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PREPARATION OF LWBR SPENT FUEL FOR SHIPMENT TO ICPP FOR LONG TERM STORAGE

(LWBR Development Program)

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Operated for the U. S. Department of Energy by
WESTINGHOUSE ELECTRIC CORPORATION

NOTICE

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 a 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. The End-of-Life test program has been completed. 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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ABBREVIATIONS AND ACRONYMS

CAM	Constant Air Monitor
COS	Cut-Off System
Cs	Cesium
CSCA	Controlled Surface Contamination Area
ECF	Expended Core Facility
EOL	End of Life
HEPA	High Efficiency Particulate Air
ICPP	Idaho Chemical Processing Plant
INEL	Idaho National Engineering Laboratory
Kr	Krypton
LCS	Liner Closure Station
LWBR	Light Water Breeder Reactor
MDA	Module Disassembly Apparatus
MTC	Module Transfer Cage
MVS	Module Visual Station
PIFAG	Production Irradiated Fuel Assay Gage
POB	Proof of Breeding
REX	Rod Examination System
RRS	Rod Removal System
VDS	Vertical Disassembly Stand
VIG	Vertical Inspection Gage

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After successfully operating for 29,047 effective full power hours, the Light Water Breeder Reactor (LWBR) core was defueled prior to total decommissioning of the Shippingport facility. All nuclear fuel and much of the reactor internal hardware was removed from the reactor vessel. Non-fuel components were prepared for shipment to disposal sites, and the fuel assemblies were partially disassembled and shipped to the Expended Core Facility (ECF) in Idaho. At ECF, the 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.

This report presents a basic description of the processes and equipment used to prepare and to ship all LWBR nuclear fuel to the Idaho Chemical Processing Plant (ICPP) for long term storage. Preparation processes included the underwater loading of LWBR fuel into storage liners, the sealing, dewatering and drying of the storage liners, and the final pressurization of the storage liners with inert neon gas. Shipping operations included the underwater installation of the fuel loaded storage liner into the Peach Bottom shipping cask, cask removal from the waterpit, cask preparations for shipping, and cask shipment by tractor trailer to the ICPP facility for long term storage. The ICPP facility preparations for LWBR fuel storage and the ICPP process for discharge of the fuel into underground silos are presented.

PREPARATION OF LWBR SPENT FUEL FOR SHIPMENT TO ICPP FOR LONG TERM STORAGE

SECTION 1

INTRODUCTION

The Light Water Breeder Reactor (LWBR) core at the Shippingport Atomic Power Station operated for five years accumulating 29,047 effective full power hours (EFPH), which was beyond the initial intended core lifetime of 18,000 EFPH. After plant shutdown, the core was removed and partially disassembled. The irradiated LWBR fuel was shipped to the Naval Reactors Expended Core Facility

(ECF) in Idaho for detailed examinations of selected fuel assemblies and fuel rods to assess core component performance including an evaluation of breeding characteristics. Upon completion of these end-of-life (EOL) examinations, the irradiated LWBR fuel was transported to the Idaho Chemical Processing Plant (ICPP) for long term underground storage. LWBR fuel assemblies excluded from the EOL program were transported to ICPP while the examinations of the selected LWBR fuel assemblies were in progress. The purpose of this report is to describe the processes required and the equipment used to prepare and ship the irradiated LWBR fuel to ICPP for storage.

A brief summary of the LWBR fuel disposal operations is presented in this section along with an introduction to the LWBR fuel assemblies and the ECF facility. Section 2 provides a brief summary of the core examination program performed at ECF. Section 3 provides detailed accounts of the operations performed, the personnel training conducted, the radiological and contamination controls, and the planning and scheduling of shipments to store the irradiated LWBR fuel. Emphasis is placed on the fuel disposal process, but equipment used and problems encountered are also presented. Conclusions from the fuel disposal operations are presented in Section 4. Specific fuel disposal processes or equipment which warrant in depth descriptions are discussed in the Appendices.

1.1 LWBR Fuel Assemblies

The LWBR core was designed to demonstrate the capability of the thorium/uranium-233 fuel system for use in a breeder reactor for conventional pressurized light water reactor plants. The objective was to demonstrate typical utility operational capability while simultaneously producing more fissile fuel than was consumed. This objective resulted in design aspects unique to LWBR as described in Reference 1.

LWBR fuel modules contained fuel rods, fuel rod support grids, module support structures and instrumentation. The LWBR core had 39 fuel modules of which 12 were seed fuel modules, 12 were blanket fuel modules, and 15 were reflector fuel modules. A module type was characterized by its cross-section geometry. Pictorial views of a seed, a blanket, and a reflector module as received at ECF from Shippingport are shown in Figures 1-1, 1-2, and 1-3. The movable seed modules traveled vertically through hexagonal passageways in the blanket modules. Core reactivity was controlled by changing the axial position of the seed modules within the surrounding blanket modules. The purpose of the reflector modules, located on the outer periphery of the core, was to reduce neutron leakage from the core thereby increasing thorium conversion (breeding). Fuel disposal equipment was designed to process all fuel module types.

Further information on the fuel modules, fuel rods, fuel rod support grids, module support structures, and core instrumentation can be found in Reference 1.

1.2 ECF Facility Description

All LWBR fuel disposal operations at ECF were performed in an area of the ECF water pits approximately 105 feet long, 40 feet wide, and 35 feet deep. This area is shown in Figure 1-4. Removable watertight gates can be used to separate and isolate the large facility into smaller water pit areas. Personnel walkways traverse the top of the water pits to allow access to the equipment within. The majority of the fuel disposal operations occurred in water pits S4-39 and N4-43.

The east side of ECF has a large laydown area. This area, called the east beach, allows railcars and tractor trailers to enter the ECF building highbay area and to be positioned adjacent to the water pits to facilitate shipping and receiving operations. The east beach is also used to store, assemble, and test equipment and to train technicians prior to installation of equipment into the water pits.

Numerous building cranes and water pit bridge cranes are available to service ECF. Building cranes are used primarily to transfer equipment between the east beach and the water pits, and the bridge cranes are used to transfer equipment within the water pits. Normal fuel disposal operations required one overhead building crane and two water pit bridge cranes. The overhead building crane had an 125 ton capacity main hoist and a 25 ton capacity auxiliary hoist. The lift capacity of each of the bridge cranes was 10 tons.

1.3 Fuel Disposal Requirements

The key engineering requirements for processing and shipping the spent LWBR fuel for long term storage at ICPP are listed below. The process operations and equipment described in this report resulted from satisfying these requirements.

1. Each fuel loaded storage liner shall be dried to the extent that no liquid water remains in the storage liner at the processing temperature. The presence of liquid water compromises the integrity of the fuel cladding and the storage liner seals under worst-case temperature conditions during long term storage.

2. The storage liners shall be backfilled with neon gas providing a chemically inert atmosphere essential for long term fuel storage.

3. The fuel storage liners shall be leak checked with neon gas to 150% of the maximum postulated liner pressure for a period of 20 minutes. This satisfies the concern that the storage liners be adequately sealed for shipment and storage.

4. Fittings atop the storage liners shall be capable of maintaining a final seal of integrity equivalent to the other storage liner seals.

5. Modifications to the existing Peach Bottom shipping cask shall be minimized. The Peach Bottom cask will be used to transport each fuel loaded storage liner.

6. Sufficient protection shall be provided to prevent criticality in the event of an accidental fuel drop.

1.4 Fuel Disposal Preparations

In addition to the normal preparations necessary for the receipt of new equipment at ECF, fuel disposal operations dictated three modifications: (1) installation of a floor mounted jib crane with electric hoist, trolley, and precision load positioner; (2) upgrading of the lift capacity of the auxiliary hoist of the assigned fuel disposal overhead building crane; and (3) installation of a fuel disposal personnel work platform.

The floor mounted jib crane with electric hoist, trolley, and precision load positioner was required for fuel storage liner closure head installation because: (1) inadequate load sensitivity existed on the bridge crane and overhead crane for handling and installing a closure head on a storage liner; and (2) use of the bridge crane or overhead crane prevented parallel fuel disposal operations.

Requirements for safe transfer of a LWBR fuel loaded shipping cask using an overhead crane necessitated implementation of a redundant rigging system. Both overhead crane hoists had to be independently capable of supporting the weight of the fuel loaded cask and its rigging (37 tons) in the unlikely event one rigging set failed. Upgrading the lift capacity of the fuel disposal crane auxiliary hoist from 25 tons to 40 tons satisfied this requirement since the fuel disposal crane main hoist had a lift capacity of 125 tons. Further details on the redundant rigging concept and design can be found in Appendix F.

The personnel work platform for water pit S4-39 was required: (1) to allow the water pit technicians to service the fuel disposal stations with the bridge crane present; (2) to improve accessibility to the work stations; and (3) to allow proper interface with dedicated fuel disposal tooling.

Safety was a prime consideration throughout LWBR fuel disposal preparations. The safety aspect was an inherent feature of equipment and facilities designs and was further enhanced by personnel training and checkout of equipment and operating procedures. Safety features included: (1) careful control of personnel radiation exposure; (2) protection against uncontrolled nuclear criticality; (3) protection against the spread of radioactive contamination; and (4) the use of specially designed and tested fuel disposal equipment to protect personnel from injury and fuel from damage. As a direct result of this emphasis on safety, all fuel disposal operations were completed with no serious injury to personnel and with no damage to fuel or equipment.

Equipment for fuel disposal operations was installed into water pits S4-39 and N4-43 and on the east beach as shown in Figure 1-4. These locations were originally used for LWBR fuel receipt from Shippingport. The fuel receipt equipment was removed prior to installation of the fuel disposal equipment. Ease of installation was a key design feature for all fuel disposal water pit equipment since the pits were full of water. This equipment was trial assembled prior to shipment to ECF to assess the ease of remote installation. Modifications to the equipment were made where required. As a result, all equipment was remotely installed in the water pits on schedule without the need for further modifications or draining of the water pits.

To prepare personnel for fuel disposal operations, an extensive training program was initiated at ECF prior to actual fuel disposal operations. Training was conducted using actual disposal tooling, hardware, and process systems to simulate actual operating conditions as nearly as possible. The first objective in the fuel disposal training program was to familiarize personnel with the tools, hardware, and system operations so that actual fuel disposal shipments would proceed smoothly, safely and with minimal radiation exposure.

The second objective of the training program was to complete checkout of all fuel disposal tools and procedures. Adequacy of the tools was determined and necessary changes made when required. This part of the program was particularly successful in that several operational sequences were changed to reduce tool handling and the time required to perform the desired operation. Compliance with detailed procedures was intended to provide safe and efficient performance of each fuel disposal evolution. Problems (short comings) in the procedures were found and improved accordingly so that subsequent delays during actual operations were minimized.

1.5 Summary of Fuel Disposal Operations

The fuel disposal process was comprised of the following operations: (1) Peach Bottom shipping cask receipt and water pit installation; (2) fuel storage liner transfer to the liner closure-station; (3) fuel storage liner closure; (4) fuel storage liner drying, inert gas back-fill; and leak testing; (5) fuel storage liner loading into the Peach Bottom cask; (6) Peach Bottom cask removal from the water pit; and (7) Peach Bottom cask shipment. These operations are discussed briefly below. To follow the progress of the Peach Bottom cask and the fuel storage liner through the fuel disposal process refer to Figure 1-4.

Upon receipt of the empty Peach Bottom cask at the ECF highbay the cask shipping cover was removed. The Peach Bottom cask, cask shipping cover, and dedicated shipping trailer are shown in Figure 1-5. Radiological surveys of the cask were performed to confirm that no unacceptable surface contamination was present and that radiation levels were acceptably low. After removal of the cask crushblocks and the shipping tie-down hardware, horizontal handling equipment was installed on the cask. The cask was lifted from the transport trailer and was placed horizontally in the downender support structure located on the water pit east beach. The lift adapter plate was bolted to the top of the cask. The primary vertical handling rigging, consisting of the primary spreader beam, wire ropes and pear links, was installed. The cask was then upended to the vertical position. The cask was lifted from the east beach, transferred over the water pit, and lowered into the cask underwater support structure at the bottom of water pit N4-43. Removal of the cask top closure lid utilizing the lift adapter plate was the final step in preparation for receipt of a fuel storage liner.

All spent LWBR fuel was stored in open fuel storage liners within the fuel storage racks located in water pits S4-37 and S4-38. To initiate liner closure operations, the loaded storage liner was transferred from the storage racks to the liner closure station head installation port.

The liner closure station, shown in Figure 1-6, was located in water pit S4-39. Concurrently, the storage liner closure head was prepared for installation while dry on the east beach. Once prepared, the liner closure head was lowered down onto the liner body. With the closure head properly installed, all closure head bolts were torqued to seal the closure head-to-storage liner interface. The liner lift adapter was then installed and the liner was transferred from the liner closure station head installation port to the liner closure station dewatering port for dewatering operations.

Five fluid processes were necessary to meet the requirements for long term storage of the LWBR fuel. The storage liners required water blowdown, air circulation, vacuum drying, neon backfill, and pressure/leak testing. All fuel liner dewatering processing was performed, monitored, and controlled by the dewatering support system and its associated mechanical tooling. Storage liner blowdown removed the bulk water from within the storage liner. Dry air circulation removed several pounds of remaining residual water, which reduced the burden on the vacuum drying process. Vacuum drying, which required approximately 22 hours of vacuuming and soaking operations, finally dried the storage liner. Neon gas backfill provided the inert atmosphere desirable for long term storage while pressure and leak testing verified the integrity of the storage liner seals.

With the loaded fuel storage liner dried and sealed, the storage liner was transferred to the Peach Bottom cask. The liner was inserted within the cask cavity and the cask top closure lid was reinstalled. The cask vertical redundant rigging, consisting of the primary rigging and the redundant rigging A-frame and independent wire rope, was attached. The loaded cask was then lifted out of the water pit. The redundant rigging technique is illustrated in Figure 1-7. Clean water was used to flush and clean the exterior of the cask and rigging as they exited the water pit. Once the cask internals were drained, the cask was transferred to the east beach downender and rotated to the horizontal position. Prior to loading the cask onto the trailer, radiological surveys were performed to verify that the cask was externally radiologically clean. Horizontal rigging was utilized to transfer the cask to the trailer, followed by the attachment of the shipping tie-down hardware, crushblocks, and the cask shipping cover.

A total of forty-eight fuel disposal shipments were made. The following comprise these 48 shipments: all 39 LWBR fuel modules, seven fuel rod liners, one spare unirradiated LWBR seed module and one "cut fuel" liner of irradiation test rods. Seven fuel rod liners were required to accommodate the rods removed from the modules for examination purposes, the unirradiated calibration rods used to verify the calibration of proof-of-breeding equipment, and the rods from the modules disassembled for fuel rod grid removal and for in-bundle fuel rod gap examinations. The spare seed shipment disposed of the unirradiated core seed module, and the "cut fuel" shipment disposed of irradiated and unirradiated test rods and rod segments from LWBR and other breeder test programs.

