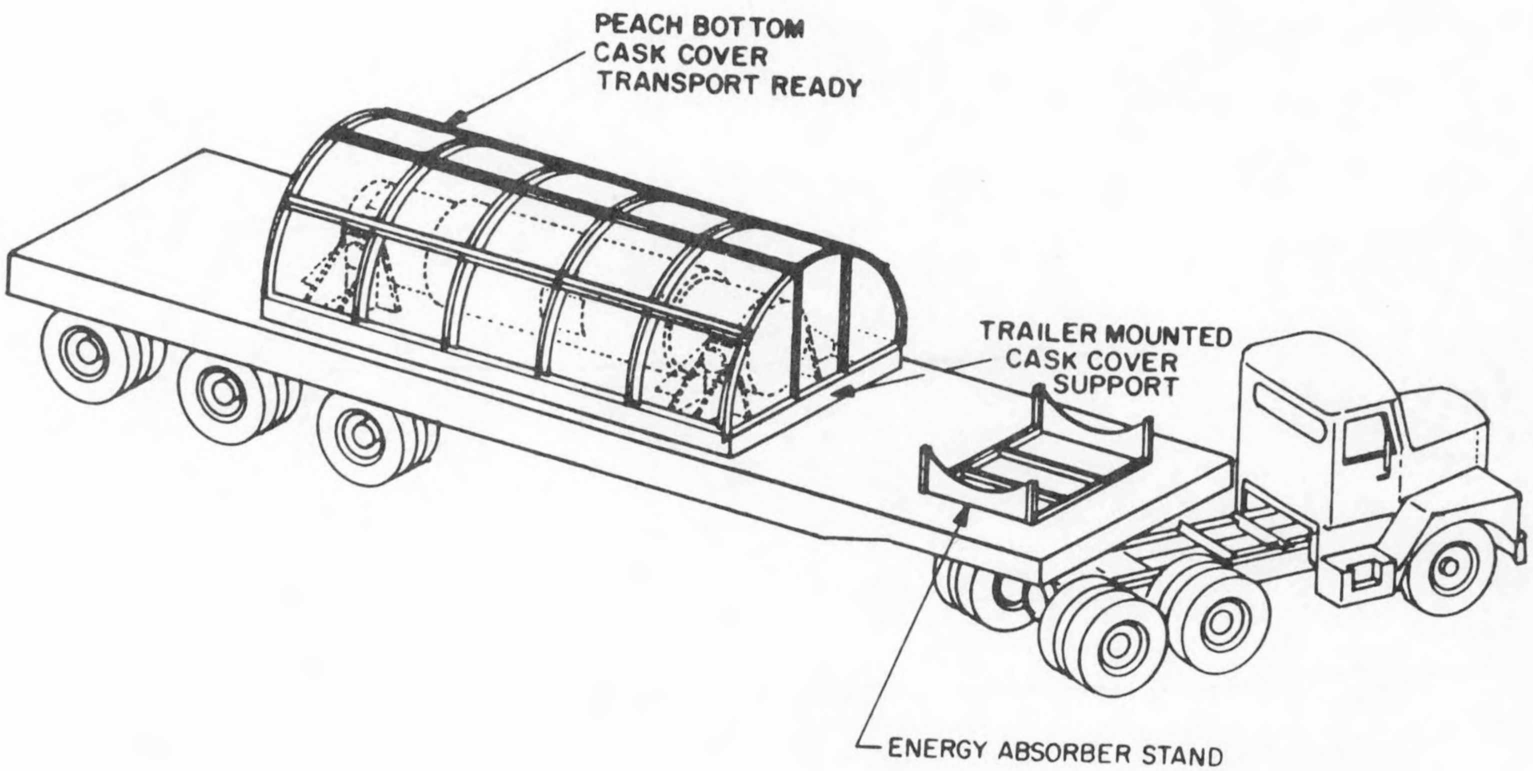

Figure 43. Peach Bottom Cask on Shipping Trailer

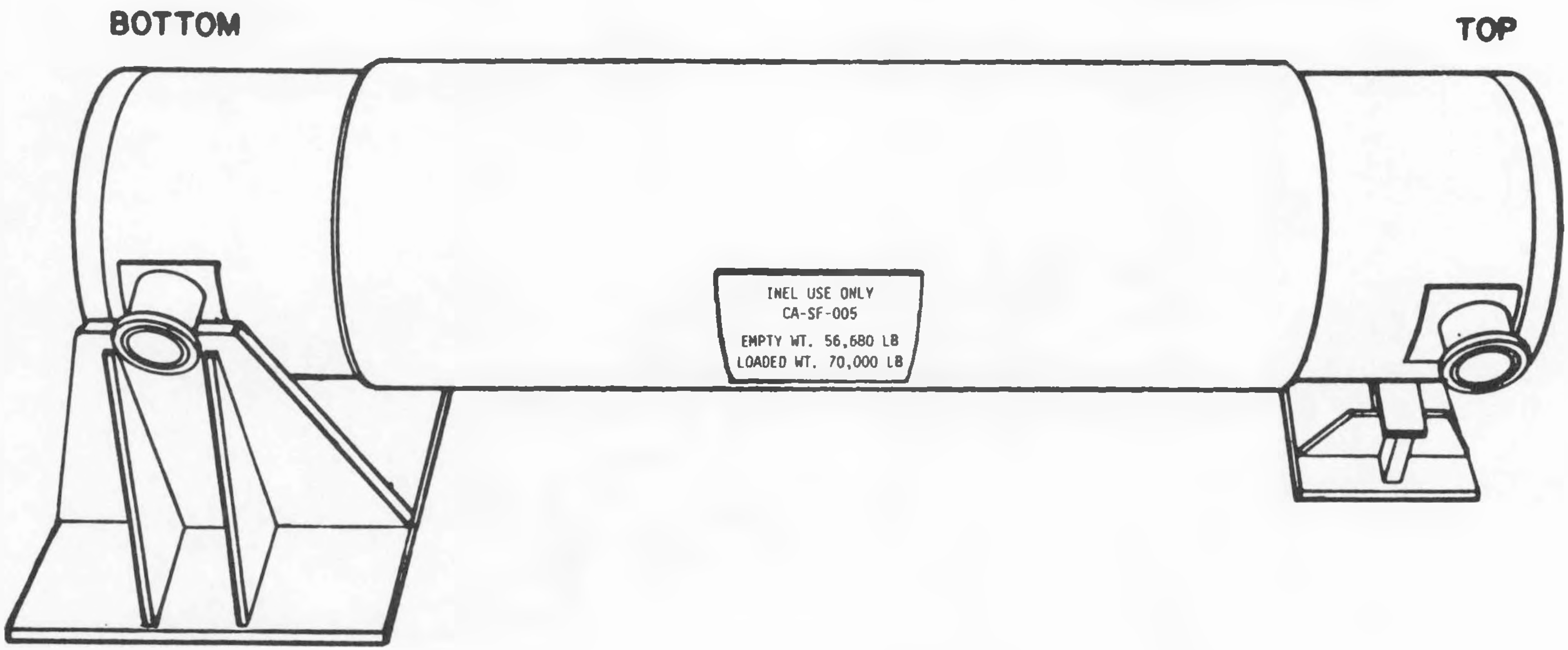

Figure 44. Peach Bottom Cask Horizontal in Downender

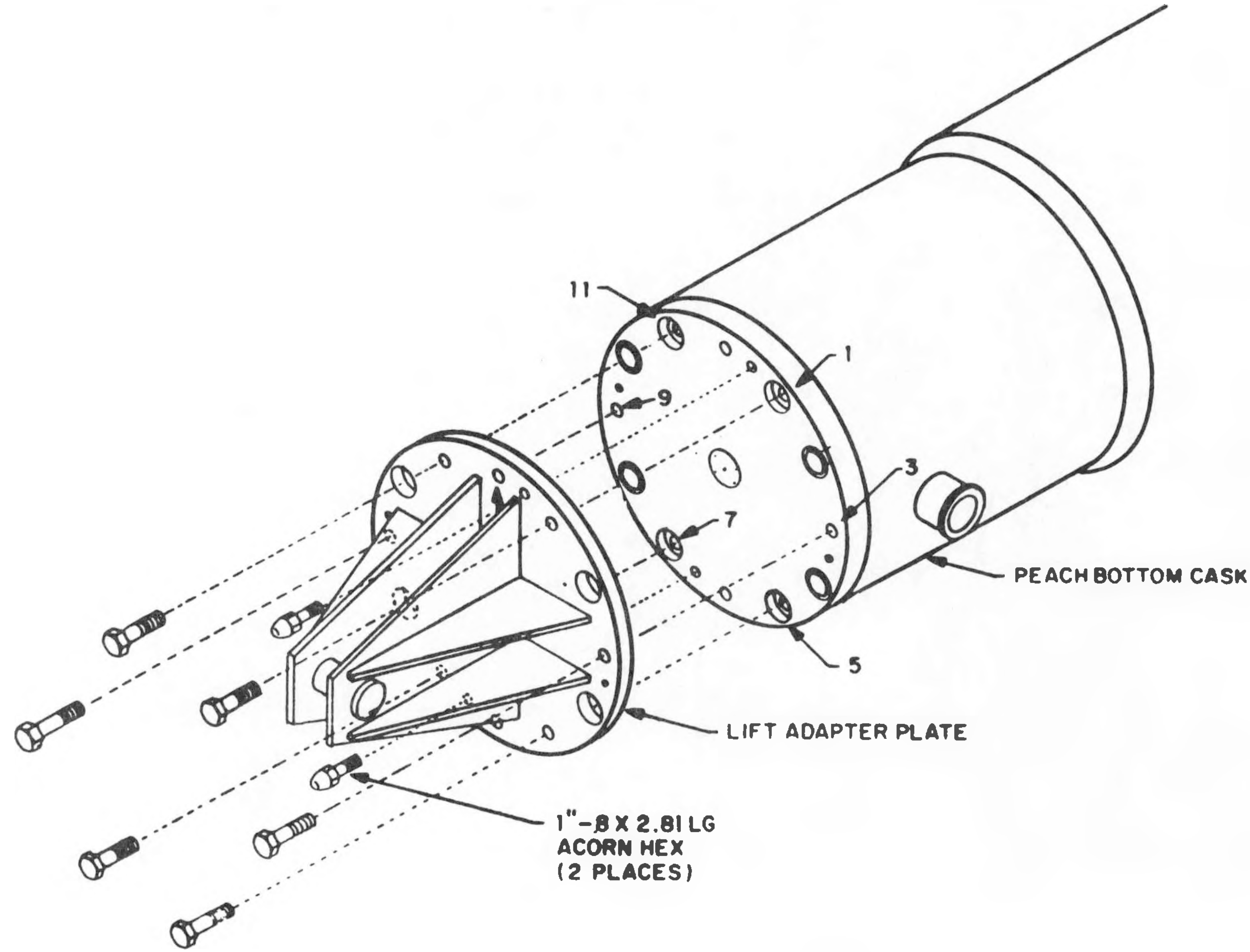

Figure 45. Peach Bottom Cask Lift Adapter Installation