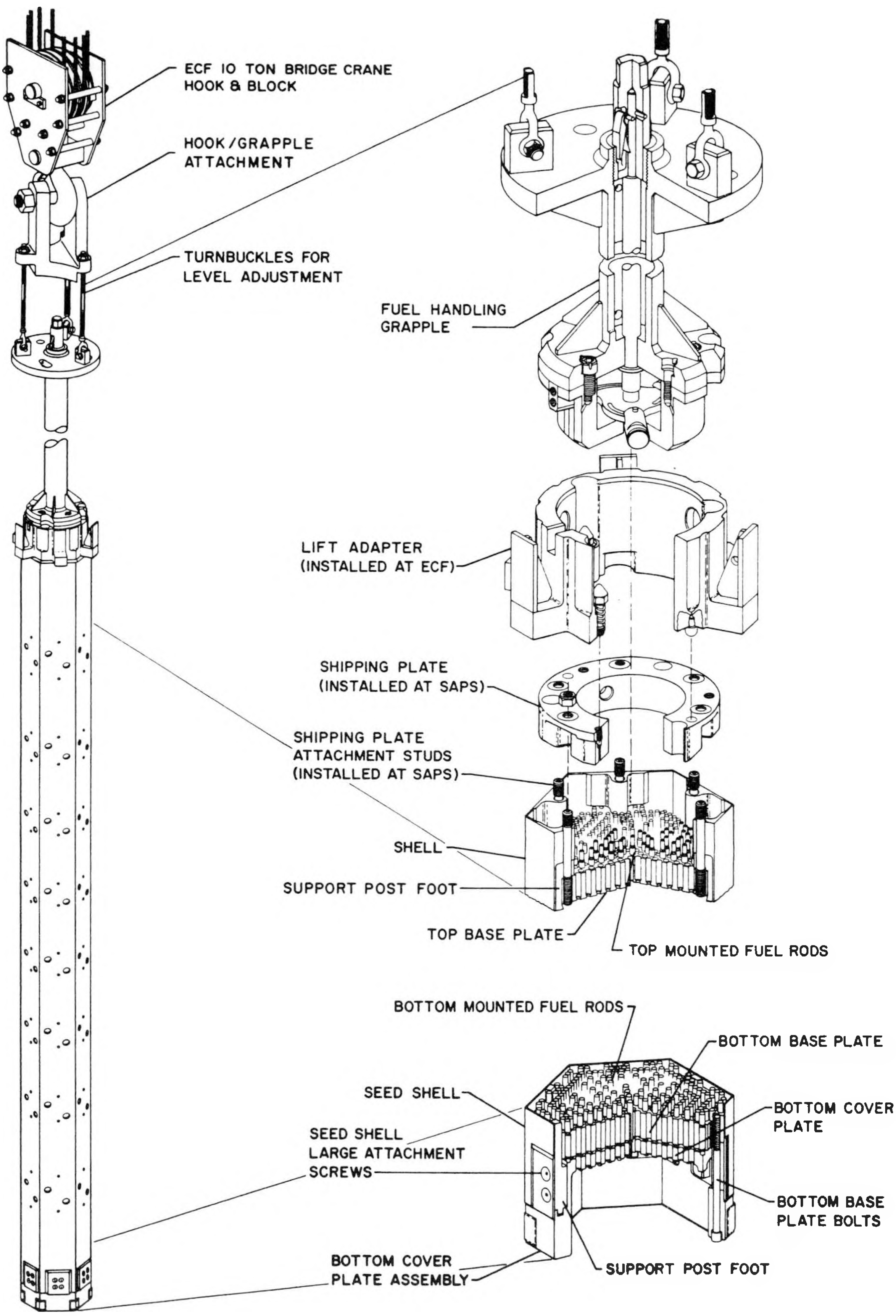

Figure 1-1: LWBR Seed Module As Received At ECF

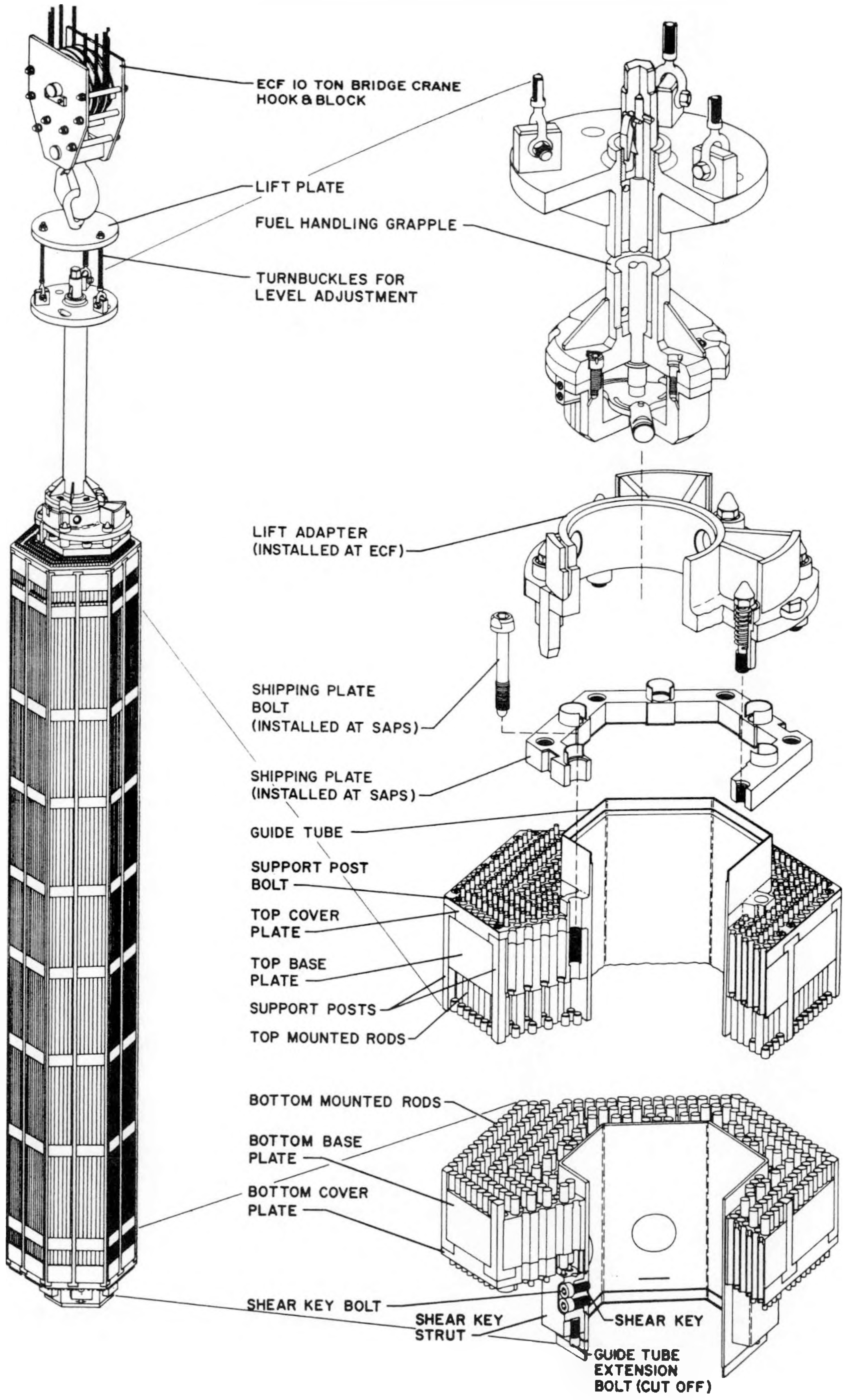

Figure 1-2: LWBR Blanket Module As Received At ECF

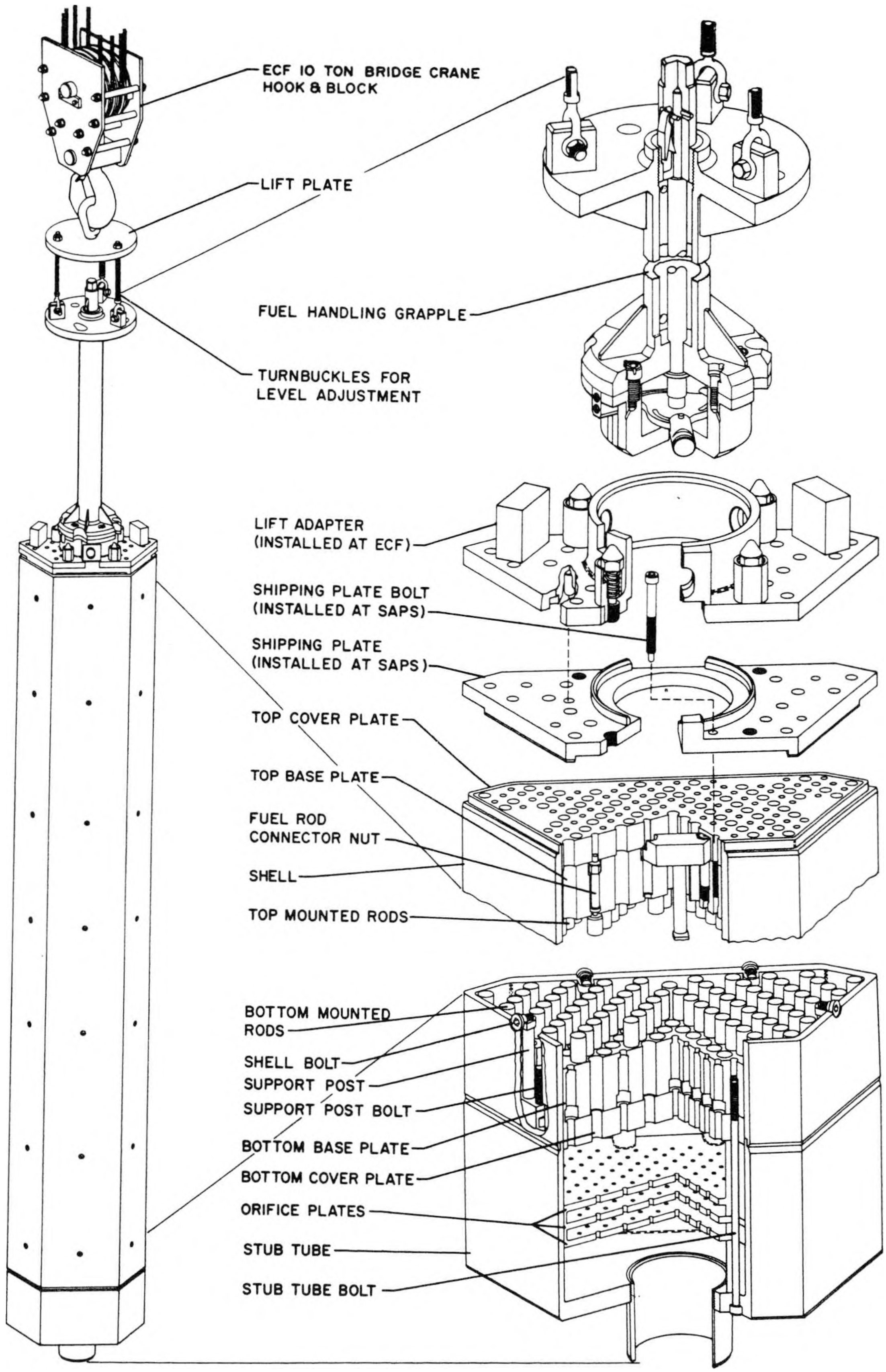

Figure 1-3: LWBR Reflector Module As Received At ECF

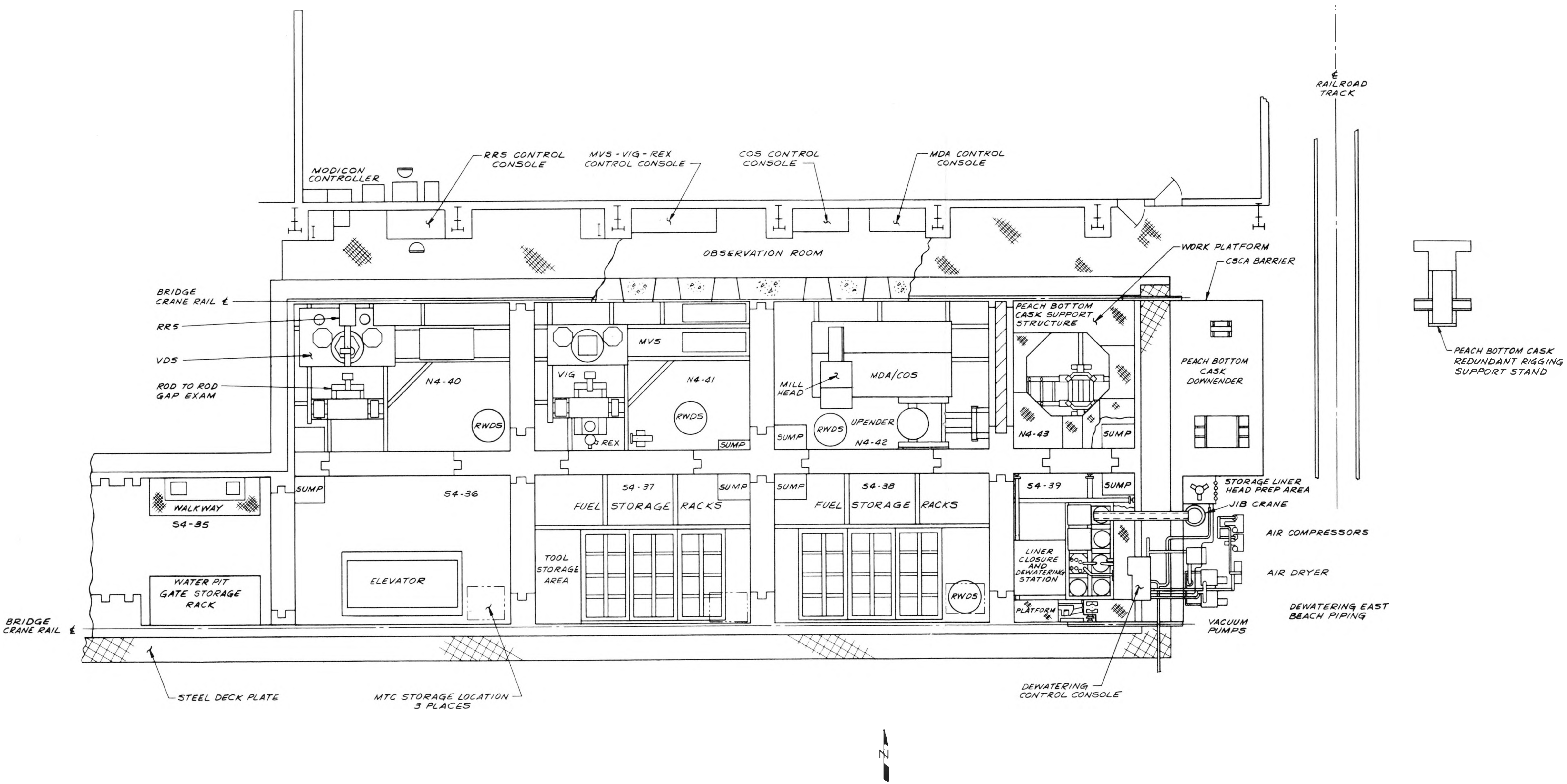

Figure 1-4: Area of ECF Water Pits Used For LWBR Program

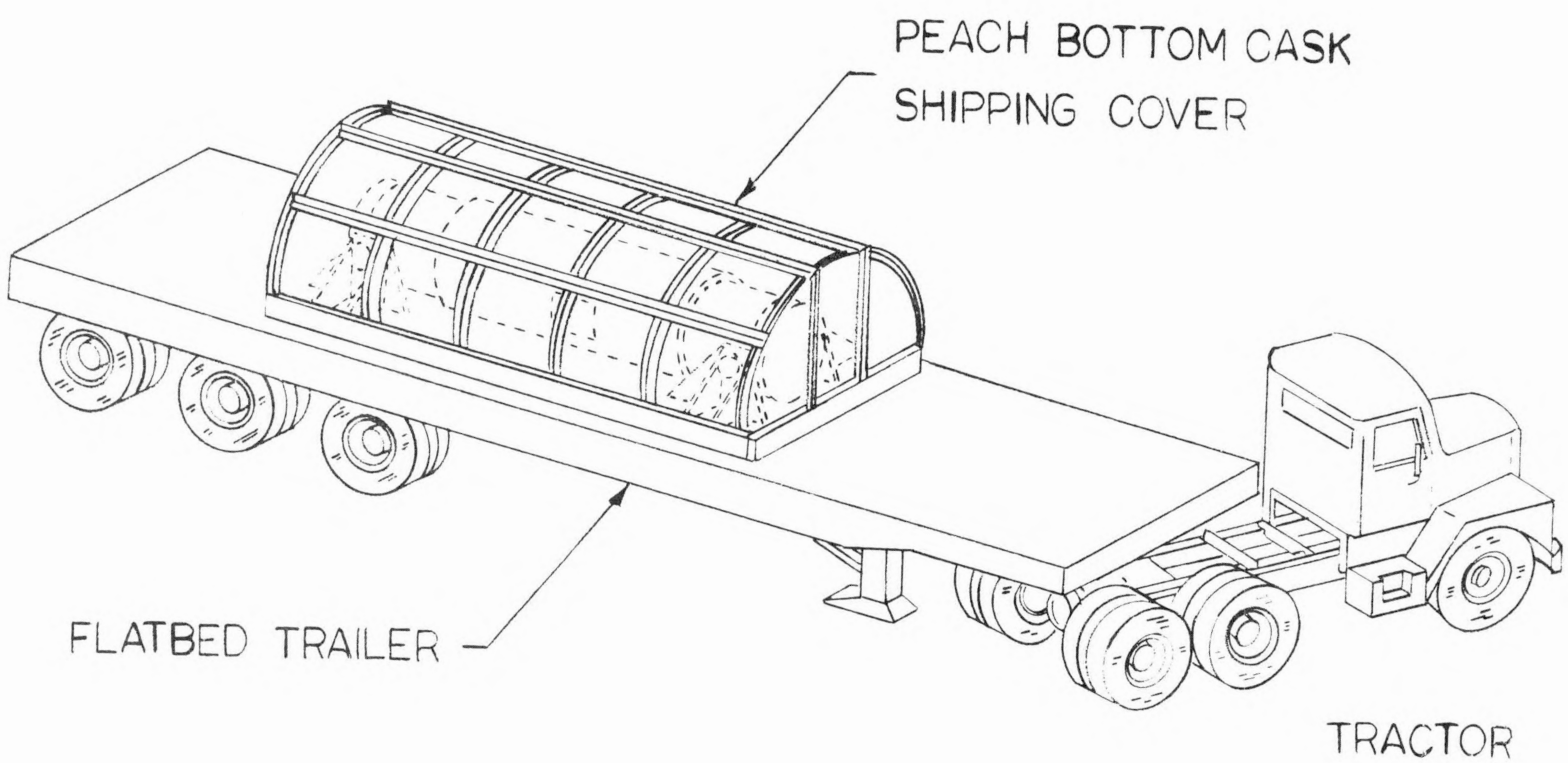

Figure 1-5: Peach Bottom Shipping Cask Receipt At ECF

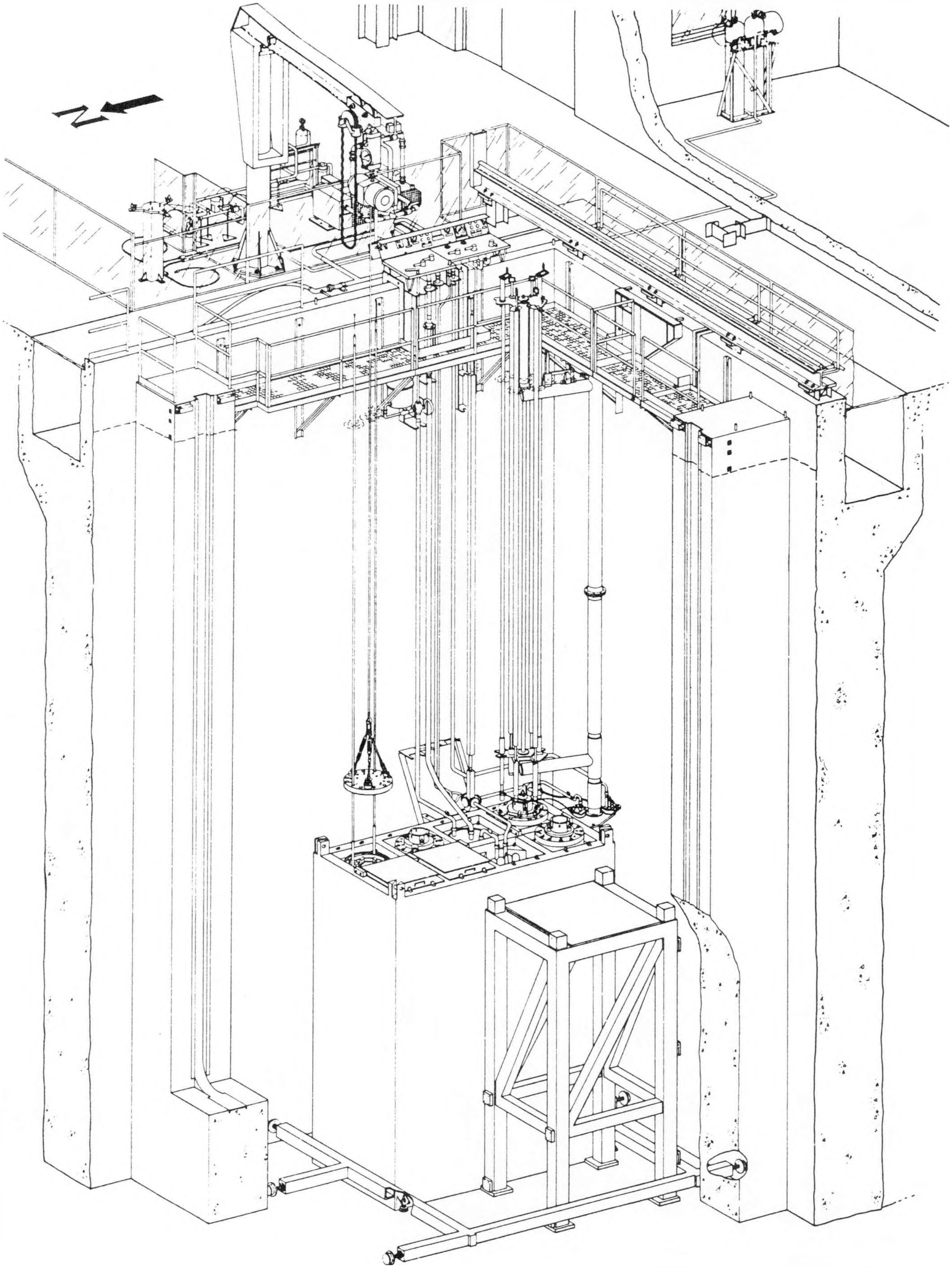

Figure 1-6: LWBR Fuel Storage Liner Closure and Dewatering Station

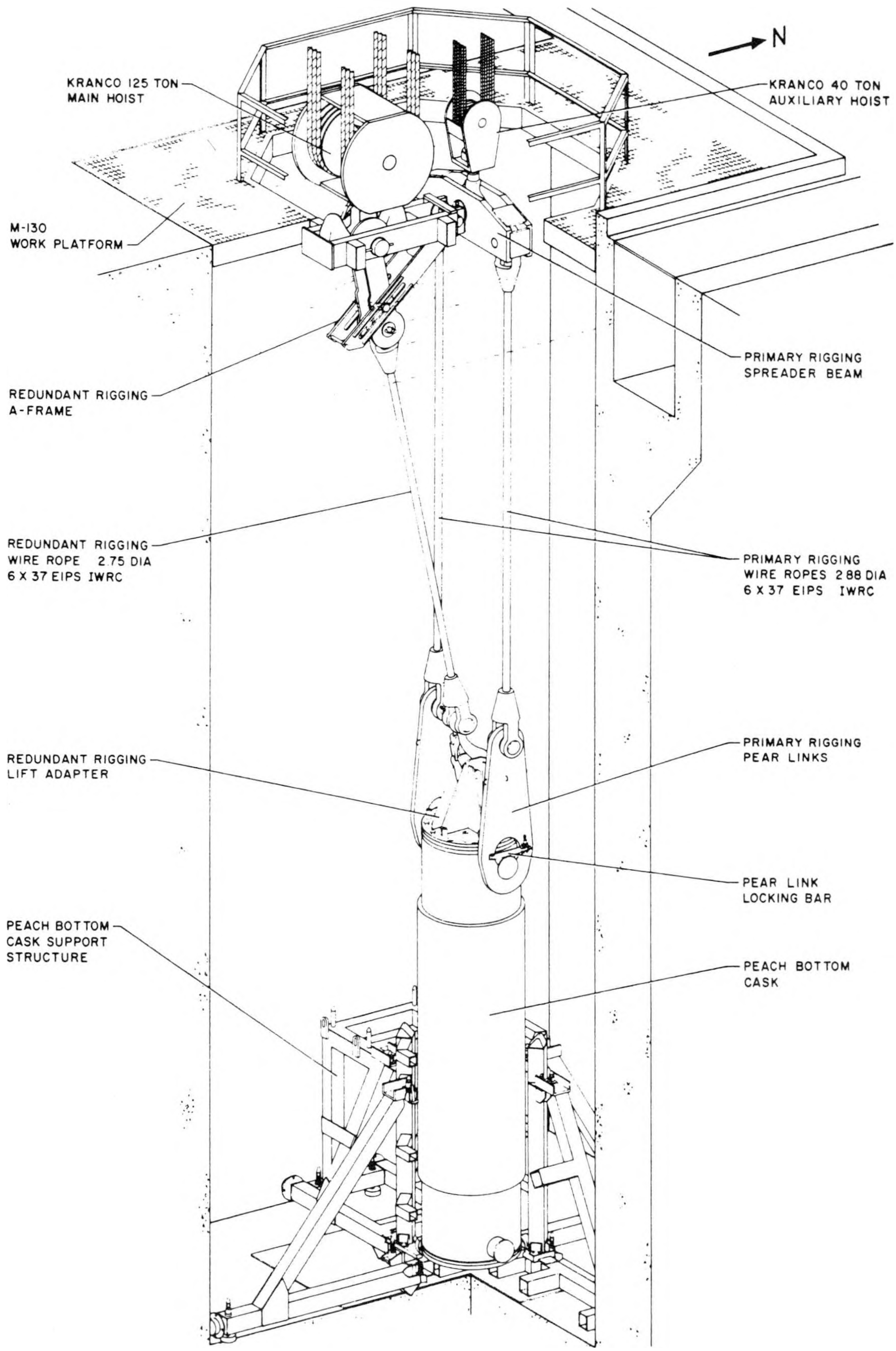

Figure 1-7: Peach Bottom Shipping Cask Redundant Rigging

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SECTION 2

SUMMARY OF CORE EVALUATION AT ECF

The LWBR core started operation in the Shippingport Station in the fall of 1977 and concluded routine power generation on October 1, 1982. Following underwater partial disassembly to a suitable length to allow shipping, the spent LWBR fuel modules were shipped to the Naval Reactors ECF for expended core evaluation. Shipment was via rail using three M-130 shipping containers with specially modified internals to accommodate the three geometrically different fuel module types. There were four shipments of blanket modules, two shipments of seed modules, and four shipments of reflector modules. The objectives of the core evaluation program were to verify the adequacy of the core component designs and to verify fuel breeding. Core evaluation included the following operations: (1) LWBR fuel module receipt; (2) LWBR module disassembly; (3) LWBR core examination; and (4) LWBR proof-of-breeding. The following is a brief summary of these operations.

2.1 LWBR Fuel Module Receipt

Upon receipt of the LWBR fuel modules at ECF, the internal atmosphere of each shipping cask was sampled for fission gases to determine the integrity of the fuel rod cladding. These tests indicated that all shipments were completed without damage to the fuel cladding in any of the fuel modules. Lift adapter plates, shown in Figures 1-1, 1-2, and 1-3, were installed on each fuel module. These adapter plates provided a means to grapple and lift the fuel modules in a vertical orientation.

The fuel modules were then transferred individually to water pit S4-37 or S4-38 for storage in the module storage racks. Further information on LWBR fuel module receipt at ECF can be found in Reference 2.

2.2 LWBR Fuel Module Disassembly

To achieve the evaluation goals of core examination and proof-of-breeding, the fuel modules had to be remotely disassembled to free core components and fuel rods. Module disassembly occurred on the Cut-Off System (COS) or the Module Disassembly Apparatus (MDA), located in water pit N4-42. The MDA and COS were actually one machine with two distinct machining heads. The MDA was a large underwater precision milling machine and the COS was a large underwater horizontal bandsaw. The MDA was converted to the COS by replacing the milling head with the bandsaw attachment. The MDA/COS table had the capability of supporting any module type horizontally along with its associated disassembly fixturing. The MDA was used (1) to mill shell screws and slit shells for module deshelling to permit external visual examination of the exposed fuel rods, and (2) to free structural components, namely grid sections, grid fasteners, support posts and support post bolts for visual examination to assess corrosion, contact, and wear markings. These MDA operations were performed on one seed and one reflector module. The COS was used to cut both ends of a module which severed the structural components and freed all fuel rods. Twelve modules, four of each module type, were severed by the COS. Further information on LWBR fuel module disassembly at ECF can be found in Reference 3.

2.3 LWBR Core Examination

Visual examinations of the fuel modules by underwater television cameras were performed in the Module Visual Station (MVS) and the Vertical Disassembly Stand (VDS). Both facilities are shown in Figure 1-4. The MVS, located in water pit N4-41, was an underwater facility for supporting fuel modules in the as-received condition and obtaining visual and dimensional characterizations of the module surfaces and shapes. Instrumentation packages mounted to a precision elevator platform, called the Vertical Inspection Gauge (VIG), were used to perform these inspections. The VDS, located in water pit N4-40, was very similar to the MVS except that the VDS handled cut-off modules from the COS. Video recordings made by the Rod-to-Rod Gap Examination Gauge, a system similar to the VIG, were used to perform fuel rod bow and gap measurements on peripheral and internal fuel rods. In total, 13 as-received fuel modules were examined in the MVS. One blanket module and both the deshelled seed and reflector modules were examined in the VDS. Further information on LWBR end-of-life visual and dimensional examinations at ECF can be found in References 4 and 5.

To perform individual fuel rod examinations, the fuel rods had to be extracted from the fuel modules. The Rod Removal System (RRS), located directly above the VDS, was used to pull the specified fuel rods from the cut-off modules. The COS preparation freed and exposed the fuel rod end stems. The RRS was a double arm jib crane with a grapple unit that utilized a collet device for engaging the fuel rod end stem.

Approximately 1100 fuel rods were removed from the 12 cut-off modules by the RRS. These fuel rods were removed to provide: (1) fuel rods for nondestructive and destructive examinations; (2) fuel rods for proof-of-breeding evaluations; and (3) to provide access for module grid sectioning and core component removal by the MDA. Further details on the RRS can be found in Reference 6.

Nondestructive fuel rod examinations were performed using the Rod Examination Gauge (REX). The REX was mounted onto a replaceable platform attached to the back of the VIG carriage at the MVS. The following examinations were performed utilizing the REX: (1) detailed visual inspection; (2) free-hanging fuel rod bow measurements; (3) fuel rod length measurements; (4) fuel rod diameter measurements; (5) ultrasonic inspection for fuel rod cladding defects; (6) fuel rod radial profile measurements; and (7) eddy-current testing to measure cladding corrosion film thickness. Nineteen fuel rods were examined by the REX. Further information on nondestructive examination of LWBR fuel rods at ECF can be found in References 5 and 7.

Destructive examinations of fuel rods were performed at Argonne National Laboratory. These examinations included visual and dimensional inspections of fuel rod cladding, fuel pellets, fuel rod plenum springs, and fuel rod nuts; metallographic examinations of fuel rod cladding, fuel pellets, fuel cladding welding, fuel rod end stems, fuel rod plenum springs and fuel rod nuts; fuel cladding tensile tests, hydrogen analysis, iodine and cesium analysis, and neutron fluence analysis; and fuel rod fission gas analysis, fuel depletion analysis and neutron radiography. In addition to the fuel rods, the following core components were also destructively analyzed: (1) grid section, (2) grid bolts, and (3) shell screws. Further information on destructive examinations of LWBR fuel rods and other core components can be found in References 8 and 9.

2.4 LWBR Proof-of-Breeding

The final aspect of the core evaluation program was proof-of-breeding. The nondestructive assay of fuel rods to determine end-of-life (EOL) fissile fuel content was performed using the Production Irradiated Fuel Assay Gage (PIFAG) located in the ECF hot cells. A total of 524 fuel rods were assayed. The hot cells were located north of the water pits and connected to the water pits via a transfer canal and elevator. The PIFAG was used to perform a nondestructive assay of a fuel rod by neutron irradiation of the fuel rod and subsequent counting of the delayed neutrons emitted from the rod. From this delayed neutron count, the amount of fissile fuel within the fuel rod can be determined. Destructive analyses on a small number (17) of fuel rods were performed by Argonne National Laboratory after they had been assayed by the PIFAG. The results of these analyses were used to obtain correction and calibration factors related to the PIFAG measurements and to corroborate the results of the nondestructively determined rod fissile loadings. Further details on the LWBR proof-of-breeding assay can be found in Reference 10.

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SECTION 3

LWBR FUEL DISPOSAL OPERATIONS

The LWBR fuel modules were received at the Expended Core Facility (ECF) in Idaho in ten consecutive shipments from Shippingport, Pennsylvania. Upon receipt the fuel modules were placed into individual storage liners located in fuel storage racks within the water pits. After each module processing operation the modules were returned to their designated storage liner. Upon completion of all scheduled module examinations, the individual storage liners housing the fuel were transferred to the Liner Closure Station (LCS) for final closure head installation and water removal. This operation was then followed by a transfer of the dried and sealed liner to the Peach Bottom Cask shipping container for subsequent shipment to ICPP for long term underground storage. Presented below is a detailed description of the equipment and processing necessary to meet the requirements for LWBR fuel disposal.

3.1 Fuel Storage Liner Closure

Prior to the receipt of LWBR fuel at ECF, the empty fuel storage liners were placed into specific storage ports within the water pit fuel storage racks to maintain required spacing between stored nuclear fuel. As each LWBR fuel shipment arrived, individual fuel modules were inserted into assigned storage liners. The fuel storage liners, as shown in Figure 3-1, were upright, right circular cylinders having an outside diameter of 25.50 inches and a length, with the closure head installed, of 157.80 inches. The major pieces that comprised a fuel storage liner were the main body, the final closure head, the final closure head bolts, and the head and bolt seals. Detailed information germane to the fuel storage liners can be found in Appendix A. During interim storage of the LWBR fuel, the storage liner loaded with fuel remained uncovered except for the storage rack security lid. This hinged lid enabled each storage location of the fuel storage rack to be secured when occupied with fuel.

The final closure and dewatering of the storage liner were performed at the Liner Closure Station (LCS) following transfer of the storage liner, loaded with fuel, from the fuel storage racks to the LCS. Transfer of the storage liner to the LCS began with installation of the storage liner lifting head assembly, shown in Figure 3-2, onto the storage liner. The vertical fuel grapple then engaged the lifting head and lifted the storage liner with fuel up into the Module Transfer Cage (MTC). The MTC was independently attached to the water pit bridge crane trolley. In the unlikely event of a dropped fuel storage liner loaded with fuel, the MTC provided a "basket" to catch the fuel. This double rigging design provided drop protection for the vertically suspended fuel during all waterpit transfers. Further information on the MTC and vertical fuel grapple can be found in Appendix B. Once within the MTC, the storage liner was transferred to a position directly above one of the head installation ports of the LCS.

The LCS, shown in Figure 3-3, was a modified fuel storage rack with four work stations, two intermediate storage ports, and two equipment ports.

Two of the four work stations were for head installation while the other two ports were for liner dewatering. The two equipment ports housed the filtration system and the water blowdown holding tank. A further discussion on the Liner Closure Station can be found in Appendix C.

Proper orientation of the storage liner within the LCS head installation port was obtained by positioning the removable guide bolt in the storage liner girth ring in the notch of the closure station guide plate, shown in Figure 3-4. Once completed, the lifting head assembly was removed from the storage liner and disengaged from the fuel grapple. After the MTC had been removed from the area, preliminary work such as preparing the liner closure head and storage liner for head installation began. In the event that the work could not begin immediately, the LCS ports for head installation could be closed and sealed placing the storage liner, loaded with fuel, into secure storage.

Prior to installation of the storage liner closure head, several preparatory operations were performed to ensure that the head would seal as required when installed. In order to employ a hands-on operation due to the finger dexterity required, which was not available with radiologically gloved hands, the liner closure head preparations were performed in a radiologically clean area on the head staging pedestal. Refer to Figure 1-4 to locate the liner closure head preparation area. The main seal of the liner closure head, a silver coated nickel O-ring having an outside diameter of 25.22 inches, was unpacked and placed into the holding grooves of the staging pedestal.

The liner closure head, which was unique to the specific liner being processed, was unpacked, inspected for acceptance and placed onto the head staging pedestal. A typical liner closure head is shown in Figure 3-5. Bolt numbers for the closure torquing sequence and an alignment mark were painted onto the head. Each of the final closure bolts and dewatering self-seal fittings were inspected. Each bolt had a silver coated nickel O-ring, similar to the main head seal, installed in the underside of the bolt head. The bolt head seals were required since these bolts were located inside the main head seal.

There were two dewatering self-seal fittings on the liner closure heads which provided sealable access to the storage liner internals. A drain fitting, shown in Figure 3-6, doubled as a closure bolt as well as a connection to the liner drain pipe to allow water to be removed from the liner. The other was a vent fitting, positioned 8.00 inches radially from the center of the head, which provided a valved fitting into the liner cavity. The vent fitting is shown in Figure 3-7. The vent fitting was assembled to the closure head by first threading the vent lower body onto the closure head vent nipple and sealing its nickel washer. Proper installation of the lower body was assured by the use of a specified installation torque and a check of the vent body position relative to the top of the closure head. An installation gage was slid over the vent lower body to ensure proper seating. This guaranteed that the vent body had seated and pinched the nickel washer as designed. Further information on the two closure head self-seal fittings is presented in Section 3.2.

Each closure head had twelve bolt hole locations. The installation of one bolt and the drain fitting into the closure head was deferred until the closure head was securely positioned on the storage liner. Because the relative location of the bolt and the drain fitting were identical for all liner types, these two positions were used in conjunction with alignment pins to align and guide the closure head during installation onto the liner.

Once the preparation of the liner closure head was completed, the head was rigged to the east beach jib crane as shown in Figure 3-8. This jib crane employed a movable trolley with electric hoist and a hydraulic load positioner to securely move the prepared closure head from the radiologically clean staging pedestal to a position above the storage liner. The closure head remained in the staging pedestal until the storage liner main body was prepared for sealing.

Preparation of the storage liner main body required installation of two alignment pins into the liner girth ring. These alignment pin positions corresponded with the open bolt and drain fitting locations in the closure head. The alignment pins accurately positioned the head when it was lowered onto the storage liner to ensure all bolt holes aligned. This technique minimized the potential for the closure head bolts to bind when threaded into the liner. Identification of the two proper bolt holes was aided by installation of an alignment pin installation guide plate. Aligning the specific identifying arrow for the liner type being worked, with the guide pin on the side of the liner, identified the proper holes for installing the alignment pins. The guide plate also covered the fuel and other open areas of the storage liner while remote tool operations were performed in the vicinity. The alignment pin installation guide plate is shown in Figure 3-9.

After the alignment pins were threaded into the exposed holes, the liner main body seal guard ring was removed. The guard ring protected the metallic O-ring sealing surface of the storage liner while in interim storage at ECF. With the sealing surface exposed, it was inspected for marks and brushed free of any loose sediment by a soft bristle brush attached to the end of a probe pole. The alignment pin installation guide plate was removed completing the preparation of the storage liner for installation of the liner closure head. A water sample was taken above the open storage liner and analyzed for fission products (Cs-134 and Cs-137). Abnormal levels of cesium activity in the water would indicate the possible existence of a through-clad defect in a fuel rod.

With both the liner and the closure head prepared, and the water sample taken, the east beach jib crane was swung to a position directly above the storage liner. Once in position, the head was slowly lowered until the top of the alignment pins protruded through the two remaining bolt holes in the closure head not yet occupied by a bolt. Since the head could only be installed in one orientation and the alignment pins could only go through the vacant bolt holes, it was impossible for the head to be installed in an improper orientation. This closure head installation technique is shown in Figure 3-10.

The electric hoist was used to slowly lower the closure head down to a predetermined height above the storage liner. At this elevation, the closure head began to engage the enlarged diameter of the alignment pins. The diameter of the alignment pins was enlarged at this point to ensure the head would properly seat with all bolt holes aligned. The alignment pins were not this diameter over their entire length in order to allow the closure head to be lowered freely without binding.

Using the hydraulically actuated load positioner mounted to the east beach jib crane, the head was lowered until a predetermined amount of unloading, a decrease in load hanging from the load positioner, was attained. At this point the closure head was resting on the storage liner with part of the head weight still supported by the installation rigging. With the head in this position, the closure head bolt handling tool was obtained and used to sequentially thread the prepared bolts into the storage liner until they were hand tight.

The closure head bolt handling tool employed an expandable rubber grommet which engaged the hex socket of the closure bolt allowing the bolt to be lifted, lowered or rotated. The closure head bolt handling tool was surrounded by an adjustable flotation collar which required a deliberate downward force to be applied to the tool when installing the bolts. The function of the flotation collar was to prevent the bolts from impacting the storage liner as they were threaded through the closure head.

With the ten closure head bolts handtight, the alignment pins were removed and the remaining bolt and drain fitting were installed and threaded hand tight. The installation rigging was unbolted from the closure head and removed from the water pit. Following the numbers which were earlier stenciled on the closure head, the closure bolts were sequentially tightened to ensure even loading and compression of the main closure head seal.

With the final closure head installed and bolted in place, the storage liner lift adapter, shown in Figure 3-2, was bolted to the head. The storage liner was then transferred, using the vertical fuel grapple and MTC, to a dewatering port of the Liner Closure Station for the final phase of extended storage preparation. The storage liner lift adapter remained bolted to the storage liner until the liner was placed into the Peach Bottom Cask shipping container.

During transfer to a dewatering port of the LCS, the guide pin which was used to orient the storage liner in the closure head installation port was removed. This guide pin no longer provided any function once the final closure head had been installed and was removed to permit the storage liner to be inserted into the Peach Bottom Cask shipping container.

Prior to disengaging the fuel grapple and removing the MTC, the storage liner was rotated until the vent fitting was aligned with an arrow permanently attached to the Liner Closure Station. This alignment ensured that the storage liner was properly oriented relative to the storage liner dewatering tooling. Once aligned, the fuel grapple was removed and the MTC moved away.

3.2 Fuel Storage Liner Dewatering

Five fluid systems were utilized to dewater and dry the fuel storage liners: (1) liner blowdown, (2) air circulation, (3) vacuum drying, (3) neon backfill, and (5) pressure and leak testing. The fuel storage liner dewatering system is shown in Figure 1-6. All fuel liner dewatering processing was performed, monitored and controlled by the dewatering support system and its associated mechanical tooling. Details on the equipment and mechanisms which comprised the dewatering system can be found in Appendix D.

Fuel liner blowdown removed the bulk water from the liner. A schematic of the liner blowdown system is presented in Figure 3-11. Preparations for blowdown required the installation of both the drain and vent umbilical tools, use of the funnel latch plate, and the opening of both the drain and vent self-seal fittings. The umbilical tools connected the fluid processing network to the fuel storage liner via the self-seal fittings. The coupling of the drain and vent umbilical tools to their corresponding self-seal fitting is shown in Figures 3-12 and 3-13. The self-seal fittings, shown in Figures 3-6 and 3-7, provided sealable access to the storage liner internals. The funnel latch plate mechanism, shown in Figure 3-14, aided umbilical tool installation plus it secured the tools to the storage liner to prevent inadvertent separation. Further details on the umbilical tools, the self-seal fittings, and the funnel latch plate can also be found in Appendix D.

Water removal from the storage liner was accomplished by forcing 35 psig air into the top of the storage liner through the vent umbilical tool. The forced air displaced the water out of the storage liner through the storage liner's standpipe, the drain fitting, and the drain umbilical tool. The water was piped through a bank of high efficiency filters, to remove radiologically contaminated particles and crud, and was collected in the blowdown tank. Water exiting the blowdown tank was piped to a volumetric flow meter which sent a signal to the flow totalizer on the dewatering control console giving instantaneous output of total gallons forced out of the liner. Water exiting the flow meter was returned back into the water pit.

To assure that all fuel storage liner water was displaced, a larger volume of compressed air was pumped into the liner than volume of water available. Uncontrolled release of bubble producing gas from this submerged dewatering process was not allowed during normal operations since the bubbles could potentially raise airborne contamination. To prevent this from occurring, when all water was finally forced from the storage liner, the extra compressed air continued to exhaust into the blowdown tank. The blowdown tank was sized to have a volume of approximately 450 gallons as compared with the nominal free volume within a fuel-loaded storage liner of approximately 250 gallons. The air which accumulated in the blowdown tank was never free to exit the closed piping system due to the size of the blowdown tank.

The water blowdown process was initiated with the entire blowdown system full of pit water. Compressed air was forced through the blowdown system until the flowmeter downstream of the blowdown tank registered 450 gallons, assuring the fuel storage liner was empty of bulk water. Once the shutdown mark was attained, valving was adjusted to stop the flow of water from the blowdown tank. In preparation for the next dewatering phase, the blowdown tank bypass valve was adjusted to open the tank bypass line to allow the air in the tank to exhaust freely to the ECF waste gas stack.

Air circulation through the fuel storage liner was the second fluid process. A schematic of the liner air circulation system is presented in Figure 3-15. Circulation of dry compressed air was found in testing to remove several pounds of the remaining water. To perform the air circulation, the air compressors continued pumping at approximately 17 cfm (air flow at zero resistance) through the air dryer system, down through the fuel liner and filter system, and into the blowdown tank.

The open blowdown tank bypass valve allowed the air to exhaust fully to the ECF waste gas stack. Air circulation continued for 20 minutes. To terminate this dewatering phase, the air compressors were stopped and the O-ringed drain fitting plug, shown in Figure 3-12, was inserted using the drain umbilical tool inner spindle. This stopped the air flow through the fuel liner by sealing the drain fitting.

Access to the fuel liner for vacuum drying occurred only through the vent umbilical tool. System valving at the dewatering control panel was adjusted to disconnect the vent umbilical line from the air compressors and to link the vent line to the vacuum pumps. A schematic of the vacuum drying process is presented in Figure 3-16. Vacuum drying, the third fluid process, was accomplished on a 6 hour pump, 2 hour non-vacuum soak cycle. The soak time eliminated the possibility of freezing the remaining water in the fuel liner. Prototypical testing, using the actual processing equipment and method, established that vacuum drying was complete when a vacuum level of 3 millibar or less was held for a period of 2 consecutive hours. Preliminary testing determined that this dry condition characteristically required 3 full vacuum cycles, or approximately 22 hours total. A representative vacuum drying curve was developed giving the ECF operators a guideline to assess whether liner drying was proceeding adequately. Figure 3-17 illustrates the typical drying curve with the pressure spikes during the soak cycles and the gradual lowering of internal pressure until the 3 millibar or less readings were observed for the required 2 hour holding period.

During the vacuum drying cycles parallel operations were performed. The cap of the drain self-seal fitting was installed using the drain umbilical tool inner spindle and the funnel latch plate staging slide. The blowdown tank was refilled during the vacuum drying operation. The blowdown diverter valve, shown in Figure 3-11, was first opened. With the blowdown tank bypass line acting as a vent, gravity forced water down into and refilled the blowdown tank. Air trapped within the tank during blowdown and air circulation was exhausted out the blowdown tank bypass line to the ECF stack. A check valve located in the piping between the blowdown tank and the filters prevented filter backflush. Backflow through the filters was undesirable since it could flush trapped contaminants back into the piping system.

After vacuum drying was completed, based upon the 3 millibar criteria, the fuel storage liner was valved off from the vacuum pumps and the pumps were shut down. The neon supply system was activated and valving was adjusted to allow the neon to enter the evacuated liner via the vent umbilical tool. A schematic of the neon backfill, the fourth fluid process, is presented in Figure 3-18. Pressure regulators controlled the maximum neon pressure to 62 psig. The lexan window on the funnel latch plate was observed for a 20 minute period for accumulation of bubbles which would indicate a leak. This completed the fifth fluid process. The high pressure neon was then bled from the liner to the ECF stacks until low atmospheric pressure was reached. The vacuum pumps were reconnected and used to reduce the pressure inside the liner down to a final level of 430 ± 50 millibar. At this vacuum pressure the vent fitting cap was closed and torqued by the vent umbilical tool inner spindle, see Figure 3-13, to seal the silver coated nickel O-ring. Final closure of the fuel storage liner had been achieved.

The forced air used to displace the water from a storage liner, the vacuum exhaust, and the neon gas bled from a storage liner were all vented to the ECF monitored exhaust stack. Gaseous storage liner effluent was monitored for fission gases (Kr-85) by a Constant Air Monitor (CAM) located where the storage liner exhaust line fed into the ECF monitored ventilation duct. A detection of fission gas during storage liner venting would indicate the possible existence of a through-clad defect in a fuel rod. Positive indications were discovered during liner preparations of two LWBR seed modules. Further information on the suspected fuel cladding defects can be found in Section 3.9.4.

The loaded fuel liner was now dry, neon pressurized (partial vacuum), and sealed for long term storage. The use of neon gas as the storage environment is discussed in Appendix D. The fuel liner was weighed to establish a "dry and sealed" standard. Upon transfer to the Peach Bottom shipping cask, the fuel liner would be weighed again and compared to this standard to ensure that water had not leaked into the fuel liner. The loaded fuel storage liner was now ready for transfer.

3.3 Peach Bottom Cask Preparation and Installation

Concurrent with the fuel storage liner dewatering processing, the empty Peach Bottom cask was received from ICPP and prepared for installation into water pit N4-43. The Peach Bottom cask, shown on its transfer trailer in Figure 3-19, was a lead (Pb) lined cylindrical shipping container that was approximately 173 inches in length and 43 inches in diameter. The cask's inner cavity was approximately 159 inches deep by 26 inches in diameter. One fuel storage liner was transported to ICPP per cask shipment.

The top and bottom of the cask had removable closure lids on the extreme ends and two trunnions per end 180° apart along the side. The trunnions provided a means for lifting and handling the cask. The trunnions also housed quick disconnect fittings for access to the cask internals via an integral tubing network. This tubing network allowed fluid flow through the cask without removal of the closure lids. All shipments between ECF and ICPP occurred with the cask secured horizontally on its dedicated trailer.

Upon receipt of the cask at the ECF east beach as shown in Figure 1-5, the first step in cask preparation was removal of the cask shipping cover. This cover was mounted to the trailer and provided weather protection for the cask's polished external surface. The four trunnion support retainers and bolts which secured the cask to the trailer were removed by hand. Using the overhead building crane, the two impact limiters, one at each end of the cask, were removed and stored on the trailer. This operation required the removal at each end of the cask of four of the twelve closure lid bolts. The cask was rigged and lifted horizontally from the trailer and set down in the cask downender. The downender, shown in Figure 3-20, was located parallel to the water pit east wall and provided the structural support to rotate the cask from horizontal to vertical and vice versa. The downender had two trunnion saddles for the cask bottom trunnions and a land support for the top of the cask. Upon transfer to the downender, the cask exterior was visually inspected for unusual dents, nicks, or gouges. The top and bottom closure lid bolts were visually verified to be the required high strength bolts by confirming their serial numbers. Proper bottom closure lid installation was confirmed by verifying that all eight bottom closure lid bolts were properly torqued.

Based on satisfactory results from these inspections, four more top closure lid bolts were removed in order to allow installation of the redundant rigging lift adapter onto the top closure lid. The redundant rigging lift adapter is shown in Figure 3-20 and its mounting bolt pattern is displayed in Figure 3-21. The last cask operation preceding cask submersion into the water pit was removal of the four trunnion face plates, exposing the trunnion quick disconnects. A portable HEPA filter was installed on the top east trunnion quick disconnect. In parallel with these cask preparations, the cask primary rigging, shown in Figure 3-22, was staged. This rigging included the primary spreader beam, wire ropes, and pear links.

The cask primary rigging pear links attached to the cask at the top two trunnions. The pear link locking bars were closed and locked to prevent inadvertent rigging removal. With the bottom trunnions remaining in the downender trunnion saddles, the crane was used to upend the cask to the vertical position as shown in Figure 3-23. The cask was then lifted out of the downender and positioned above water pit N4-43 over the cask underwater support structure. The water inlet and outlet drain lines were attached at the two lower trunnion quick disconnects. These lines allowed water to enter the cask and push air out through the portable HEPA filter attached to the top trunnion fitting. The cask was slowly lowered into the water pit to a convenient height for replacing the portable HEPA filter with the stationary HEPA filter vent hose. The inlet and outlet drain line attachments to the Peach Bottom cask are shown in Figure 3-24. The last four cask top closure lid bolts were removed. The bolts to be used for securing the redundant rigging adapter plate and the top closure lid to the Peach Bottom cask body after fuel storage liner insertion were staged in the adapter plate bolt holders. The cask was lowered until the head was totally submerged and held until the cask filled with water. Once full, the stationary HEPA filter vent hose was removed and the cask was lowered and seated within the support structure as shown in Figure 3-25. Using a probe pole, the pear link locking bars were opened and the pear links removed. Further details on the Peach Bottom cask underwater support structure can be found in Appendix E.

3.4 Peach Bottom Cask Loading, Removal and Shipment

Remote removal of the cask top closure lid, shown in Figure 3-26, was achieved by rigging the adapter plate lifting pin and lifting the closure lid and adapter plate combination. Top closure lid removal was simplified due to the previous removal of the top closure lid bolts. The cask top lid and adapter plate were stored on a platform adjacent to the cask. This platform was an integral member of the support structure and is shown in Figure 3-25. During transfer to the storage platform, the top closure lid was visually inspected to ensure that it was undamaged. The inner cask cavity was also visually inspected to ensure freedom from obstructions.

With a fuel storage liner containing LWBR fuel sealed, dewatered, dried, and pressurized with neon, and with the Peach Bottom cask installed within the underwater support structure, the Peach Bottom cask was ready for loading. Loading the cask required the transfer of the fuel storage liner from the dewatering pit S4-39 to the Peach Bottom loading pit N4-43.

The fuel storage liner processed for shipment was weighed to ensure that water had not leaked into the liner. Transfer of the fuel storage liner from the LCS dewatering ports to the Peach Bottom cask was permitted if this weight corresponded with the previous weight taken subsequent to neon pressurization. Using the MTC, the fuel storage liner was transferred from the LCS dewatering port to the Peach Bottom cask and positioned over the inner cask cavity. Following alignment adjustments, the fuel liner was slowly lowered and seated within the cask as shown in Figure 3-27. This operation was video taped to provide a certification of exactly which liner (by serial number) was inserted. The storage liner lift adapter was removed and returned to the LCS equipment storage table. The MTC was transferred to its storage location. To confirm that the fuel storage liner was properly installed, a liner seating verification fixture was employed. The verification fixture, shown in Figure 3-28, seated on the top of the cask and interfaced with the cask outside diameter. The verification fixture had depth indicators which registered the distance from the top of the cask to the top of the fuel storage liner. These measurements were made to ensure adequate clearance existed between the cask top closure lid and the top of the fuel storage liner. Based upon acceptable height indicator readings, the verification fixture was removed. The cask top closure lid and adapter plate were rigged and re-installed.

The Peach Bottom cask bolt handling and torquing tool was used to secure the top closure lid and redundant rigging adapter plate to the cask body. All top closure lid bolts were previously stored in bolt holders on the adapter plate. The bolt handling and torquing tool, shown in Figure 3-29, was a long tubular socket wrench with an added provision for securing the tool to the top closure lid bolt in order to transfer the bolt from the adapter plate to the cask. The inner, small diameter central shaft engaged with the tapped hole in the cask top closure lid bolt head. The outer wall of the tool served to transmit bolt tightening and loosening torque. This outer wall was configured to make the tool buoyant yet stable in the vertical position to simplify the use of the tool. The four top closure lid to cask body bolts were installed first, followed by the six adapter plate to cask body bolts. (See Figure 3-21) The cask was now ready for removal from the water pit.

Redundant rigging was employed to lift the fuel loaded cask from the water pit. LWBR seed and blanket fuel modules contained sufficient fissile material such that if the fuel rods were ruptured, optimally rearranged and moderated due to a drop accident, criticality could have occurred. While it was highly unlikely that these fuel rod segments would ever have been rearranged into the required configuration, the use of redundant rigging rendered this postulated drop accident implausible. Redundant rigging, shown in Figure 3-30, provided two sets of handling equipment between the Peach Bottom cask and the assigned fuel disposal overhead building crane trolley. Primary rigging was attached from the crane 40 ton auxiliary hoist to the cask upper trunnions. The primary rigging included the primary spreader beam, wire rope cables, pear links, and pear link locking bars. The redundant rigging was independently attached from the crane main 125 ton hoist to the cask adapter plate lift pin. The redundant rigging included an A-frame and a single wire rope cable with a captured hook. Simultaneous operation of the two crane hoists was required to lift the cask. An inclinometer system, mounted to the redundant rigging A-frame, monitored and controlled the lift. A more detailed description of the Peach Bottom cask redundant rigging can be found in Appendix F.

The staging of handling equipment to lift a fuel loaded cask, shown in Figure 3-31, required the assembly of the primary spreader beam to the crane auxiliary hoist hook and the redundant A-frame to the crane main hoist hook. The primary spreader and the redundant A-frame were pinned together, and all wire rope cable assemblies were attached. Preoperation checkout of the inclinometer system was performed. Simultaneous operation of both crane hoists was required to position the redundant rigging assembly over the cask and to attach the redundant rigging hook to the lift adapter lift pin. The overhead crane trolley was translated slightly south to align the primary rigging pear links with the upper cask trunnions. The pear links were installed and locked to the cask using the pear link locking bars. The Peach Bottom cask redundantly rigged is shown in Figure 1-7. With the dual hoist inclinometer control system on, the fuel loaded cask was lifted out of the support structure by simultaneous operation of both crane hoists.

As the cask was being raised, first the rigging and then the cask were sprayed with water and wiped down to remove any contaminated particulates. The stationary cask vent line was connected to the upper trunnion fitting when the trunnion became accessible. This connection allowed air to enter the cask and water to drain from the bottom trunnion fittings. The stationary vent line also prevented unfiltered air from escaping the cask internals. At a convenient height during the lift, the stationary vent line was replaced by the portable HEPA filter. The cask remained suspended with the bottom trunnion drain lines submerged until the cask was drained. Once completed, the two drain lines were removed from the bottom trunnion fittings.

To downend a fuel loaded cask to the horizontal position, the cask was first transferred to the east beach area and set down vertically. The redundant rigging hook was removed from the adapter plate lift pin. With the cask now only single rigged, the dual hoist inclinometer control system was de-activated. From this point on until the cask was seated horizontally in the downender, two fuel handlers with independent crane "kill" switches monitored the cask movement. The cask was lifted to a sufficient height to insert the two bottom trunnions into the downender trunnion saddles and was rotated approximately 45° toward the downender top landing pad. At this orientation any remaining residual water within the cask was removed using a suction pump. Upon completion of this water removal process, the cask was rotated to the horizontal position.

The disengagement of the pear link locking bars and the removal of the pear links from the cask top trunnions completed the cask removal phase of operations. The rigging assembly was returned to its storage fixture. The two crane hooks were uncoupled from the redundant rigging assembly. All further operations were in preparation for shipment. The portable HEPA filter was removed from the upper trunnion. The four trunnion face plates were reinstalled on the trunnions preventing access to the quick disconnect couplings. The cask redundant rigging lift adapter was removed and the six lift adapter bolts were replaced with cask top closure lid bolts. All top and bottom closure lid bolts were verified to be the required high strength bolts by confirming their serial numbers. Proper bolt installation was confirmed by verifying that all top and bottom closure lid bolts were torqued appropriately. Extensive final radiation and swipe surveys on the cask assembly were performed to obtain approval to transfer the cask to the trailer.

Subsequent to radiological control approval, the loaded cask was rigged for a horizontal lift and transferred from the cask downender to the shipping trailer. The top of the cask was oriented toward the front end of the trailer. Two fuel handlers with independent crane "kill" switches monitored the cask movement to the trailer. The four trailer trunnion support retainers were installed to secure the cask to the trailer. The top and bottom impact limiters were attached. The cask shipping cover was installed on the trailer and secured using toggle clamps. Following a final radiological control survey of the loaded vehicle and review of all cask loading documentation to assure all requirements for packaging had been completed, the cask was released for shipment to ICPP.

3.5 ICPP Facility and Storage

ICPP constructed the LWBR Fuel Storage Facility to store the LWBR fuel in dry storage vaults buried in the ground. ICPP is located within the Idaho National Engineering Laboratory (INEL), five miles from ECF. The tractor trailer hauling the loaded Peach Bottom cask traversed this distance at a maximum allowable speed of fifteen miles per hour. The LWBR fuel storage facility at ICPP is designed to provide safe storage for a minimum of 20 years. Fifty storage vaults are provided for the irradiated fuel and one vault for the unirradiated spare seed module. Each vault is designed to hold one storage liner. With 48 fuel shipments, three of the 50 irradiated fuel storage vaults are spares. The main advantages for placing LWBR fuel in underground storage vaults are: (1) built-in shielding from radioactivity and adequate shielding for criticality safety; (2) dry fuel storage; (3) fuel isolation from the environment; (4) ease of monitoring; (5) fuel retrieval capabilities; (6) low manpower requirements; (7) low capital cost; and (8) previous satisfactory experience with dry vault storage of other nuclear fuel.

The dry storage vaults, shown in Figure 3-32, are fabricated from carbon steel pipe. The storage vaults for the irradiated fuel are arrayed in two rows of twenty-five. The two rows are constructed on thirty foot centers with each vault within each row spaced on ten foot centers. The storage vault for the unirradiated fuel is isolated from the irradiated fuel vaults. A reinforced concrete slab is constructed around each vault to provide a working surface and laydown area. Each vault consists of a smaller diameter lower section which holds the fuel storage liner and an upper section which contains a concrete shielding plug. A crushblock is placed in the bottom of the storage vault to absorb energy and prevent damage to the fuel storage liner in the unlikely event of an accidental drop. A 1/4 inch diameter stainless tube extends from the bottom of the vault, up the sides, and through the vault body wall near the top. This tube is used for obtaining gas samples and would be used for removing water from the vault if necessary. A 1/2 inch diameter stainless tube, adjacent to the gas sample tube, is sealed at the bottom and is used for placement of a thermocouple to monitor temperature. The storage vault lid is fabricated from carbon steel plate and is bolted to the flange of the storage vault body. A gasket is used under the storage vault lid to assure a seal between the storage vault lid and flange. The storage vault lid contains a pressure gauge for manually monitoring internal pressure. The storage vault is designed for an ultimate internal pressure of 15 psig. Each storage vault is to be periodically inspected and the storage vault contents are to be monitored for the presence of liquid water and fission gas to assure the integrity of each storage vault.

Upon receipt of the LWBR fuel at ICPP, the tractor trailer carrying the loaded Peach Bottom cask was positioned adjacent to the designated storage vault. Two pieces of equipment were utilized by ICPP to prepare the cask for storage liner removal; these were the cask support pedestal and the cask centering and shielding device. The cask support pedestal, shown in Figure 3-33, was positioned on the storage vault concrete slab laydown area. This pedestal allowed the cask bottom closure lid bolts to be removed while the cask was seated vertical on its bottom closure lid. The cask centering and shielding device, also shown in Figure 3-33, was placed on the top of the open storage vault. This device centered the cask over the vault opening and shielded ICPP personnel during storage liner insertion into the vault.

With the cask still on the trailer, the shipping cover and two impact limiters were removed. To obtain access to the storage liner, the cask top closure lid center plug was removed. The liner lift rod guide was inserted into this opening and the lower liner lift rod was threaded into the storage liner head as shown in Figure 3-34. The cask was lifted from the trailer by a mobile crane rigged to the cask upper trunnions through a lifting yoke. The cask was placed vertically on the cask support pedestal, as shown in Figure 3-33, and all eight bottom closure lid bolts were removed. Prior to transferring the cask to the vault, the liner lift rod shear plate was installed. This shear plate prevented the storage liner from falling out the bottom of the cask now that the bottom lid was to be removed. With the storage vault open, the cask was transferred to the vault by the mobile crane and lifting yoke. The cask bottom closure lid was left on the support pedestal. The weight of the storage liner was supported by the cask top closure lid. The cask was inserted into the centering and shielding device and the lift rigging was removed. The long liner lift rod was coupled to the lower lift rod. The mobile crane was then rigged to the long liner lift rod handle.

With the cask properly aligned over the vault opening, the liner was first lifted by the lift rod in order to remove the shear plate, and then lowered to the bottom of the vault. During storage liner insertion into the storage vault, shown in Figure 3-35, shielding was provided by the Peach Bottom cask and the centering device. When the storage liner was seated within the vault, the liner lift rod was disengaged from the storage liner and pulled out of the vault and cask. The empty cask was returned to the support pedestal for bottom lid installation and then reloaded onto the shipping trailer for return to ECF. The vault was sealed by installing the concrete shield plug, lid gasket, and lid.

3.6 Training Program at ECF

The LWBR fuel disposal training program was designed to prepare and qualify personnel for performing the operations required for LWBR fuel disposal. The training program was structured with three goals in mind. The first goal was to give the trainees an understanding of what was to be accomplished in fuel disposal. The second was to teach personnel the manner and techniques in which components, tools, mechanisms, and control consoles were to be operated. Finally, the program was designed to enable trainees to understand the necessity for strict adherence to specific controls and procedures. These goals were achieved through the use of numerous training methods such as lectures, briefings, self study, use of visual aids, demonstrations of equipment and procedures, and participating in operations closely simulating actual fuel disposal conditions.

Training was administered and tailored based on consideration of each worker's previous water pit experience and the requirements of their job classification. For example, lead technicians were required to read and comprehend all procedures prior to assuming their respective responsibilities in fuel disposal due to their proven expertise in water pit operations. Water pit technicians, on the other hand, were required to participate in a minimum of two cycles of selected training operations involving the use of actual fuel disposal equipment per procedural instructions. Technicians were considered qualified by demonstrating their ability to perform the assigned operations safely and effectively.