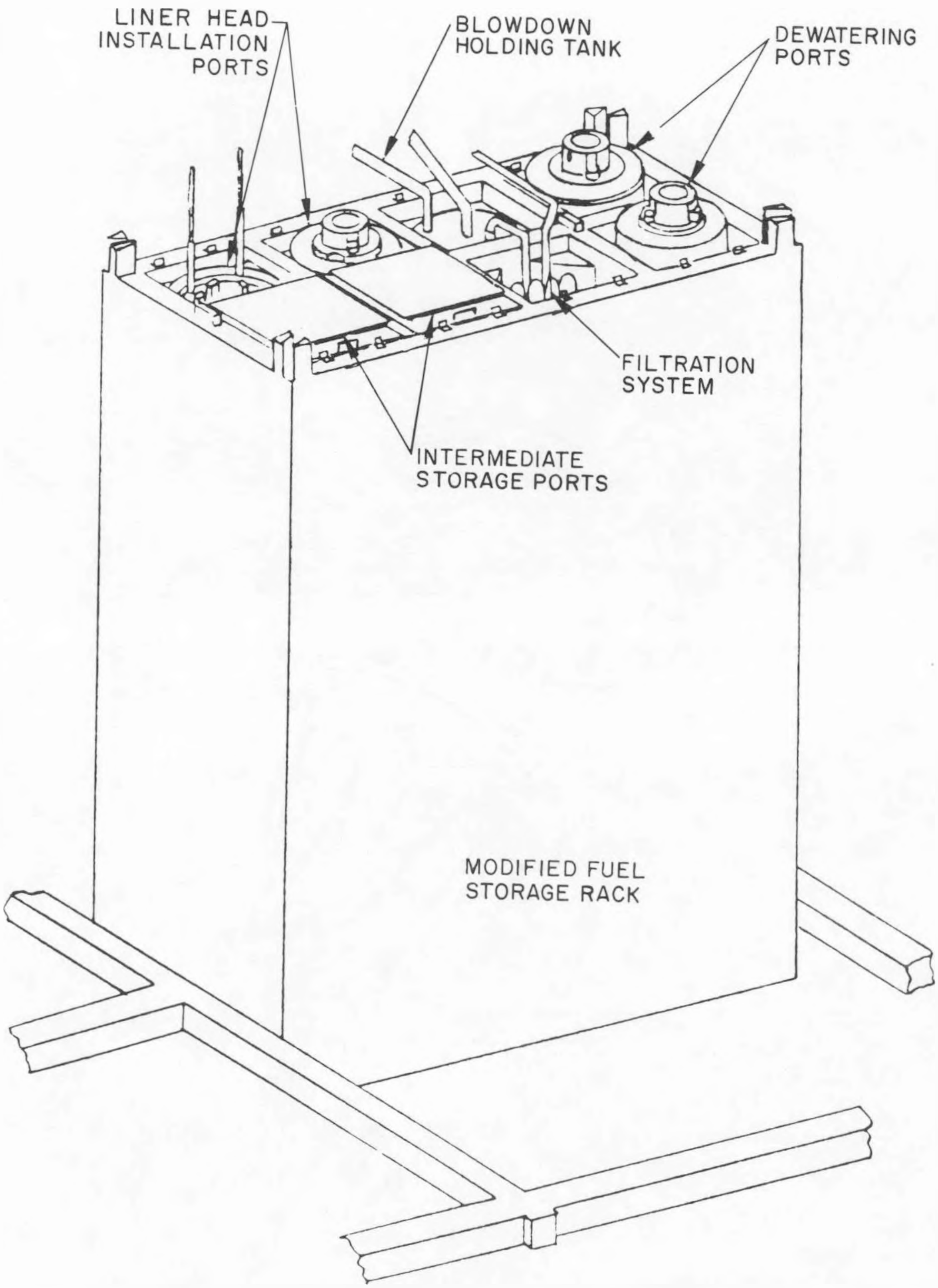

Figure 46. LWBR Storage Liner Closure Station

both the drain bolt and vent penetrations. These tool assemblies were a part of the LCS and were pivoted in position with probe poles. A probe pole with an adapter was used to latch the assemblies in place. Compressed air was forced into the vent, thus driving water out of the liner drain fitting, through an underwater filter system, and into an underwater holding tank. Once all the water was removed from the liner, the drain fitting plug was installed by the drain tool assembly inner spindle, and the drain tool assembly was removed. The liner was then vacuum-dried. Finally, the liner was backfilled with neon to pressure-test the liner; with a successful test, the vent fitting was sealed. From the dewatering port, the liner was moved directly to the PBC or to a storage port in the LCS to await transfer to the PBC.