The adequacies of the LWBR fuel disposal procedures, tools, equipment, and safety provisions were verified during the training sessions. During fuel handling training for Peach Bottom Cask redundant rigging, for example, difficulty was encountered while attempting to grapple the cask redundant rigging lift adapter with the secondary rigging hook. The cause of the problem was traced to the hook and cask lift adapter interface. The hook was too thick in the transition area between the hook bowl and neck for the opening in the lift adapter. The hook was modified to alleviate the interference and re-load tested. Discovery and correction of this and other minor problems during training avoided schedular delays and problems during actual fuel disposal operations.

Several procedural problems were identified and corrected during training operations. Operational sequences within the procedures were rearranged to simplify the work effort. The corrected training instruction then became the actual fuel disposal procedure.

The training program helped minimize the radiation exposure to fuel disposal personnel by providing, prior to actual operations: (1) familiarization with equipment and procedures; and (2) identification and correction of hardware and procedure deficiencies. Simulation of radiological conditions during training also helped improve personnel proficiency in the control and handling of radioactive materials. This resulted in minimizing: (1) the time spent in radiation fields; (2) the spread of radioactive contamination; and (3) the generation of radioactive waste.

Initial fuel disposal training was performed without emphasizing operational sequence. This allowed parallel training in storage liner dewatering processing and Peach Bottom cask handling. Final training, where proper operational sequencing was mandatory, included two dry runs of the entire fuel disposal process operations. The dry runs were identical to actual fuel disposal operations except that the fuel storage liner contained no fuel. The successful completion of both dry runs qualified the technicians for fuel disposal.

The training program depended on each individual worker's attention to detail and ability to demonstrate proficiency at his assigned tasks. The fuel disposal training program thus contributed towards the successful completion of the LWBR fuel disposal effort at ECF in the required time and quality constraints.

3.7 Radiation and Contamination Control

LWBR fuel disposal operations were directly influenced by concerns for minimizing personnel radiation exposure and controlling the spread of radioactive contaminants. During all water pit operations the water provided the necessary radiological shielding. Equipment was designed and fabricated to support and process the fuel loaded storage liner at the bottom of the water pit. Once the loaded storage liner was inserted into the Peach Bottom cask and lifted out of the water pit, the cask itself provided sufficient shielding. The lead (Pb) and steel lining of the cask permitted safe extended operations in the cask vicinity. The fuel storage liners provided containment for the LWBR fuel. Containment of the storage liner effluent was provided by the dewatering system piping network.

Specific radiological control requirements for each fuel disposal operation were spelled out in the procedures. Temporary controlled surface contamination areas (CSCA), areas where loose radiological contamination might exceed clean limits, were created on the east beach of the water pits for the dewatering control console, Peach Bottom cask downender, and Peach Bottom cask tractor trailer. These CSCA barriers isolated the dewatering control console and the Peach Bottom cask from the remainder of the ECF and from non-qualified personnel. The liner closure head staging area was maintained radiologically clean due to the finger dexterity involved in liner closure head preparation. The decision to perform this operation as a "clean" operation eliminated the need for complex hardware or cumbersome radiological gloves.

An additional radiological control requirement was Peach Bottom cask wipe down. As the cask was removed from the water pit, the cask exterior and its rigging were rinsed with clean water and wiped down to remove any potential radiological contaminants. During this operation the water pit technicians were required to wear a wet suit and a face shield in addition to their normal anti-contamination clothing.

Preventing the spread of airborne contaminants was another radiological control requirement. The storage liner dewatering system accomplished this by channeling all gaseous effluent from the air circulation, vacuum drying, and neon overpressurization phases to the ECF exhaust stack. For Peach Bottom cask water pit installation, HEPA-filtered ventilation on the air escaping the inner cask cavity during water fill prevented an airborne release.

As a result of careful equipment and process design, procedural radiological controls, and personnel training, fuel disposal operations were completed with minimal personnel radiation exposure and no uncontrolled release of radioactive contaminants.

3.8 Planning and Scheduling Fuel Shipments

Planning and scheduling of LWBR fuel disposal shipments was an important aspect of the overall LWBR core evaluation program at ECF since the required completion date was fixed in time. Forty-eight shipments were required which consisted of thirty-nine fuel modules, seven fuel rod liners, one spare unirradiated seed module and one "cut fuel" liner. The mandatory completion date for the LWBR core evaluation program was September 1987. With the fuel disposal technicians gaining experience and confidence with each shipment, the shipping plan anticipated three fuel shipments per month for the majority of 1986 and all of 1987. The scheduled sequence of fuel to be shipped was a function of the core evaluation program. Since all fuel modules were not involved in end-of-life disassembly, the first 20 shipments were as-received modules. With fuel disposal shipments occurring in parallel with other core evaluation examinations, the remaining 19 modules were shipped once all evaluation data had been obtained, evaluated and accepted. These 19 modules included 12 COS and POB modules, the final two MVS blanket modules, the last three backup POB modules, and the two seed modules suspected of fuel cladding defects. The remaining shipments of rod storage liners, "cut fuel" and the spare seed module were scheduled for the very end of the disposal program. The rod liners housed the proof-of-breeding and REX rods. They were retained until completion of the fuel module shipments in the event data evaluation revealed erroneous results and re-examination was required. Preparations to load the special fuel items, the spare seed module and the "cut fuel", into their respective storage liners were performed during gaps in the schedule waiting for modules to be released for disposal.

The first two fuel shipments were completed by the end of December 1985. Once fuel disposal operations began, storage liner preparations and shipments occurred more rapidly than anticipated. By March of 1986, preparation of liners for shipment were averaging one every 15 shifts or every five days of three shifts per day operation. Storage liner closure head preparations, installation, and storage liner transfer to the dewatering port averaged four shifts. The storage liner blowdown, vacuuming and neon backfill, and leak check averaged between four and six shifts depending on the module type within. Peach Bottom cask water pit installation, fuel liner loading, cask removal, and shipping paper certification review averaged eight shifts. Overhead building crane availability and technician support to perform parallel operations were the major factors in the ability to prepare the cask for shipment in 15 shifts. Beginning in September 1986, shipments slowed to an average of two per month.

3.9 Summary of Problems Encountered

LWBR fuel disposal operations were successfully completed without hazard to personnel or the environment. Those problems that did occur were minor and fell into the following categories: (1) deficiencies in written procedures that remained after checkout and training due primarily to the fact that training was not 100% prototypical of actual fuel disposal operations, (2) operator errors, (3) tool malfunctions that occurred after functional checkout, and (4) unscheduled/unexpected events. Corrective actions included procedural changes, worker training, or modification of equipment. Several of the problems that did occur are summarized below.

3.9.1 Peach Bottom Cask Residual Water Removal

The Peach Bottom cask handling procedure originally called for water removal from the cask internals by gravity drainage through the two bottom trunnion quick disconnects. Although a small quantity of residual water was expected, the actual water content that remained within the cask during the first few shipments was troublesome for ICPP. This more than expected quantity of water, although adequately handled, posed radiological concerns during cask bottom closure lid removal. The Peach Bottom cask handling process was changed to 1) remove the two cask closure lid O-rings to aid drainage, and to 2) utilize a pump to remove any residual water that remained after gravity drain. This problem was not detected and resolved during training since the cask bottom closure lid was never removed during training operations. With the above changes, additional residual water problems were not encountered.

3.9.2 Fuel Storage Liner Closure Head Leak

During storage liner blowdown to remove the bulk water from within a reflector storage liner, the interface seal between the closure head and storage liner body leaked. The storage liner was returned to the closure port, and the closure head was removed.

Visual examination of the closure head metal O-ring revealed an imperfection on the O-ring. The metal o-ring was replaced, the closure head re-installed, and liner blowdown re-initiated. This time a bolt seal leaked. The bolt was removed, and the O-ring inspected. The O-ring had slipped out of its groove during re-installation and had seated improperly. This O-ring was replaced, and the bolt was reinstalled into the closure head. With these two metal o-rings replaced, the closure head and bolt seals held and the storage liner was successfully processed through the entire dewatering operation. Storage liner closure head and closure bolt seal leaks occurred only once.

3.9.3 Dewatering Umbilical Tool Leak

During storage liner blowdown to remove the bulk water from within a blanket storage liner, the interface between the vent umbilical tool and vent self-seal fitting leaked air. Visual examination of the vent umbilical tool revealed dislodged O-rings. The O-rings were reseated into their grooves, and the vent umbilical tool reconnected to the vent self-seal fitting. An umbilical tool air leak could potentially result in an airborne contamination release since the umbilical tools channel large volumes of air directly through the storage liner internals where the fuel was located.

To eliminate the potential for an airborne contamination release, the dewatering procedure was changed to require a vent and drain umbilical tool pressure check prior to opening the vent cap and drain plug. If a leak occurred, the air escaping would be radiologically clean air since the storage liner self-seal fittings were still closed. Once the umbilical tools passed the leak check, the self-seal fittings were opened and storage liner blowdown was initiated. With this additional check, an umbilical tool leak did not recur during liner processing.

3.9.4 Suspected Through-Clad Fuel Rod Defects

The storage liner preparation process monitored for fission products (Cs-137 and Cs-134) and fission gas (Kr-85) to indicate the possible existence of through-clad defects in fuel rods. Positive indications were discovered during liner preparations of two of the twelve LWBR seed modules (III-5 and III-6) at initiation of the neon gas bleed cycle. CAM indications from one of the seed modules (III-5) showed a radioactive gas concentration about twice the CAM alarm set point, while the second seed module (III-6) showed a radioactive gas concentration about three times the CAM alarm set point. The CAM which alarmed is located in the ECF ventilation ducts. To ensure that the CAM indications were caused by the dewatering process, a second CAM was installed in the dewatering exhaust line closer to the dewatering station operator console. The neon gas backfill and bleed was then repeated twice on seed module III-5. Although both CAMs indicated the presence of Kr-85 gas during the first repeat cycle, the indication was below the CAM alarm setpoint. Analysis of gas samples also taken during the first repeat cycle revealed the presence of Kr-85 gas. The second repeat cycle showed no indication at either CAM. The dewatering processing was repeated a third and last time on seed module III-5 in an attempt to obtain confirming evidence that it has defected rods. Gas sampling from the storage liner during vacuum pump-down and during neon backfill and bleedoff did not reveal Kr-85 gas. The results from the retest of seed module III-6 were similar to seed module III-5. The first sample drawn during the vacuum pump-down indicated the presence of Kr-85 gas; however, subsequent samples showed no indication.

These results suggested that there were fuel rod cladding defects in seed modules III-5 and III-6 and that they were small, that dewatering vacuum processing drew out the Kr-85 gas, and that all available Kr-85 gas had been expelled. But the available data was insufficient to conclude that fuel rod defects actually existed in seed modules III-5 and III-6. There was no evidence to suggest the suspected defects occurred during core operation or during module shipment to ECF. Reactor coolant monitoring capable of detecting a single defect, equivalent to a 0.005 inch hole, in a single rod was conducted at frequent intervals at Shippingport.

There was no evidence that the core fuel rods had developed any through-clad defects. Upon arrival at ECF after core shutdown, the shipping container fill water was sampled and analyzed for cesium. This sampling and analysis technique was as sensitive as the one conducted at Shippingport. That data again showed no evidence to suspect through-clad defects. The mechanism which may have led to a cladding defect while the modules were in storage at ECF was not identified. None of the other storage liners prepared for shipment before or after seed modules 111-5 and III-6 exhibited any fission product activity. Further detailed examination or testing results would be necessary to determine undeniably whether fuel cladding defects existed. Additional examinations were not performed. The presence of through clad defects in seed modules III-5 and III-6 remains questionable. ICPP indicated that their Safety Analysis addressed fuel modules with potential cladding defects and they accepted the storage liners for underground storage.

3.9.5 Condensate in the Dewatering Exhaust Line

The storage liner preparation process on a reflector module was delayed due to a small water spill or leak. The spill occurred at the constant air monitor (CAM) located in the dewatering exhaust line near the east beach dewatering equipment. The spill apparently was caused by the accumulation of condensate in the exhaust line piping over many liner blowdown and dewatering cycles. Condensate eventually blocked the exhaust line at a low point and caused back pressure in the exhaust system. A CAM seal was the weakest point and it lost its seat allowing the leak. To resolve this problem the exhaust line was drained and the CAM resealed. Exhaust system piping was changed to allow the monitoring of exhaust line pressure and condensate accumulation. A cold trap was added to the system to remove the condensate in the exhaust air. An exhaust line water spill did not recur.

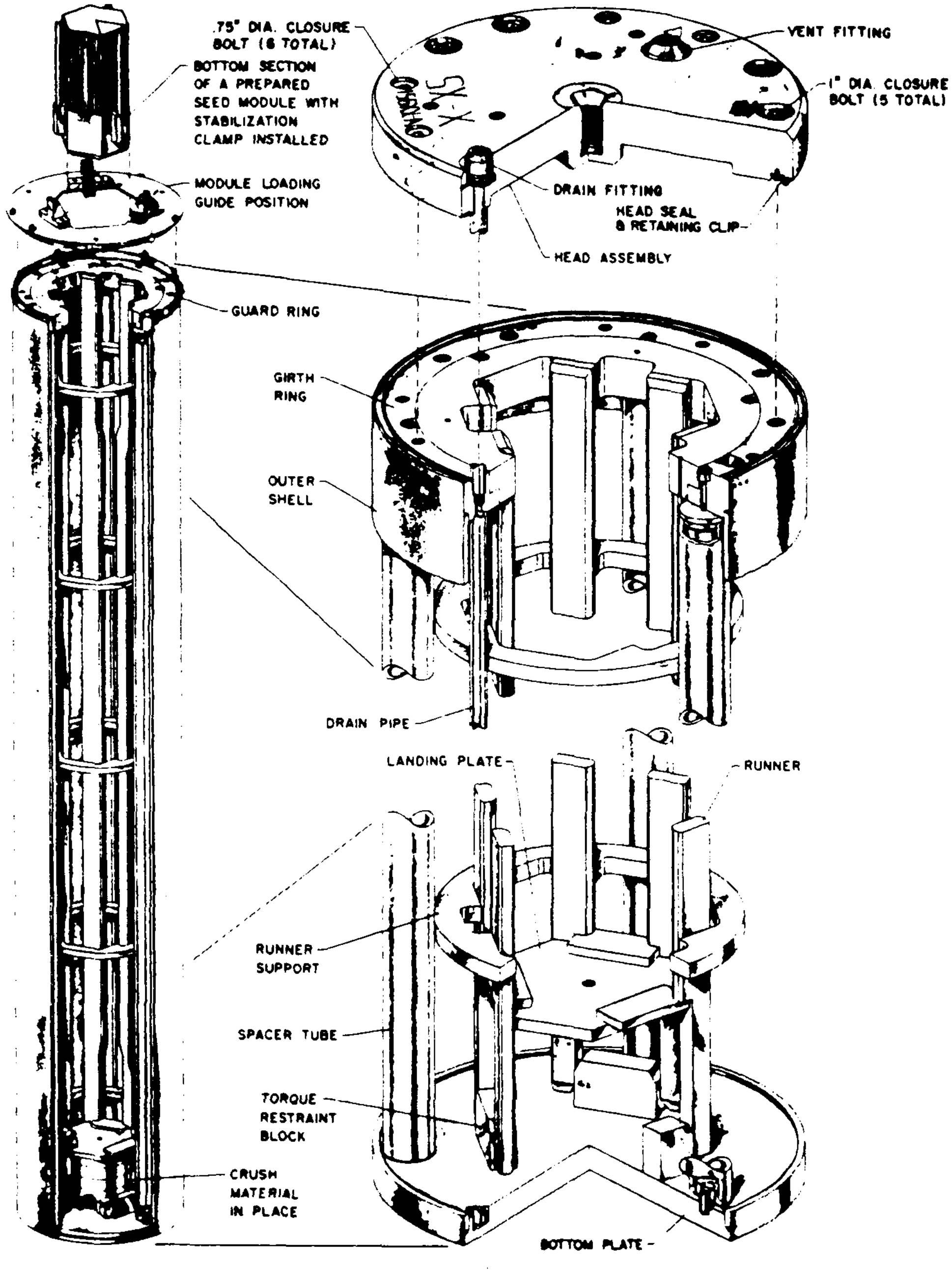


Figure 3-1: Typical LWBR Fuel Module Storage Liner

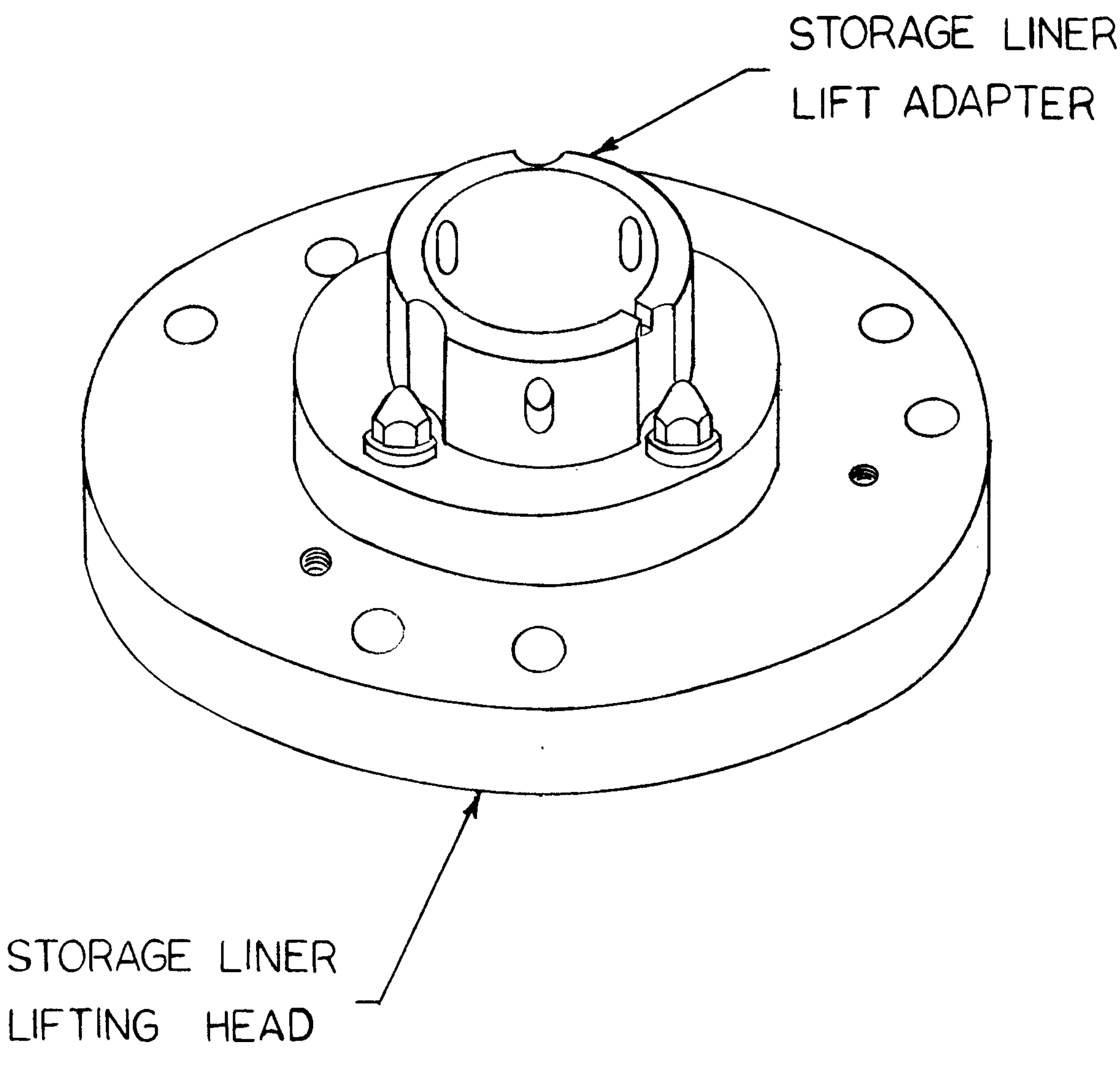


Figure 3-2: LWBR Storage Liner Lifting Head Assembly

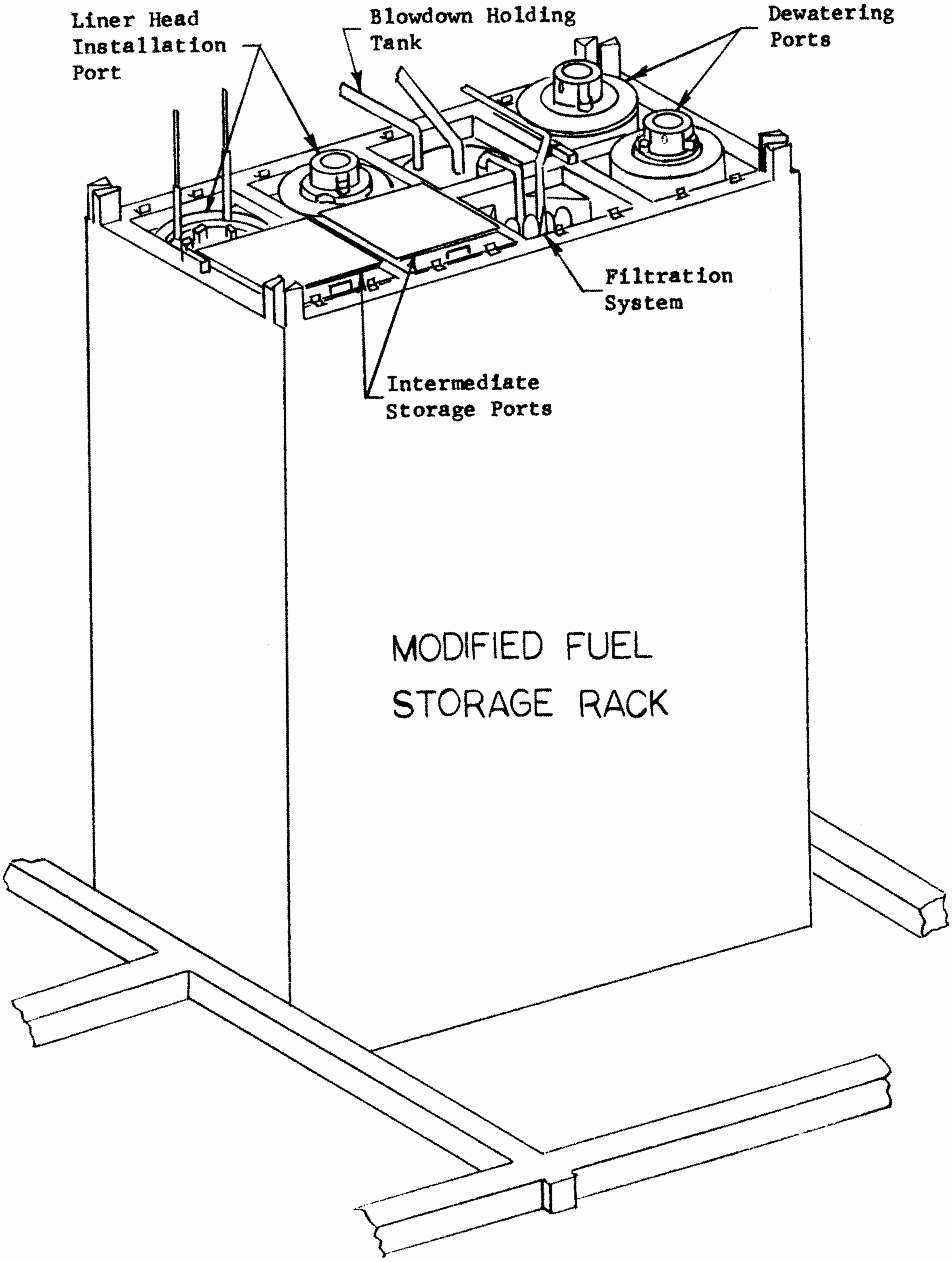


Figure 3-3: LWBR Storage Liner Closure Station

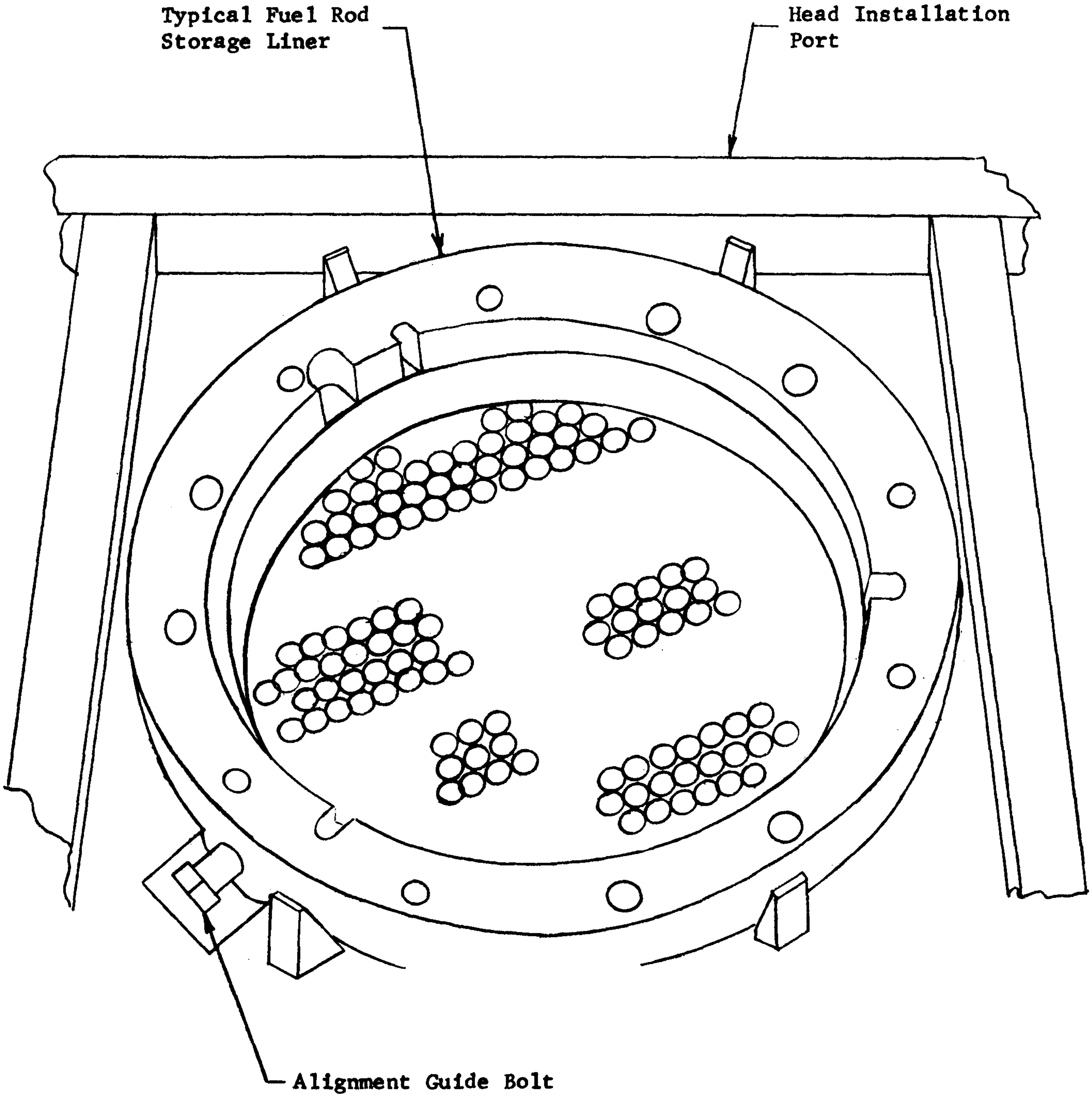


Figure 3-4: LWBR Storage Liner Orientation in LCS Port

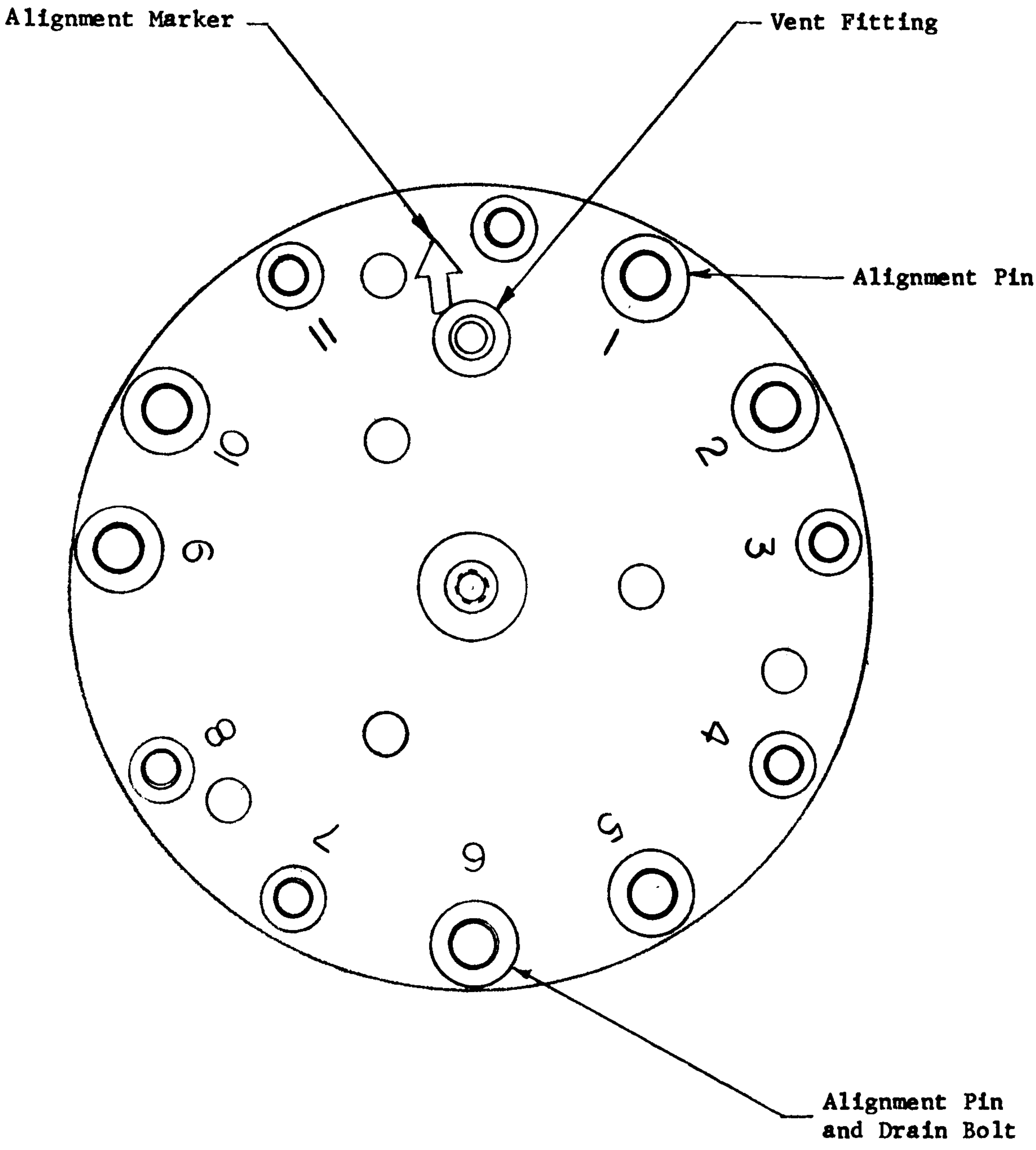
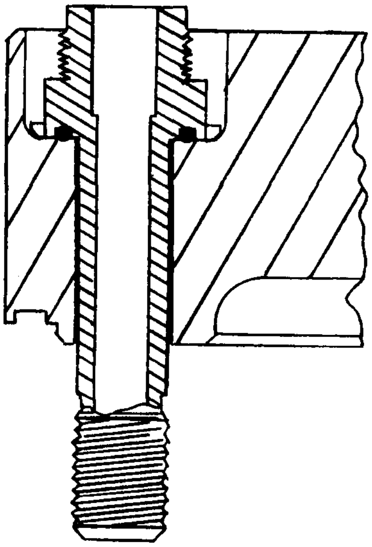
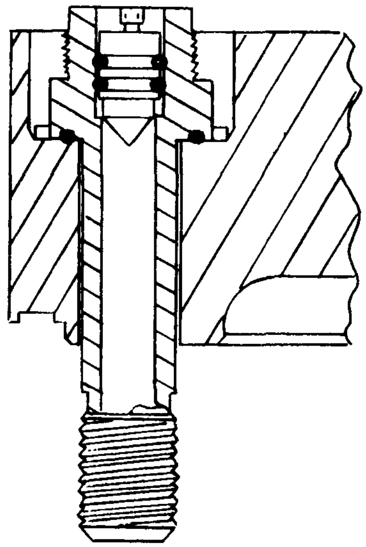


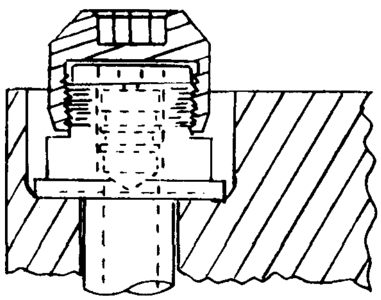
Figure 3-5: LWBR Storage Liner Closure Head

Drain Fitting
Open



Drain Fitting
Plug Installed

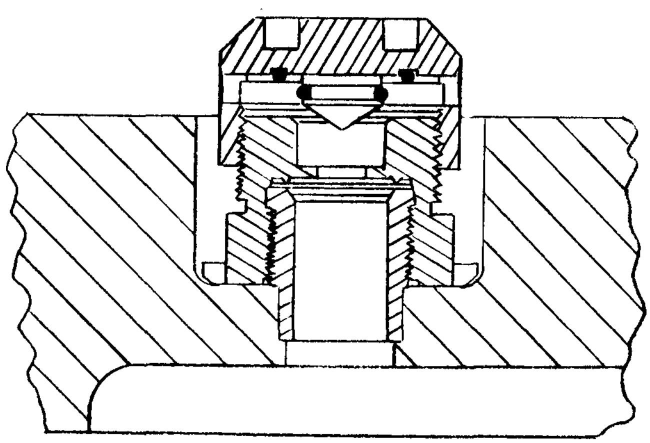




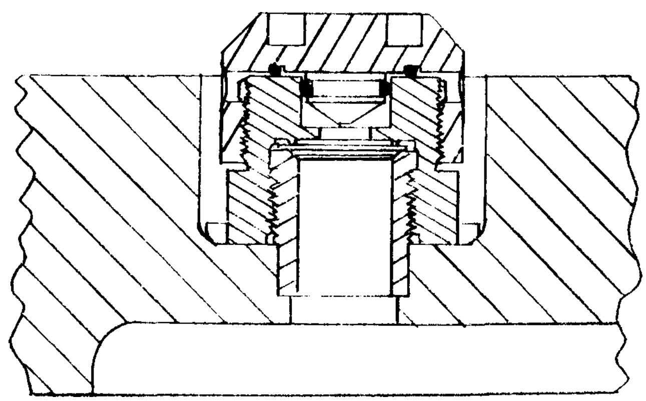
Drain Fitting
Cap Installed

Figure 3-6: LWBR Storage Liner Drain Fitting

Vent Fitting Open



Vent Fitting Closed



3-7: LWBR Storage Liner Vent Fitting

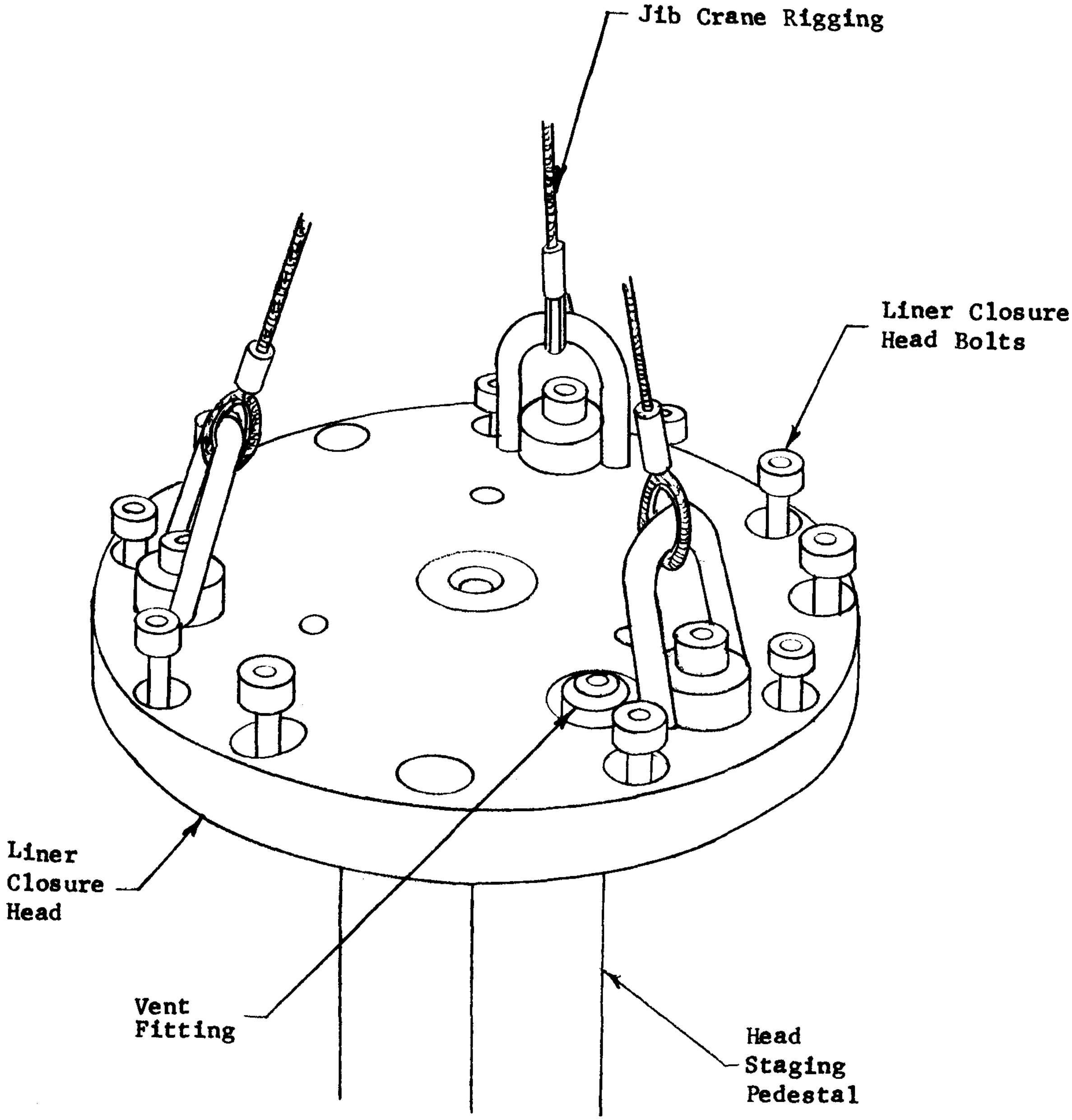


Figure 3-8: LWBR Storage Liner Closure Head Staged for Installation

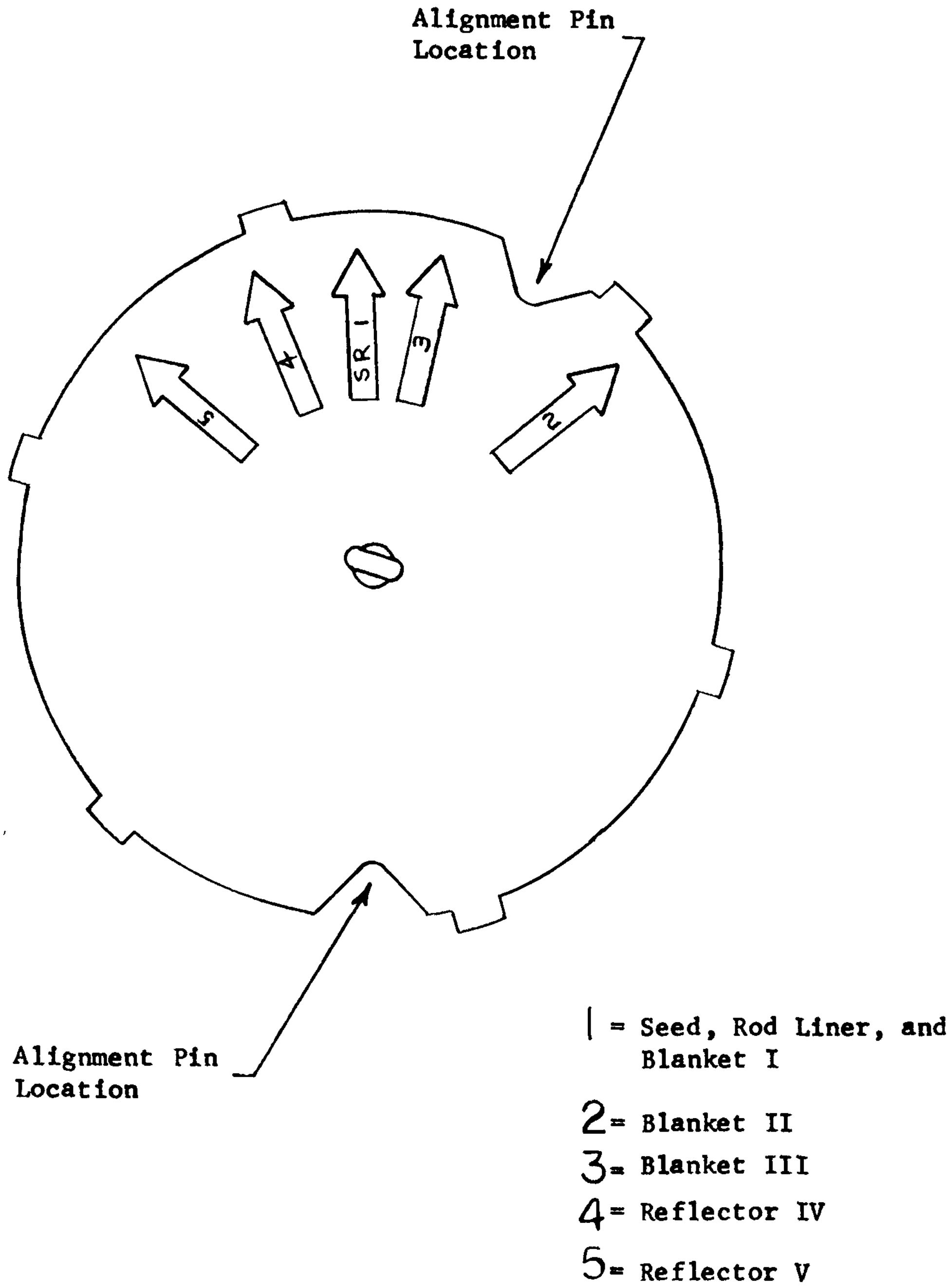


Figure 3-9: LWBR Storage Liner Closure Head Alignment Pin Installation Guide Plate