When a module was scheduled to be shipped to ICPP, the liner containing the module was lifted into the MTC, transferred to the PBC which was already placed in the water as detailed above, and lowered into the cask. The closure lid was installed, the bolts torqued, and the PBC was lifted out of the water pit to the downender where it was rotated to the horizontal position. The lift adapter was removed, and the PBC was transferred to the truck. After comprehensive radiological surveys were performed on the cask and the truck, the shipping cover was installed over the cask, and the cask was transported to the ICPP. Fuel shipments were commonly accomplished in five to six days.

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SECTION 4 - LIGHT WATER BREEDER REACTOR FUEL HANDLING SAFETY

4.1 - SAFETY ASSESSMENTS

All planned Light Water Breeder Reactor (LWBR) fuel handling operations and equipment were designed and analyzed to protect against inadvertent criticality. Three safety assessments were performed covering fuel receipt, disassembly, and shipment for long-term storage as well as special assessments for the spare seed and irradiated test material storage. These assessments identified potential accidents and the procedures or equipment used to protect against them. Each assessment was completed and approved prior to the corresponding evolution of work to ensure safe handling of LWBR fuel.

4.2 - CRITICALITY HAZARDS

Equipment and operations were designed to prevent the following potential criticality hazards of LWBR fuel in water.

1. Uniform radial expansion of 1.0 inch of the seed module rod lattice.
2. Uniform radial expansion of 0.7 inch of a partially derodded seed module (i.e., 91 rods removed).
3. Arrangement into an optimum spherical slurry of the fuel from 65 end-of-life (EOL) seed rods or 75 EOL blanket rods.
4. Insertion of a seed module into a blanket module.
5. Arrangement of 230 EOL seed rods or 220 EOL high-zone power flattening blanket rods in an optimum 0.5 inch spacing.

Criticality hazards 1, 2, and 3, which might have resulted from an accidental drop of the module, were prevented by the design of the module transfer cage (MTC) and the horizontal grapple (HG) as discussed in Sections 4.5.2 and 4.5.8. Additionally, all possible module storage locations were supplied with crush blocks which would absorb module drop energy as well as prevent unacceptable module damage in the event of an accidental drop. Possible storage locations were the module storage liners, the module visual station (MVS), the utility fixture (UF) at the module disassembly apparatus (MDA), and the vertical disassembly stand (VDS).

Criticality hazard 4 was prevented by the design and use of equipment, such as the blanket plugs and module lift adapters. Blanket plugs, which were inserted into the center of a blanket module prior to shipment from Shippingport Atomic Power Station (SAPS) to the Expended Core Facility (ECF), and the module lift adapters physically prevented the insertion of a seed module into a blanket module.

Criticality hazard 5 was prevented by the design and operation of the computer-controlled rod removal system (RRS) which allowed only the pulling of fuel rods from specified module locations and the placement of such rods into specified cassette, rod box, rod caddy, or rod storage liner locations.

4.3 - ESTABLISHED FUEL LIMITS

As a result of the above mentioned criticality hazards, the following limits were established by the safety assessments for handling LWBR fuel. The limits were applicable to each zone or isolated water pit area.

1. General Water Pit Limit: 32 out-of-storage rods or 175 equivalent grams of U^{235}. Out-of-storage is defined as rods which are neither in a module nor a rod storage liner or as modules which are neither in an M-130 nor a fuel storage rack.
2. General Water Pit Limit: 1 module (seed, blanket, or reflector) or 1 rod or module storage liner containing fuel.
3. Alternate RRS Water Pit Out-of-Storage Limit: 16 rods (including the core calibration rods) and either 1 module (seed, blanket, or reflector) or 1 rod or module storage liner containing fuel.
4. Alternate Rod Examination System (REX) Water Pit Out-of-Storage Limit: Same as 3 above.