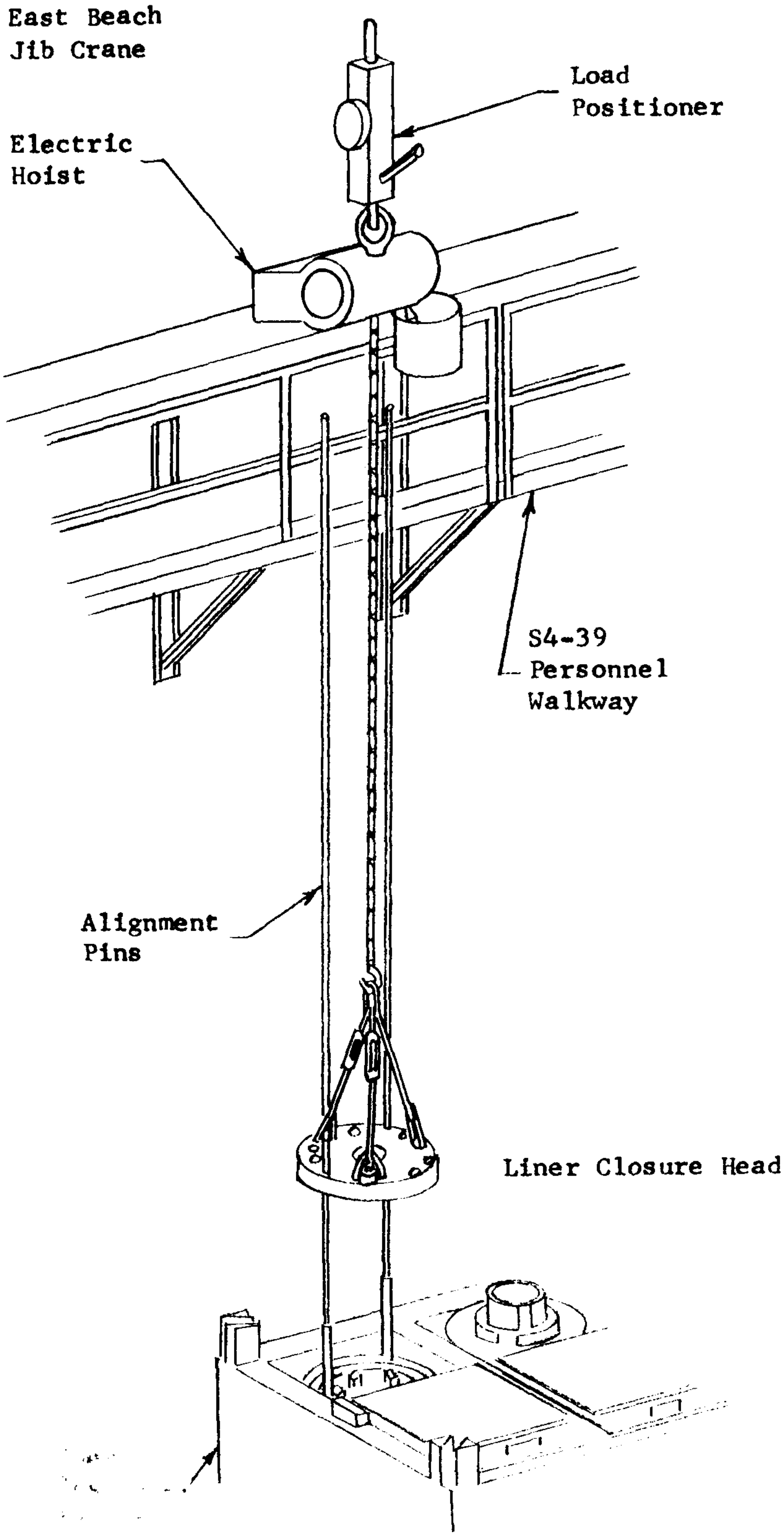


Figure 3-10: LWBR Storage Liner Closure Head Installation

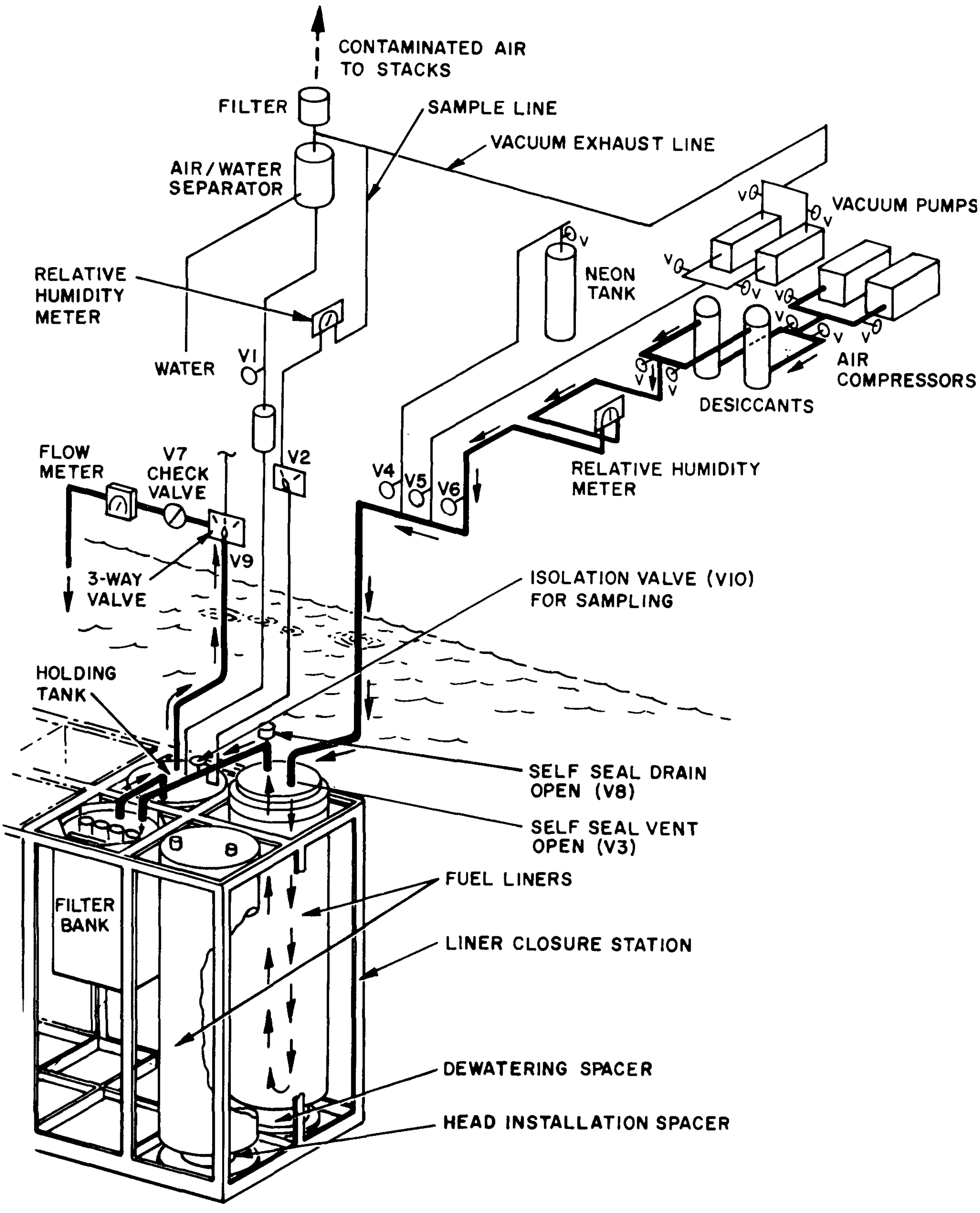


Figure 3-11: LWBR Storage Liner Blowdown Schematic

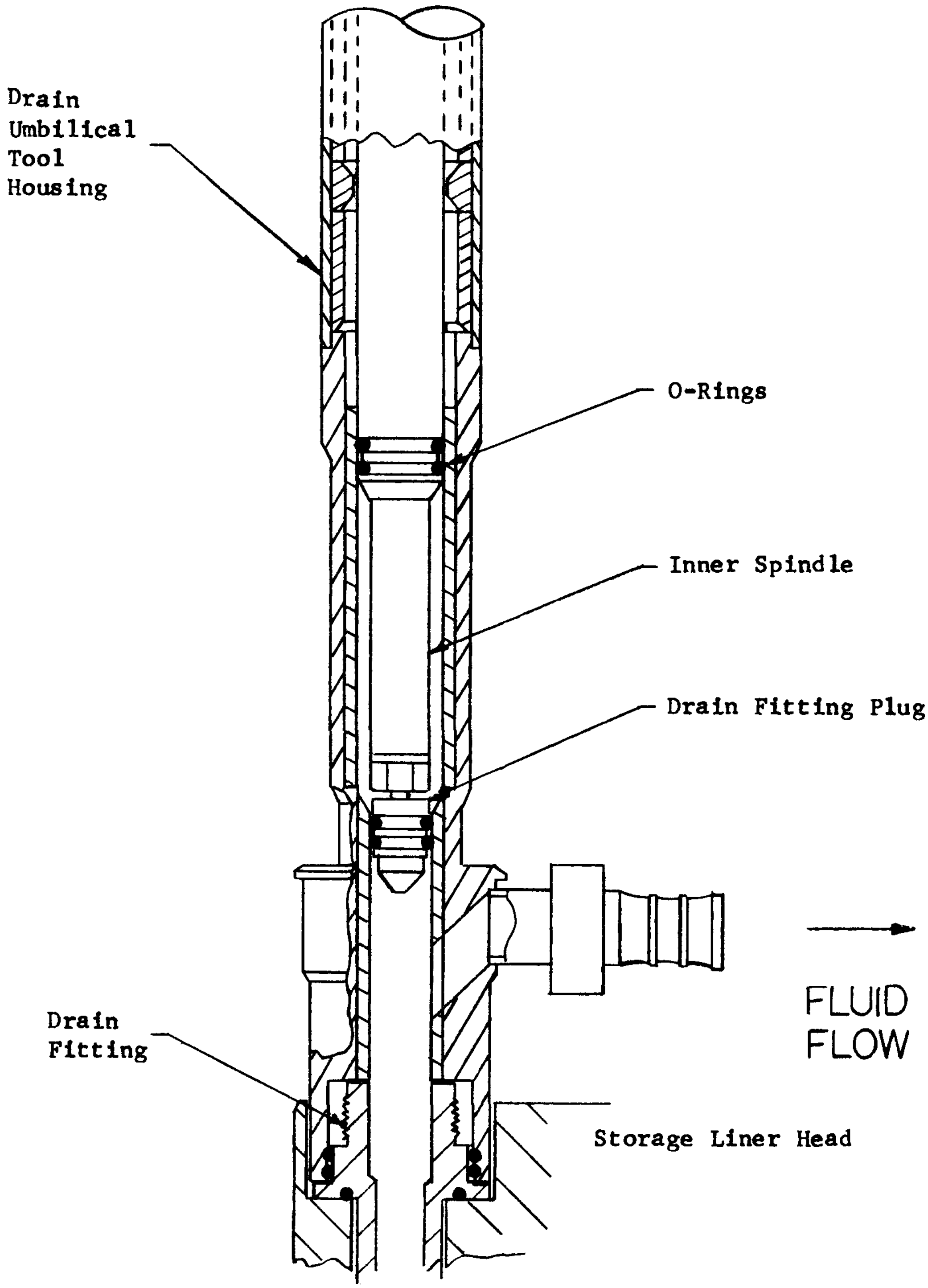


Figure 3-12: LWBR Storage Liner Drain Umbilical Tool Coupled to Drain Fitting

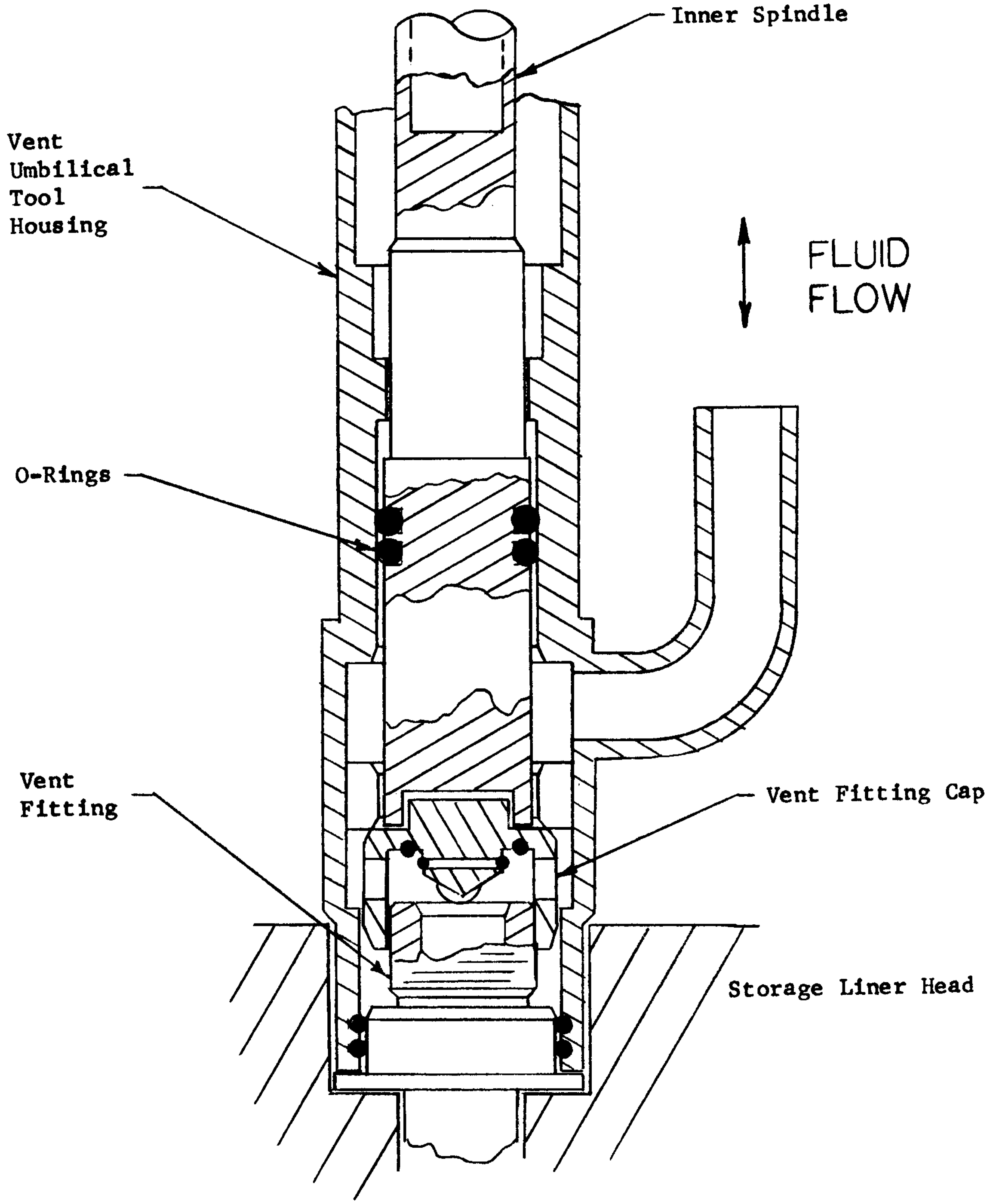


Figure 3-13: LWBR Storage Liner Vent Umbilical Tool Coupled to Vent Fitting

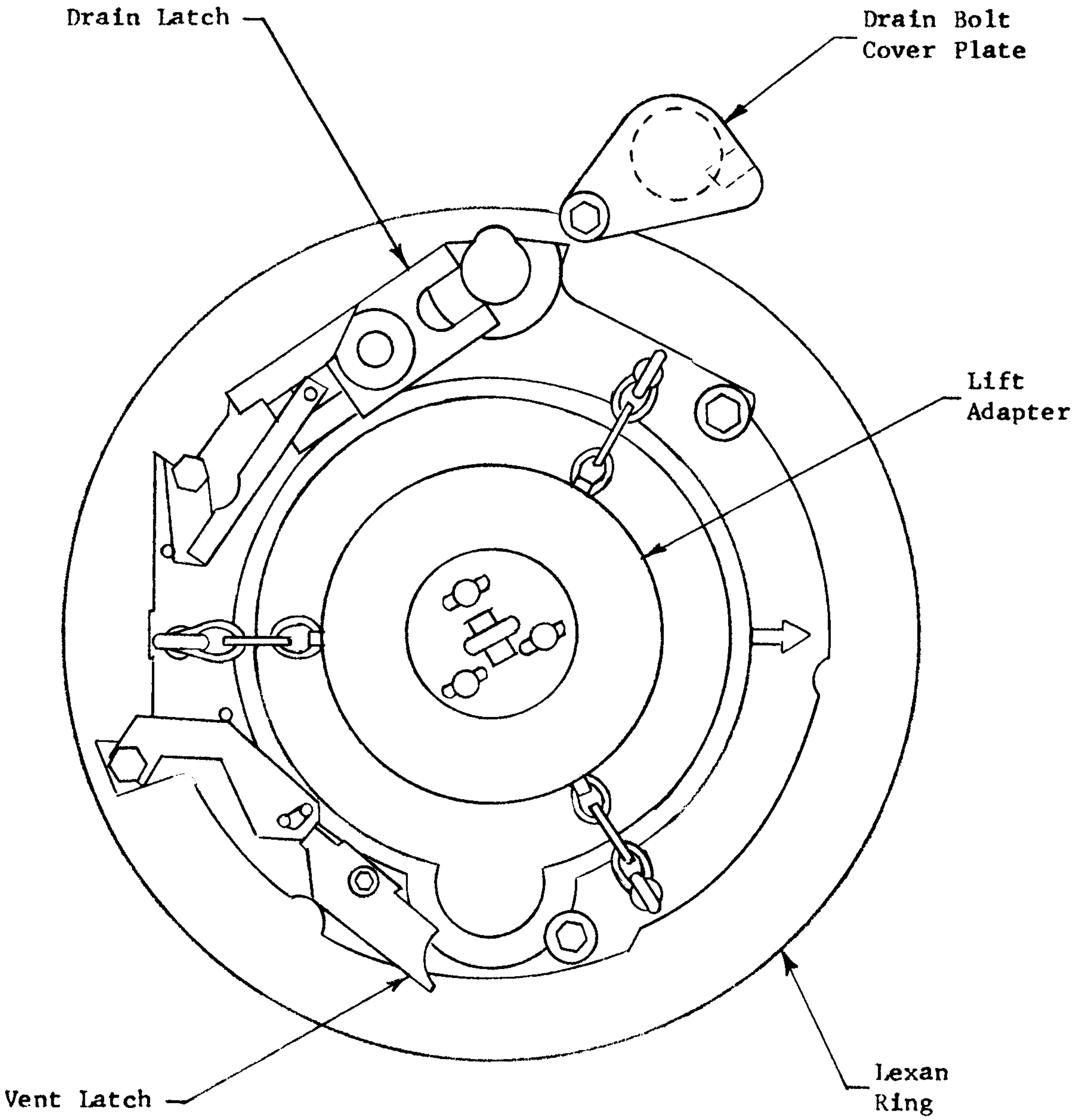


Figure 3-14: LWBR Storage Liner Funnel Latch Plate

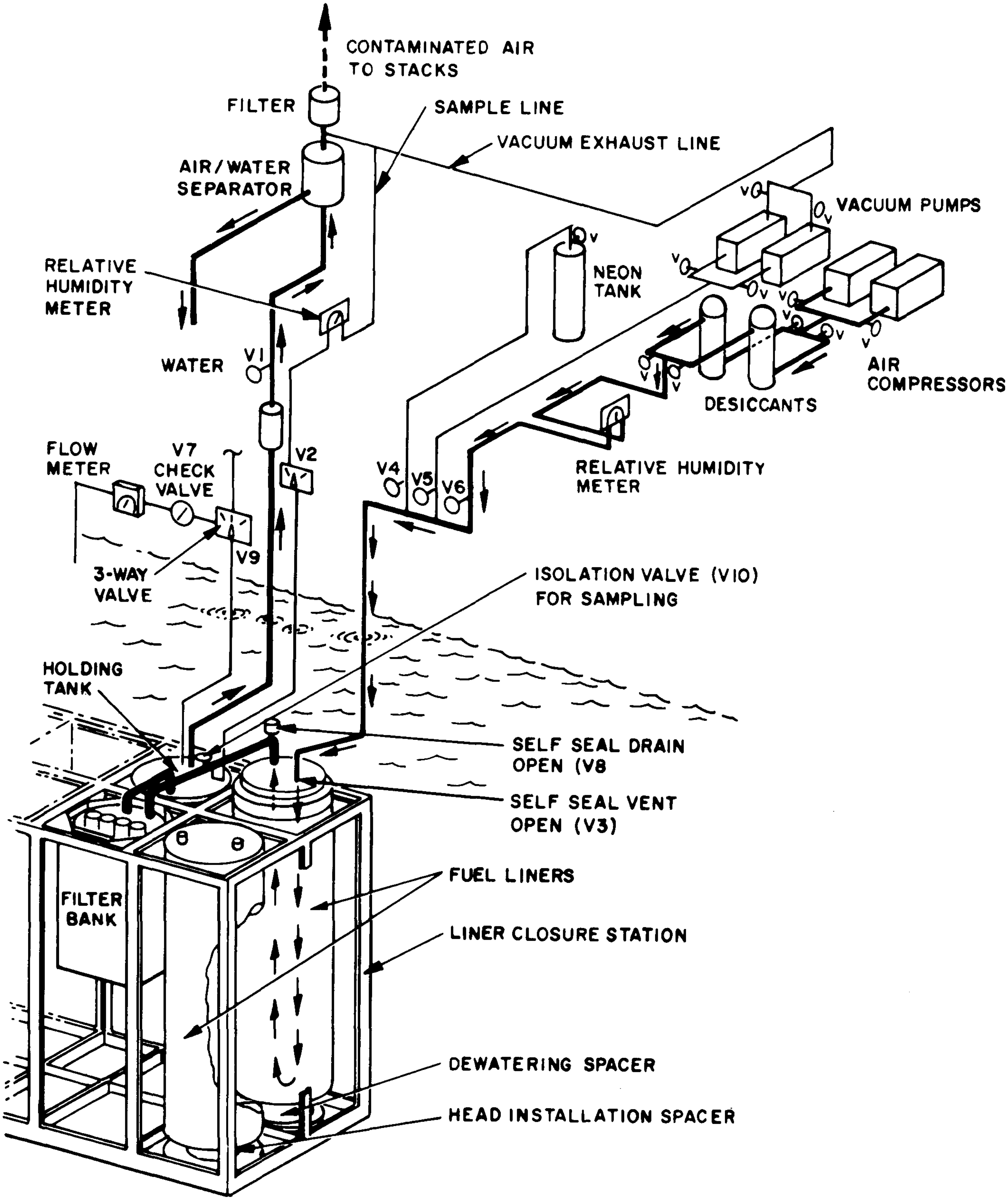


Figure 3-15: LWBR Storage Liner Air Circulation Schematic

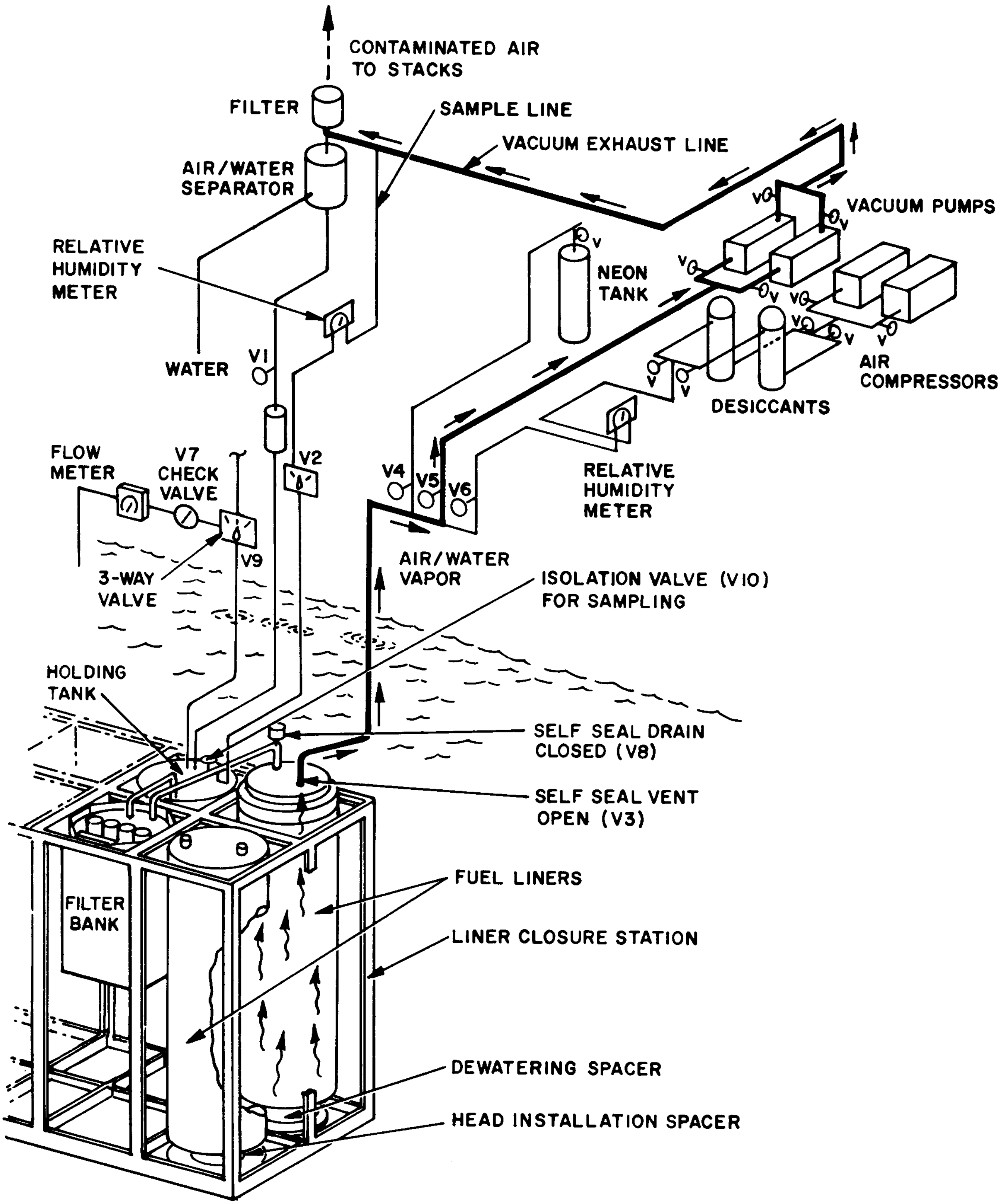


Figure 3-16: LWBR Storage Liner Vacuum Drying Schematic

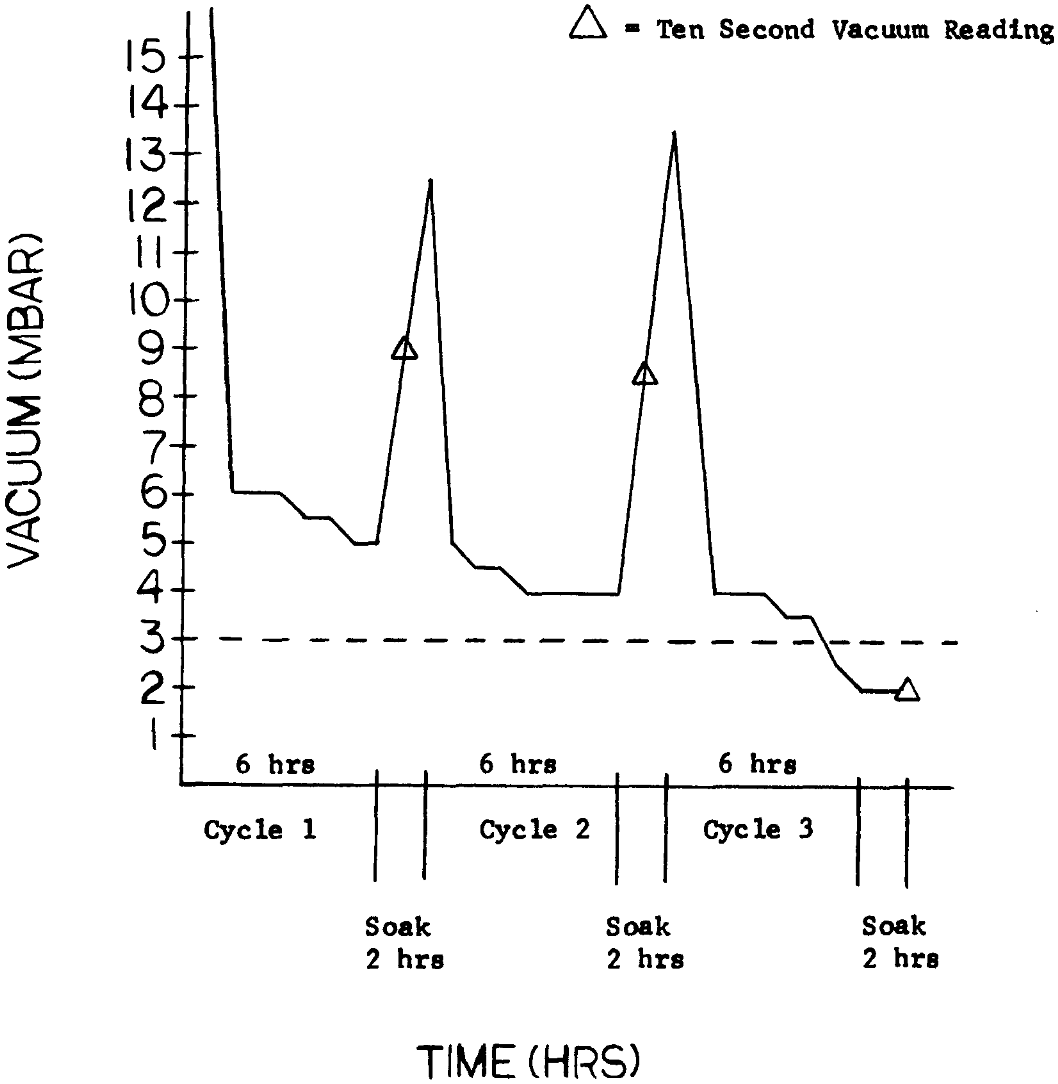


Figure 3-17: LWBR Storage Liner Vacuum Drying Curve

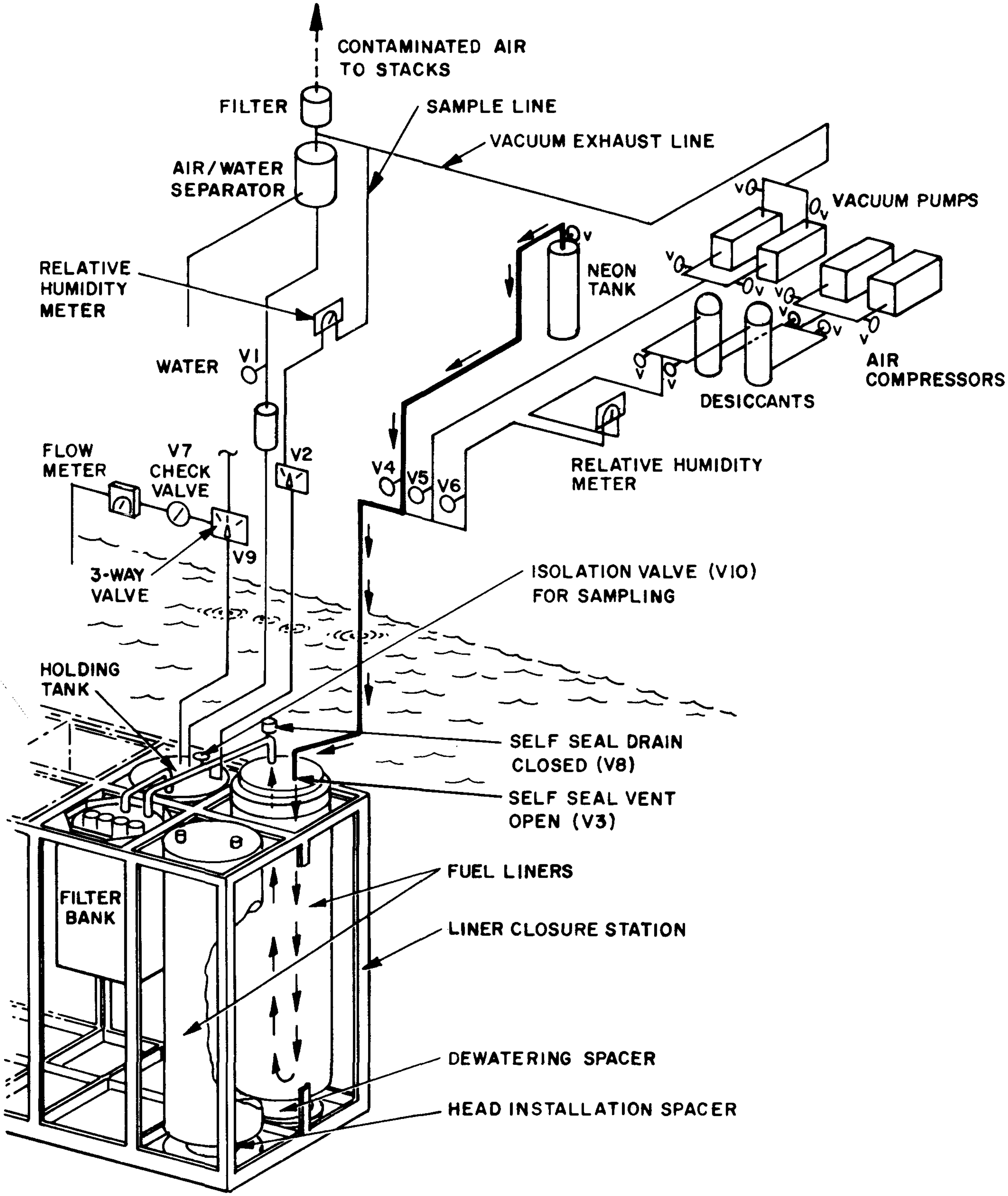


Figure 3-18: LWBR Storage Liner Neon Backfill Schematic

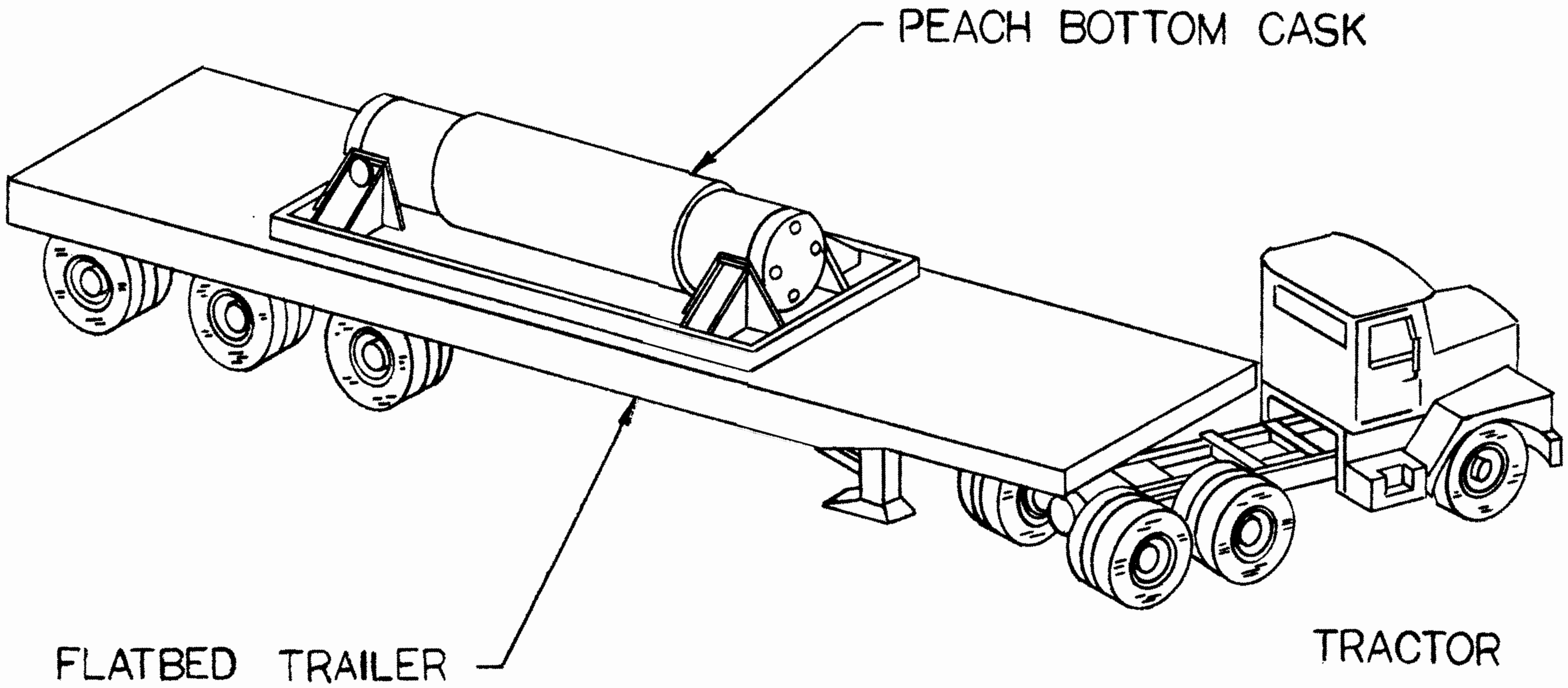


Figure 3-19: Peach Bottom Cask on Trailer Shipping Cover Removed

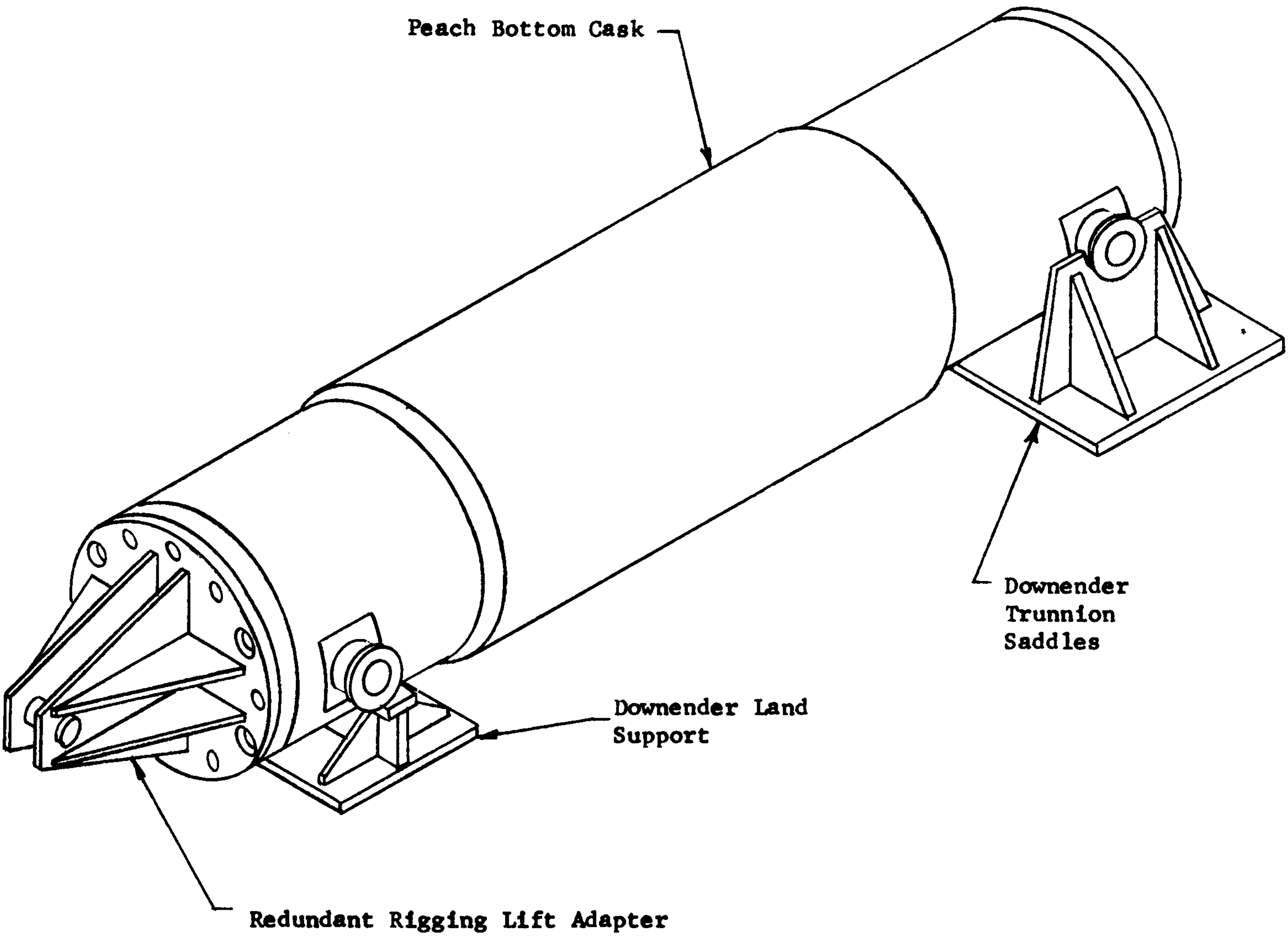


Figure 3-20: Peach Bottom Cask on Downender with Lift Adapter

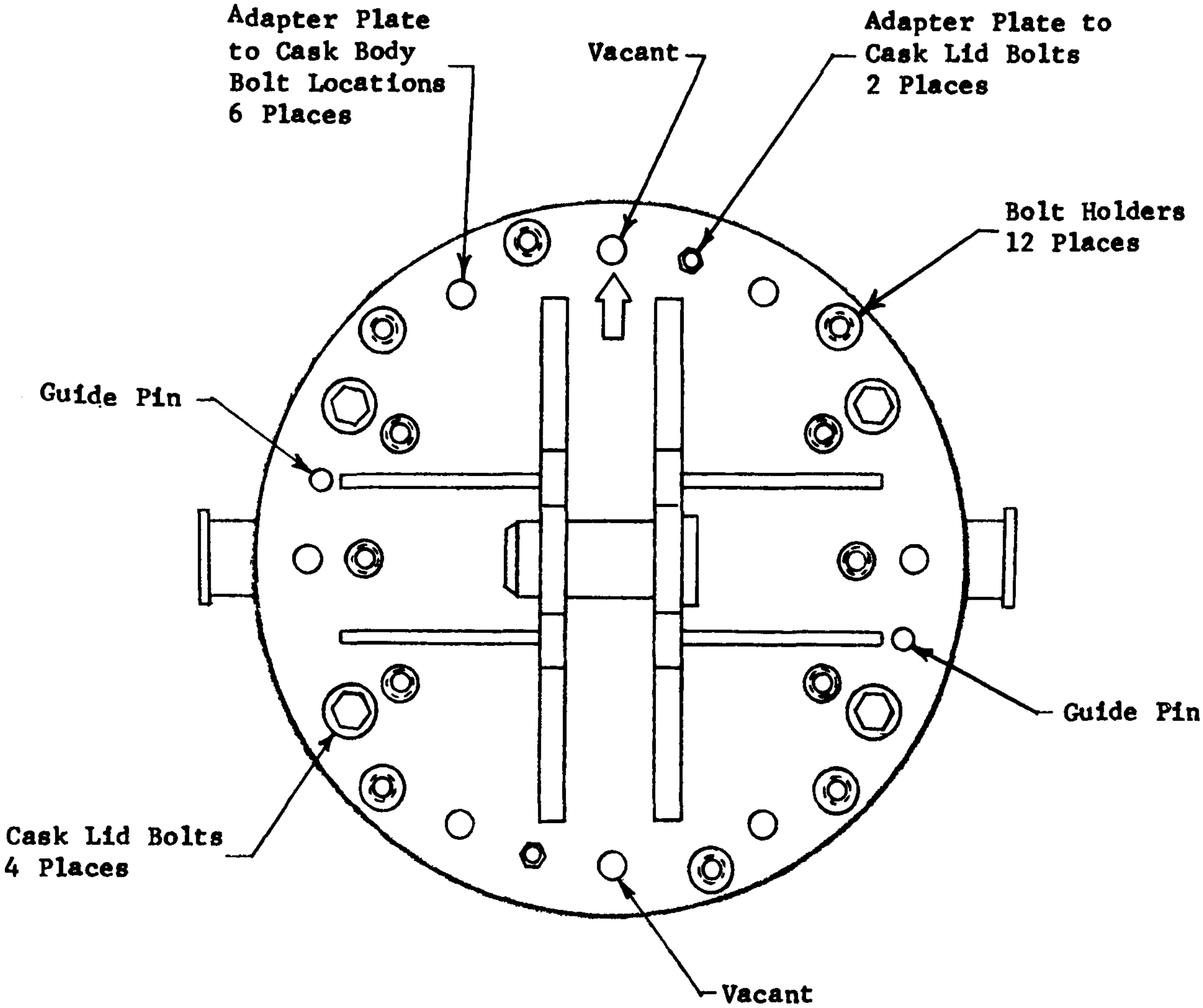


Figure 3-21: Peach Bottom Cask Adapter Plate Bolt Pattern

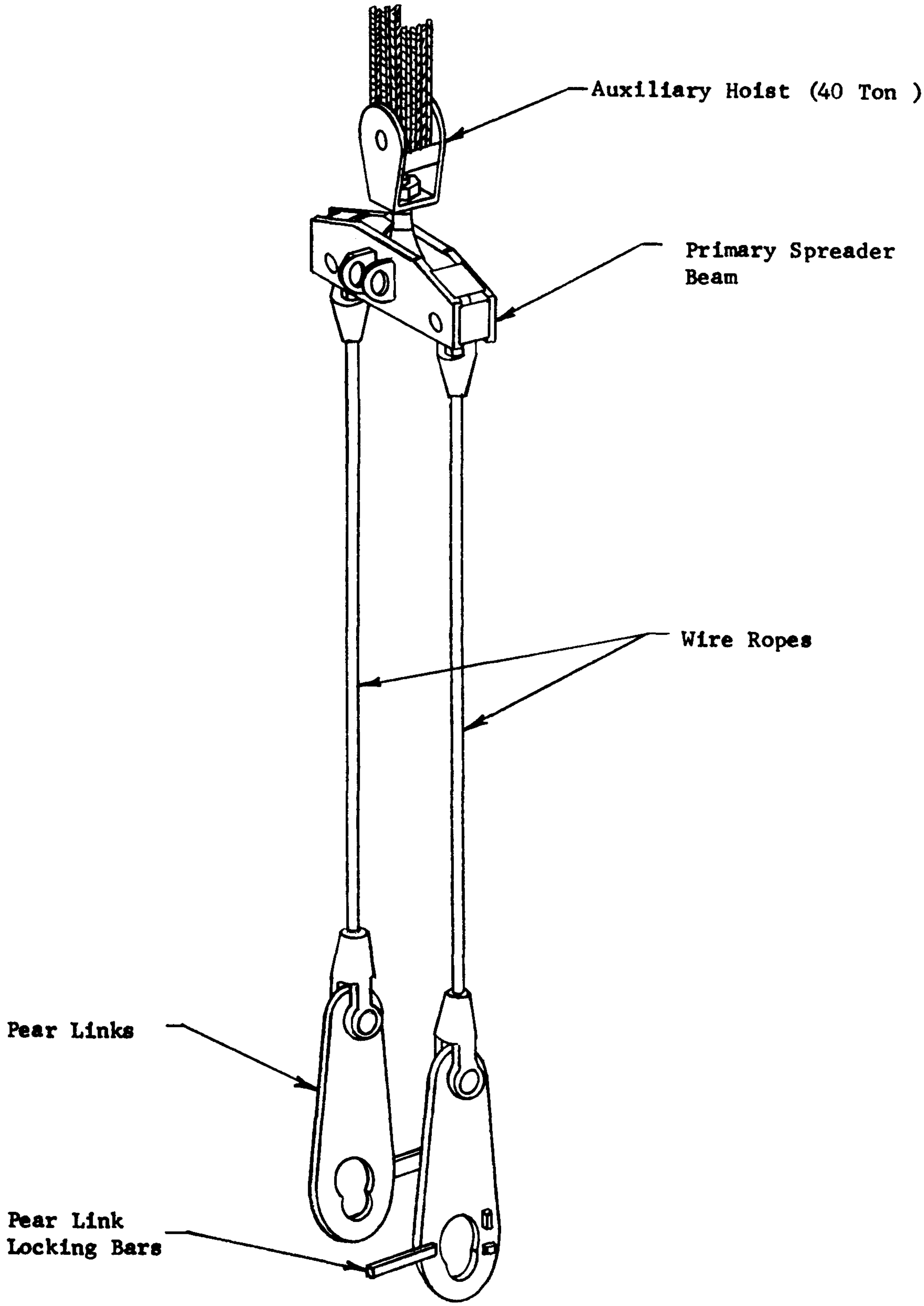


Figure 3-22: Peach Bottom Cask Primary Rigging

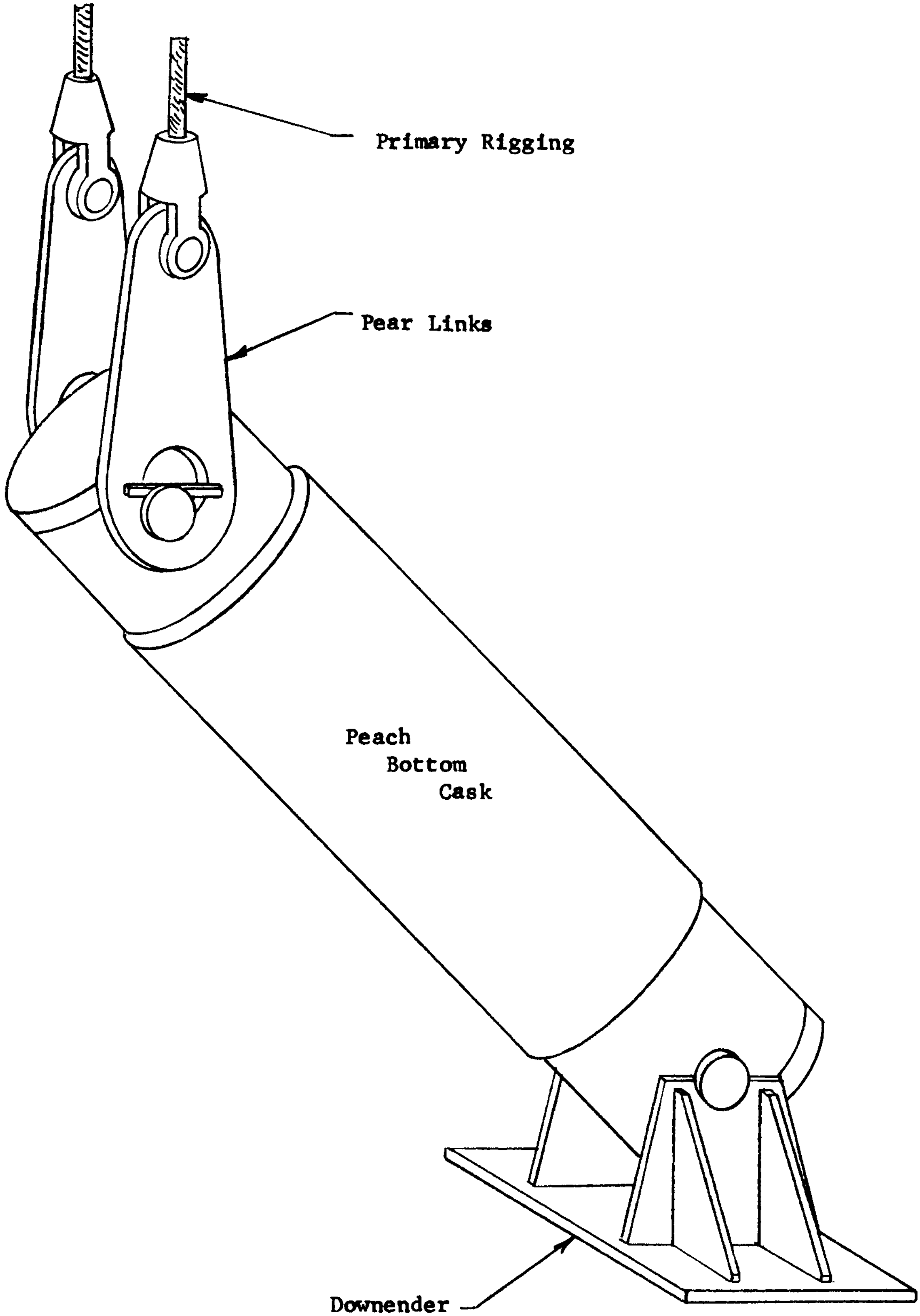


Figure 3-23: Peach Bottom Cask Upending

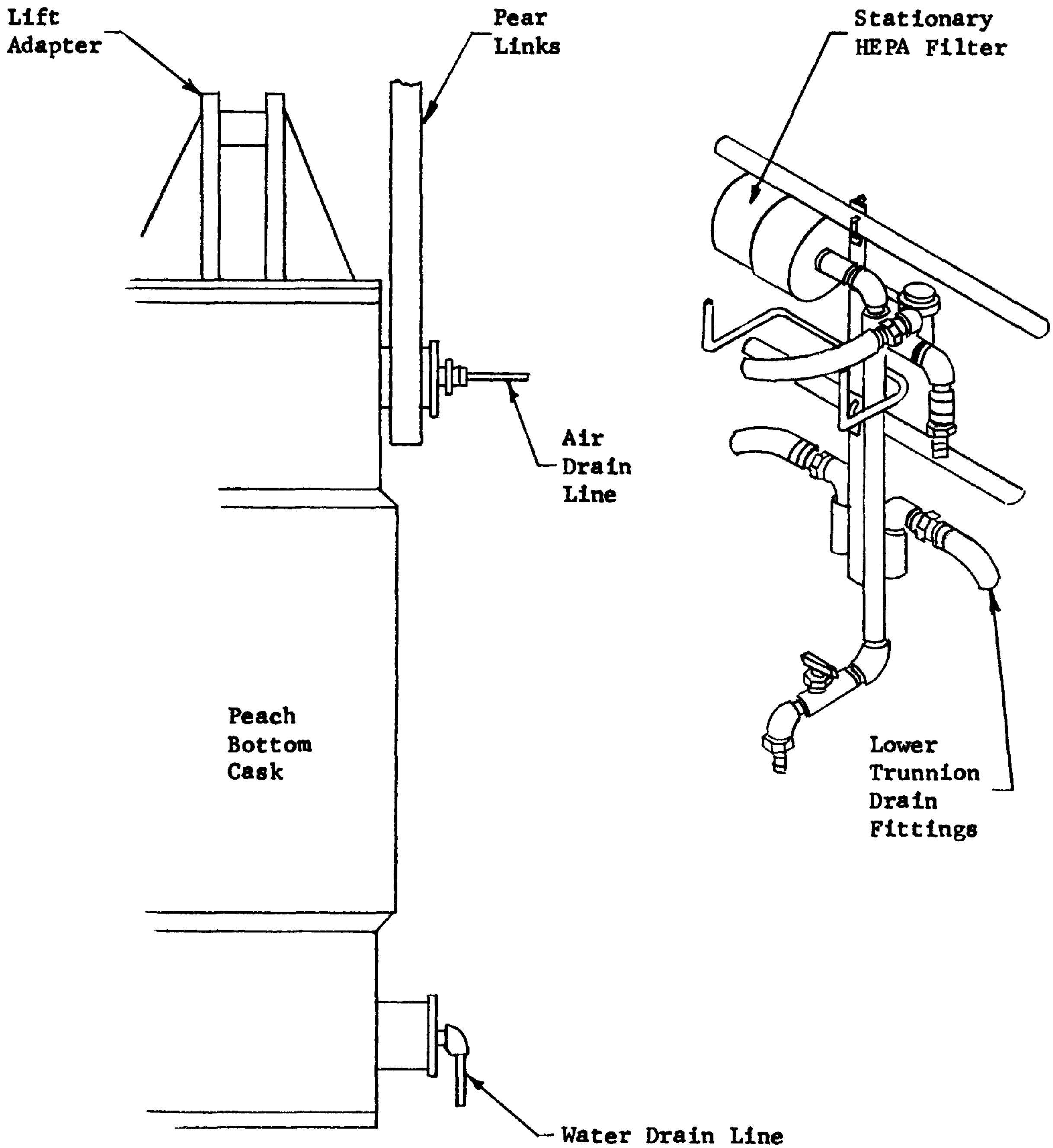


Figure 3-24: Peach Bottom Cask Vent and Drain Lines

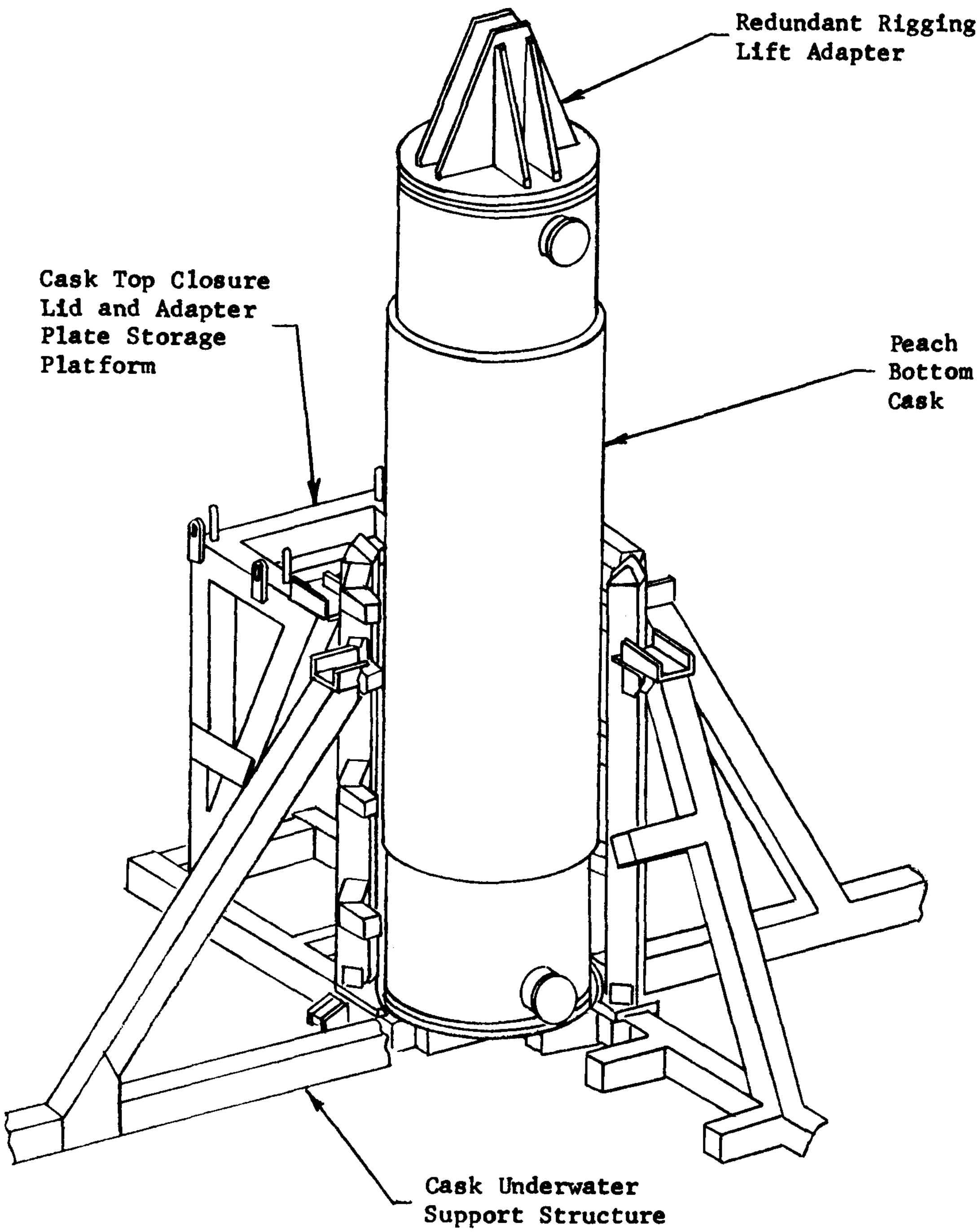


Figure 3-25: Peach Bottom Cask in Water Pit Support Structure

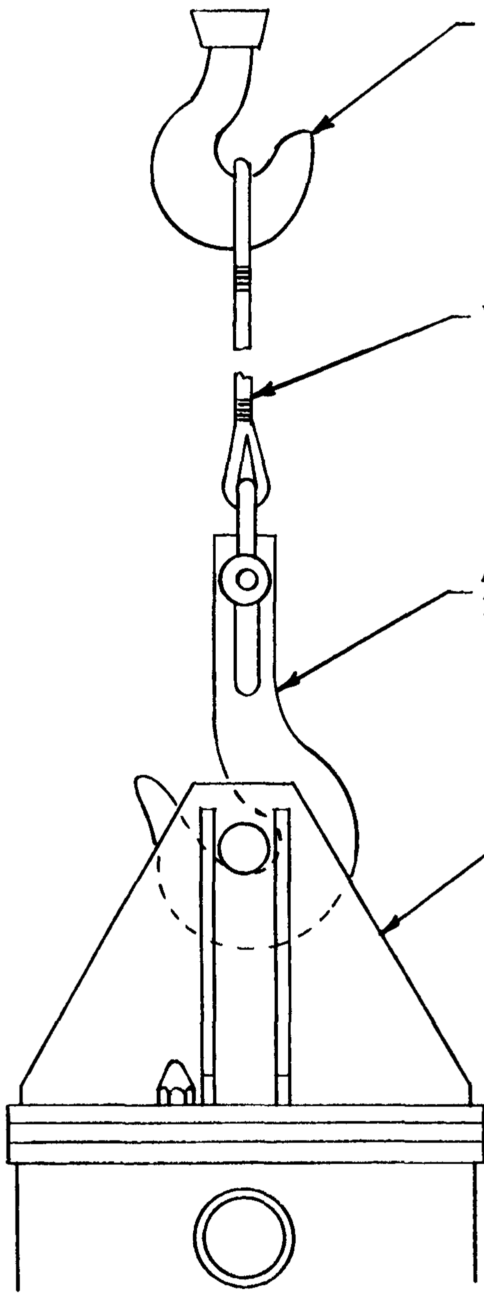


Figure 3-26: Peach Bottom Cask Top Closure Lid and Adapter Plate Removal