4.4 - CRITICALITY CONTROL PROCEDURES

Criticality control procedures were required at ECF for each work area handling LWBR nuclear fuel. These procedures described specific measures and precautions required to ensure safe fuel handling and detailed the method to maintain a current inventory of all accountable fuel and nonfuel items. All operations involving LWBR nuclear materials were conducted in accordance with these criticality control procedures.

4.5 - EQUIPMENT AND OPERATION

The following areas, pieces of equipment, and operations were designed to provide safety in handling LWBR fuel and were administratively controlled by the above-mentioned criticality control procedures. A criticality zone was an area defined by the criticality control procedures and provided physical and administrative controls over the amount of fuel in the zone. A water pit zone is a criticality zone only if criticality barriers are in place to separate the zones. The concrete islands and sides of the pit are approved criticality zone barriers. Catwalks used to bridge island openings are approved criticality zone barriers whenever they are in place at the openings. The pit gates are not normally approved criticality zone boundaries unless they mechanically provide a minimum of 8 inches of water separation between criticality zones. The water pit gates in the area used for the LWBR Program met this criterion.

4.5.1 - M-130 Transfer Operations

The loaded M-130 was required to be properly rigged when it was removed from the railcar, and its elevation above the beach was limited to heights for which it had been shown by analyses that the container would survive an accidental drop.

4.5.2 - Module Transfer Cage

The MTC was required for all moves of a vertically-oriented LWBR fuel module or storage liner containing fuel. The module or storage liner containing fuel was rigged using the LWBR module grapple secured onto the module lift adapter or the liner lift adapter with a storage liner lifting head or closure head. The module or storage liner was required to be above the MTC doorway before the MTC doors were closed, and the height above the doors was controlled mechanically and administratively. The MTC door pressure was controlled so as not to exceed a maximum-specified closure force while the doors were being closed with a module or storage liner inside. Before lateral movement of a seed or blanket module or a storage liner containing a seed or blanket module was initiated, the MTC doors had to be closed and locked. This did not include the maximum 3/8-inch jogging allowed to center the MTC over a destination. When a blanket or seed module or a storage liner containing a seed or blanket module was transferred, the MTC was centered over the destination before opening the MTC doors. In addition, in the case of a seed module discharged to storage, the seed module installation guide was required to be properly installed on the port liner before opening the MTC doors.

Seed or blanket module discharge from the MTC was allowed only to an LWBR fuel storage rack, the MVS, the VDS, or a UF in the upender. Seed or blanket modules in storage liners were only discharged to the liner closure station, the Peach Bottom Cask (PBC), or an LWBR fuel storage rack port.

4.5.3 - Fuel Storage Racks

The LWBR fuel storage racks were installed in two adjacent water pits. Both modules and rod storage liners were stored temporarily in these racks for the length of the LWBR Program. Each port in the storage racks was considered to be a criticality zone; seed modules were stored in seed storage ports, blanket modules were stored in blanket storage ports, and reflector modules were stored in reflector module storage ports. The bridge crane was used to block a loaded LWBR fuel storage port while the port lid was opened or unlocked. Ports were locked when loaded, and the keys were controlled by the Shift Supervisor.

4.5.4 - Cassette Carrier

The Cassette Carrier (CC) was designed to remain intact and retain the five cassettes it carried after a worst case drop accident. It was designed to provide at least 8 inches of water separation from its external boundary to the fuel within the cassettes. This allowed the CC to be used as a traveling criticality zone. An interlock prevented rotation of the lifting bail to the lift position unless the dummy cell was positioned to the cutout and the locking pin was lowered into a mating feature which locked the dummy cell in position.

4.5.5 - Peach Bottom Cask

When a seed or blanket module was transferred in the Peach Bottom Cask (PBC) from the water pit to the beach and from the beach to the trailer, the following conditions were required to be met. The loaded PBC was double-rigged via a special rigging arrangement to the overhead crane during transfer from the water pit to the high bay beach area. The loaded PBC was single-rigged to the overhead crane when the cask was handled over the high bay beach area. No portion of the loaded PBC was permitted to be located over the water pit when the cask was single-rigged.

4.5.6 - Liner Closure Station

Each of the six types of fuel storage liner ports of the Liner Closure Station (LCS), with the port cover in place, was considered to be a criticality zone. A port which contained a loaded module storage liner with a liner closure head in place was a criticality zone and did not require a port cover. Transfer operations for fuel storage liners were required to be made in the MTC in accordance with MTC operation requirements, which are described in Section 4.5.2. Any time a storage liner lifting head, closure head, or lift adapter was installed or removed from a storage liner, controls were implemented to prevent the accidental lifting of the entire storage liner.

4.5.7 - Rod Removal System Water Pit and Rod Examination System Water Pit Operations

Prior to opening the MTC doors for discharging a seed or blanket module to the MVS or to the VDS, the MVS or VDS floater was required to be at the top of the stand. Additionally, the MVS module restraint and landing adapter had to be the correct type for the module being transferred. The VDS clamping ring had to be the correct type for the module transferred, and the landing base must have been installed. When a module was lifted out of the MVS or VDS, the floater was ensured to follow the module up during the lift.

Each of the three large ports of the MVS and each of the three large ports of the VDS was a criticality zone if the port cover was in place. All fuel in any other port was considered to be out-of-storage. A large port containing a rod storage liner was a criticality zone and did not require a port cover. The center port was allowed to contain one module. Each of the two side ports were allowed to contain a limit of fuel.

Lifting and moving the vertical inspection gage (VIG) was performed only if the center port of the MVS was free of fuel and the VIG was properly rigged.

The number of rods removed from a seed module must have been less than or equal to 139, or the module must have been completely derodded. Lifting of a seed module with more than 139 rods removed was prohibited.

4.5.8 - Module Disassembly Apparatus Water Pit Operations

The HG and UF were used to move any LWBR module in the horizontal orientation, providing both were properly rigged to the bridge crane. The auxiliary hoist chains were required to be properly rigged to the HG so that they had no more than 7 inches of slack.

After installation of the end cap plate on the UF, the end cap plate rigging was disconnected from the end cap plate before lifting the rigging away.

Prior to opening the MTC doors for discharging a seed module to the upender, the seed/blanket UF with seed inserts was required to be properly installed.

4.5.9 - Production Irradiation Fuel Assay Gage Hot Cell Operations

A limit of LWBR core and core calibration rods (as described in Section 4.3) plus up to 5 equivalent grams in fission counters were allowed to be out-of-storage at any given time in the production irradiation fuel assay gage (PIFAG) hot cell area. Intermixing of LWBR fuels with any other fuel was prohibited.

SECTION 5 - SUMMARY AND CONCLUSIONS

The first M-130 shipment of Light Water Breeder Reactor (LWBR) fuel modules was received at the Expended Core Facility (ECF) in September of 1983. The fuel receipt phase of the program extended over the following 17 months at which time all 39 modules were stored in the underwater storage racks. Thirteen of the modules were visually examined. Twelve modules were disassembled to permit internal examination and extraction of individual rods. A total of 1,075 rods were removed from the 12 modules, and 524 of them were examined with specialized LWBR examination equipment at ECF. Thirty-four rods were sent to Argonne National Laboratories (ANL) for additional examination. At the conclusion of the examination program, all modules and rods were shipped to the Idaho Chemical Processing Plant (ICPP) for long-term underground storage. A total of 48 shipments were made to ICPP: 39 fuel modules, 7 shipments of packaged fuel rods, 1 spare seed module, and 1 shipment of miscellaneous fuel specimens.

The daily fuel handling operations for the LWBR program were complex and restrictive, because the fuel modules were fragile and potentially critical. Many of the examination and disassembly evolutions required more time than originally planned due to equipment problems and strict fuel handling controls. Nevertheless, the program was successfully and safely completed in the fall of 1987.

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