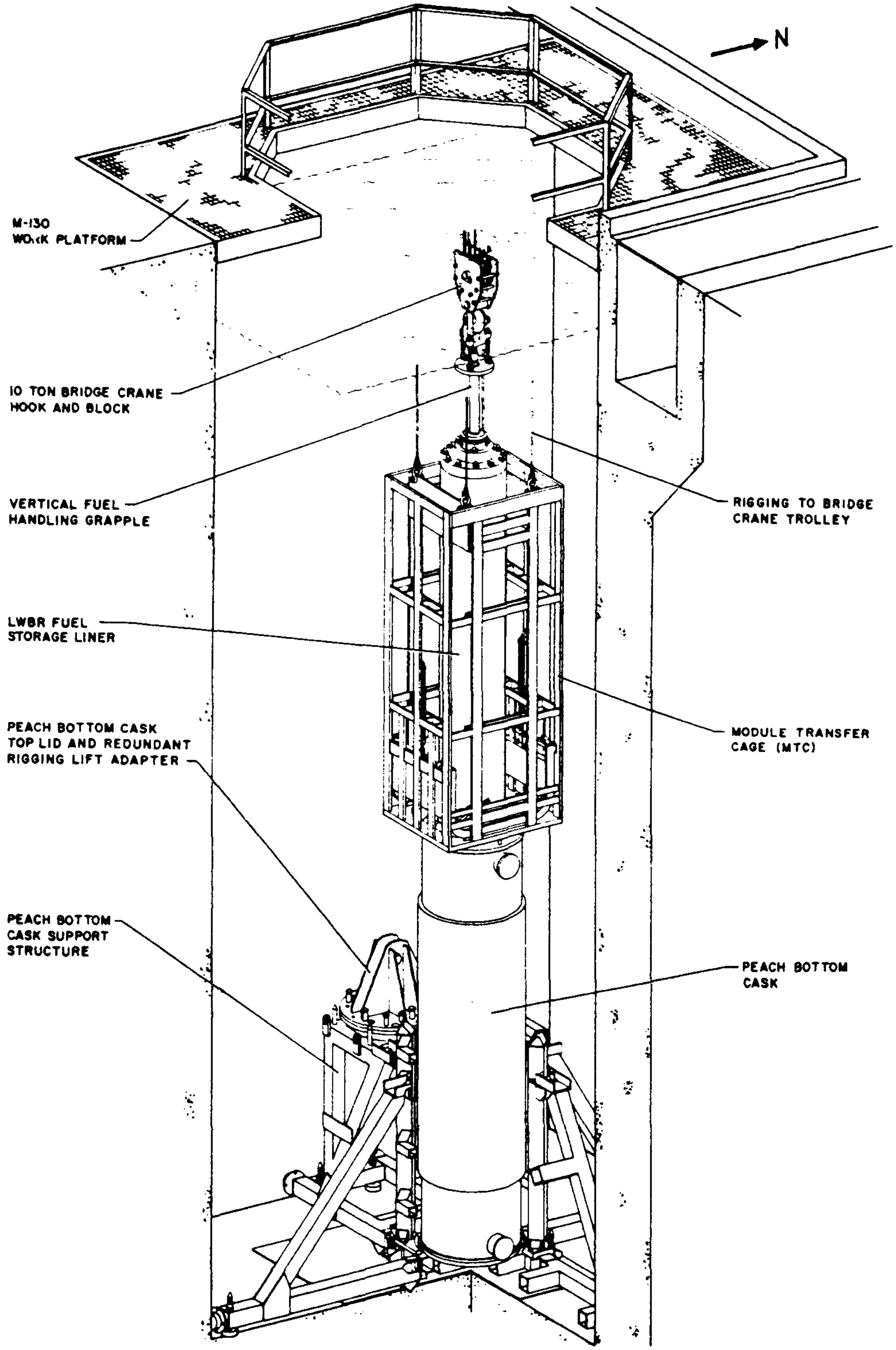


Figure 3-27: LWBR Storage Liner Insertion into Peach Bottom Cask

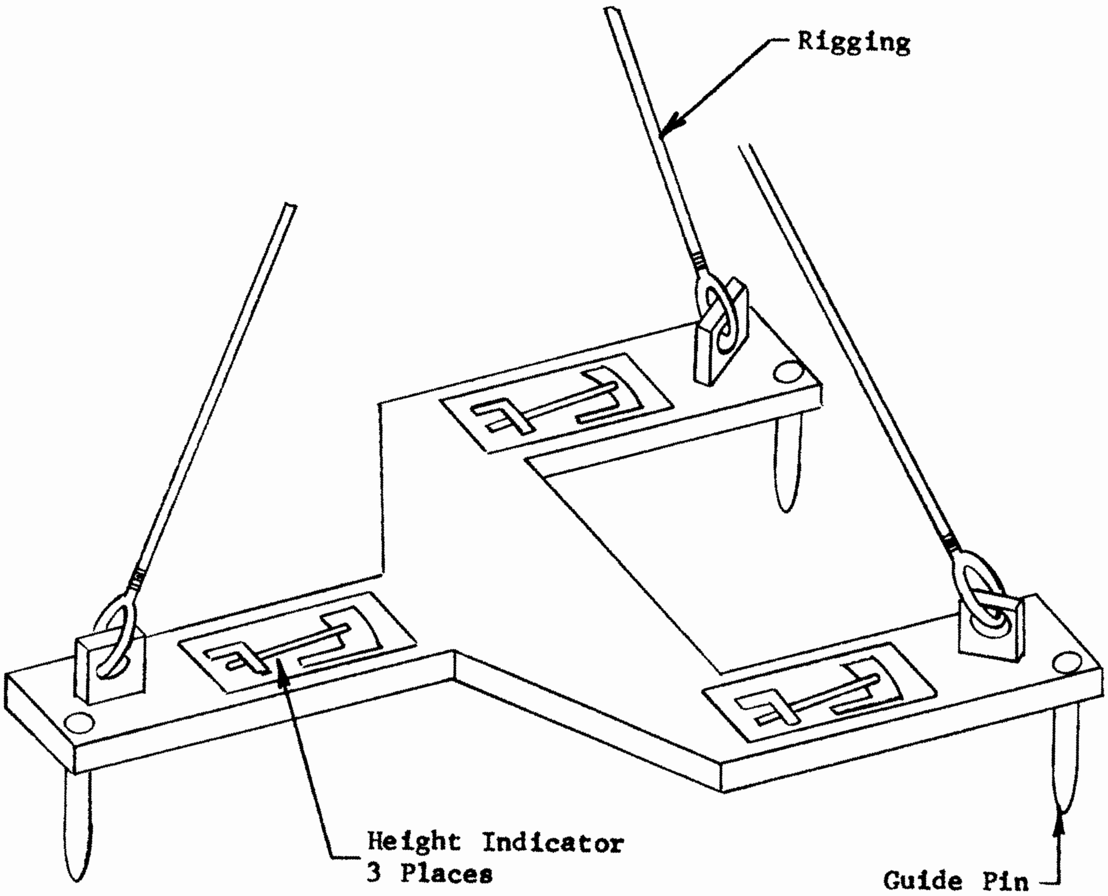


Figure 3-28: LWBR Storage Liner Seating Verification Gauge

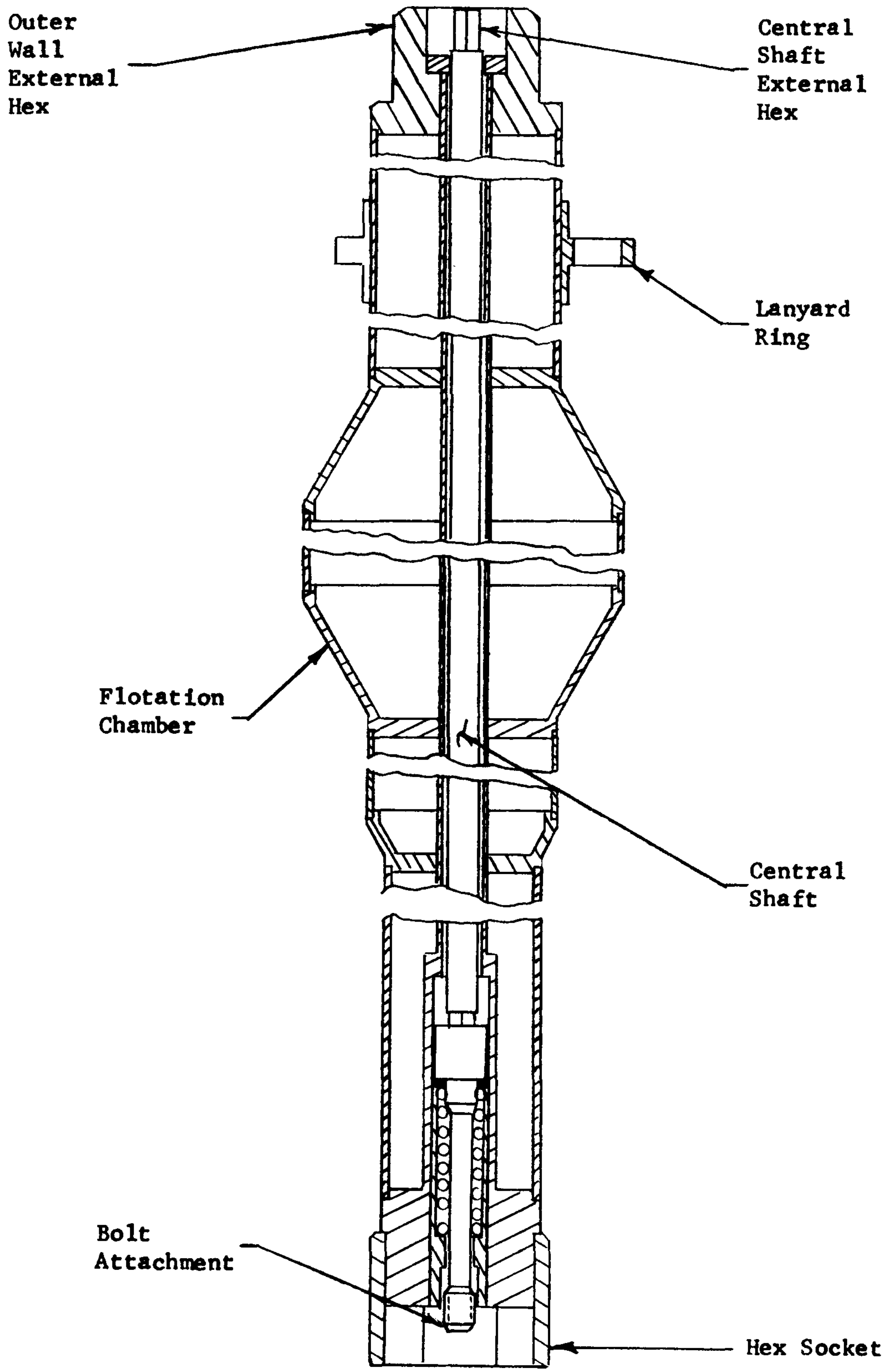


Figure 3-29: Peach Bottom Cask Top Closure Lid Bolt Handling and Torquing Tool

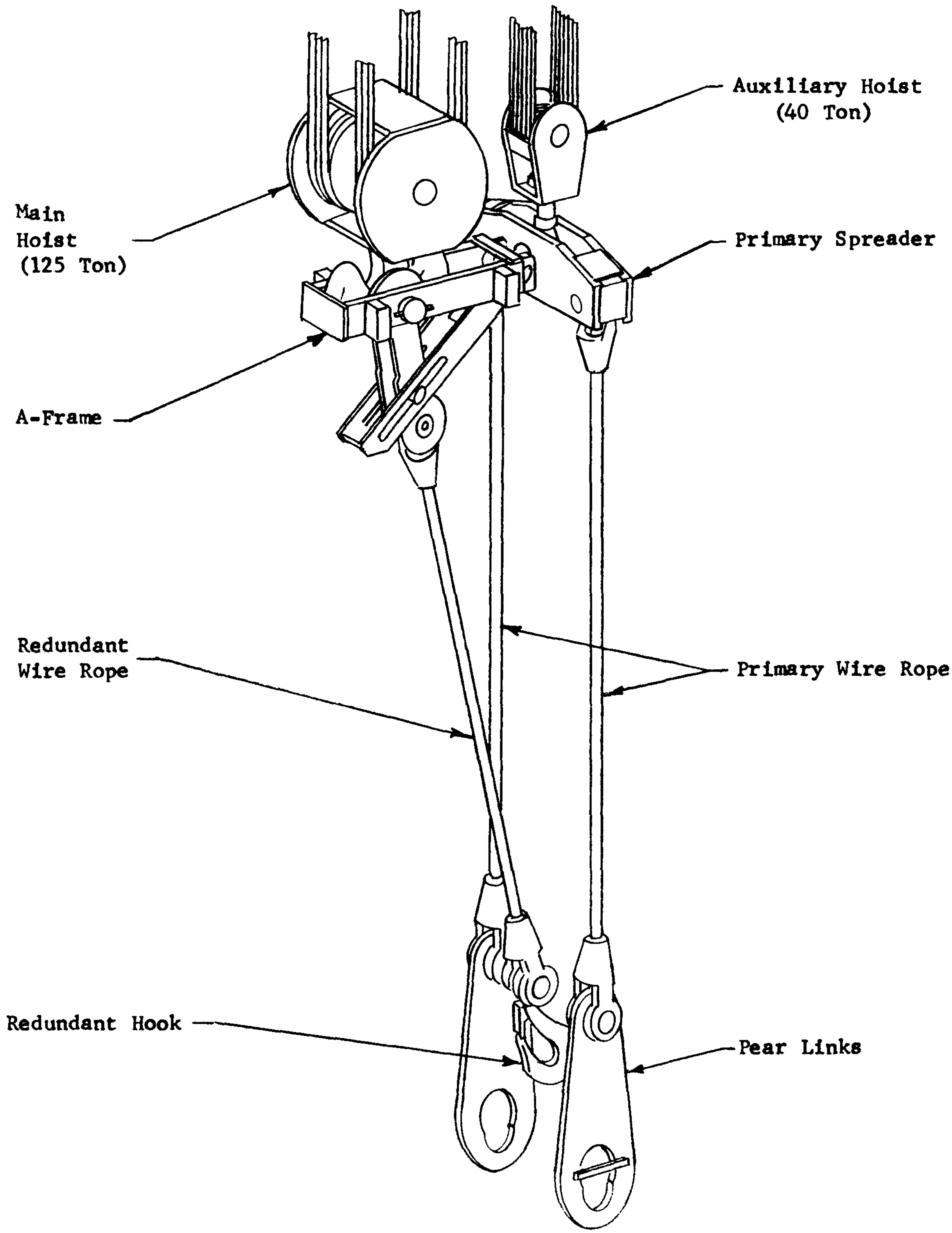


Figure 3-30: Peach Bottom Cask Redundant Rigging

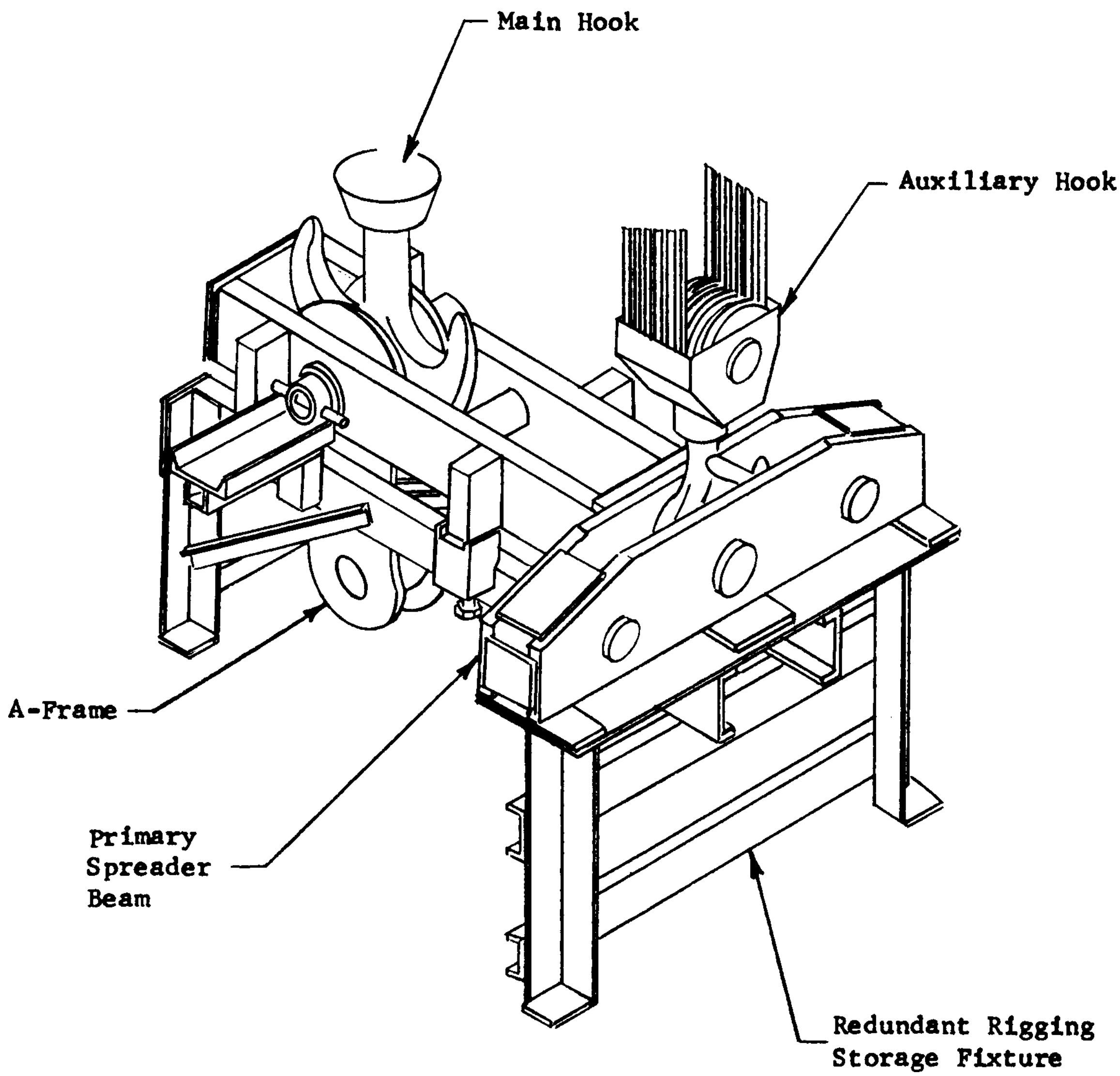


Figure 3-31: Peach Bottom Cask Redundant Rigging in Storage Fixture

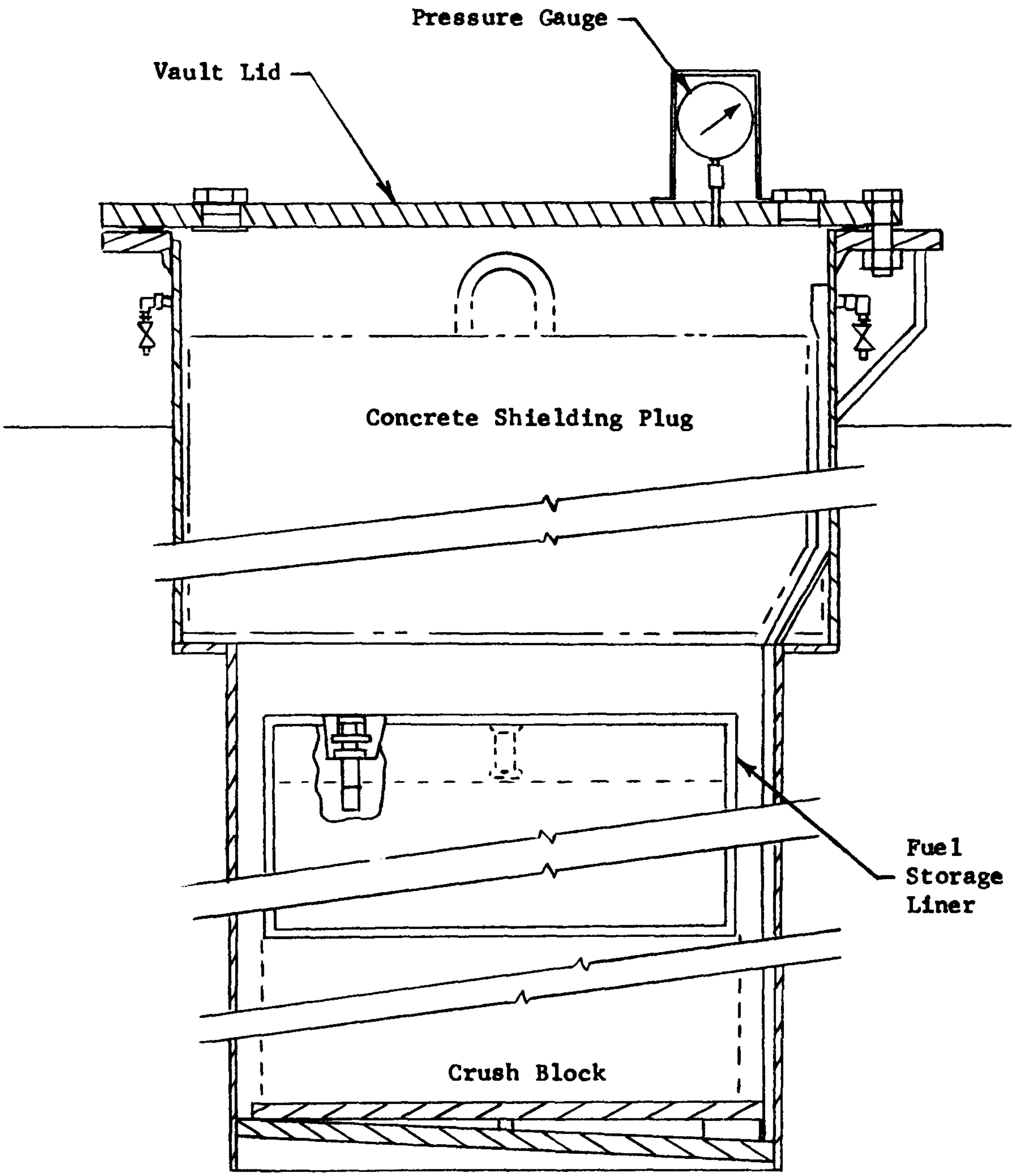


Figure 3-32: ICPP Storage Vault

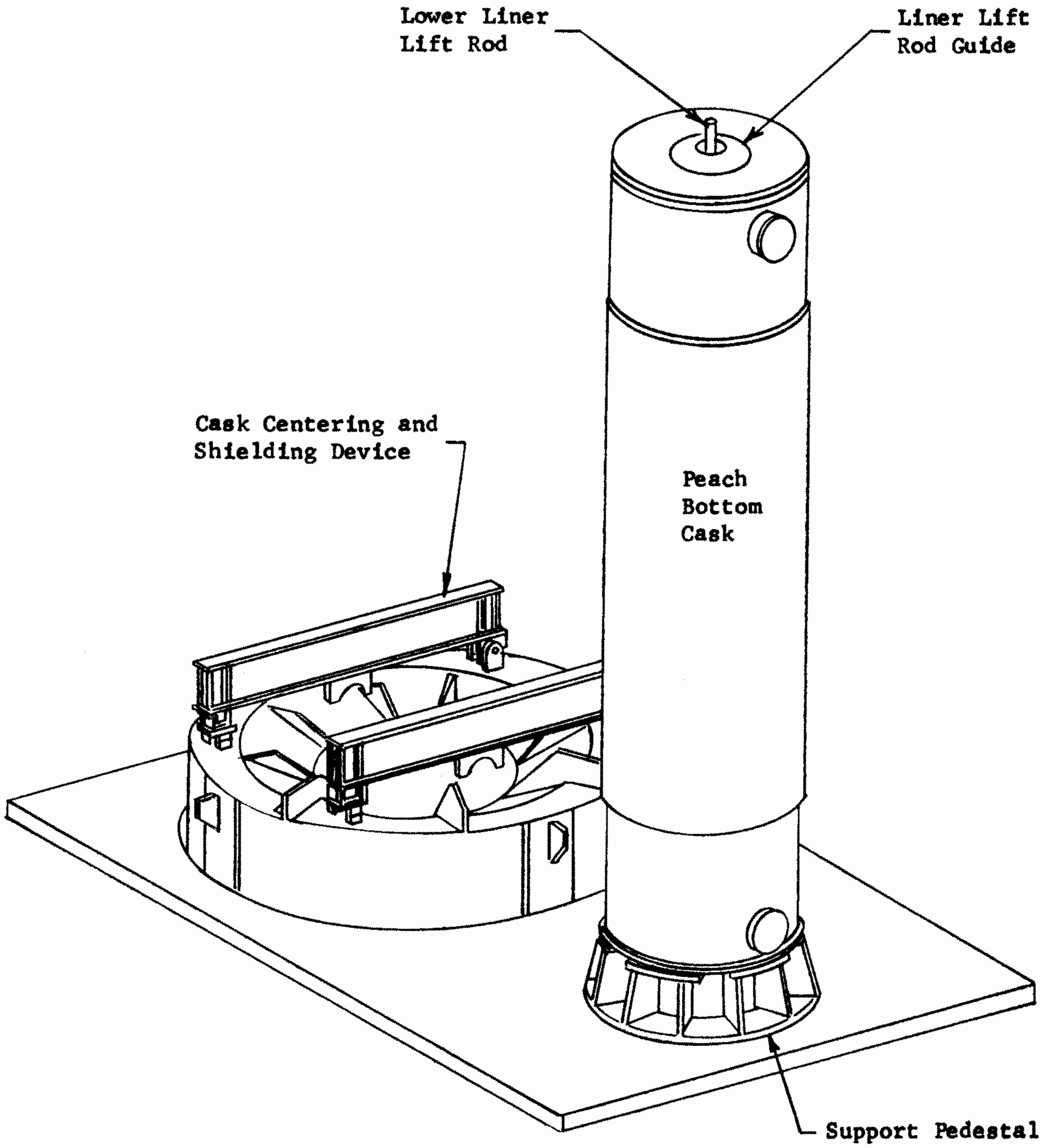


Figure 3-33: Peach Bottom Cask Bottom Closure Lid Removal

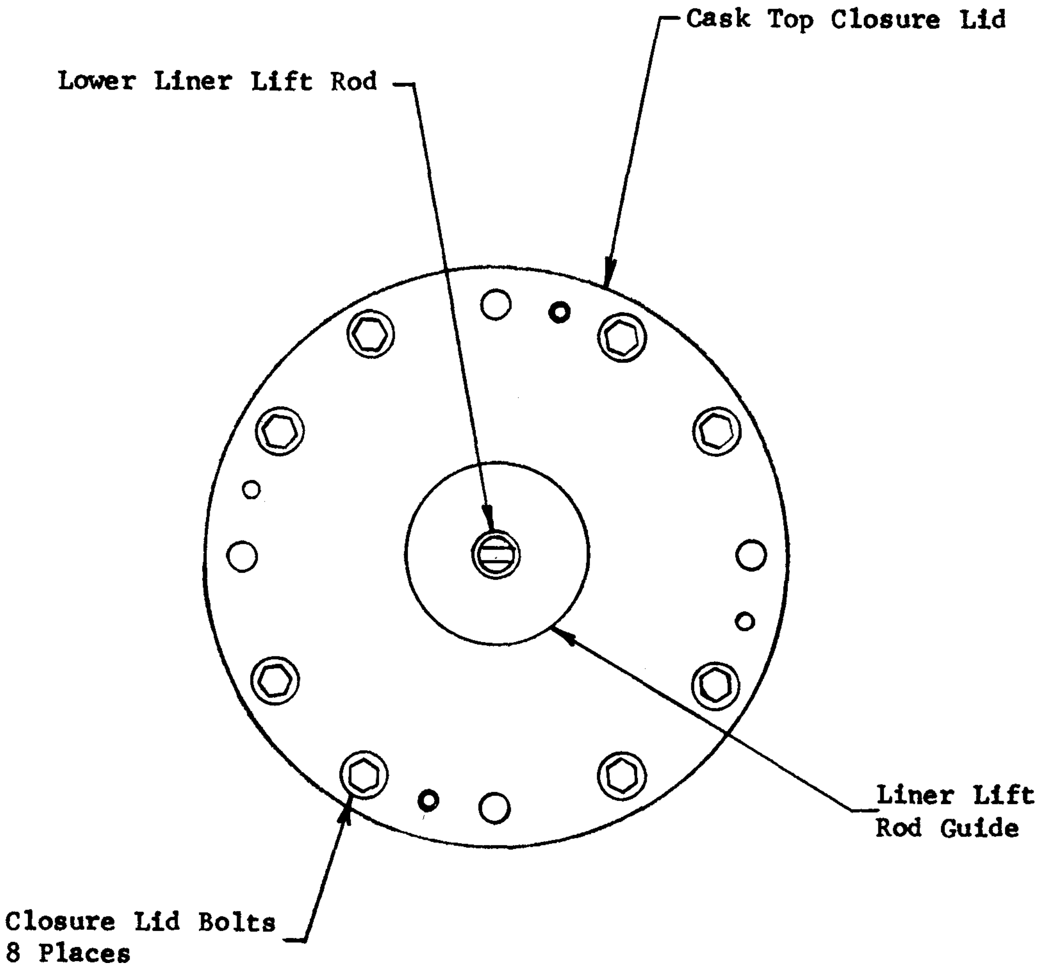


Figure 3-35: LWBR Storage Liner Lift Rod Guide
and Lower Lift Rod Installation

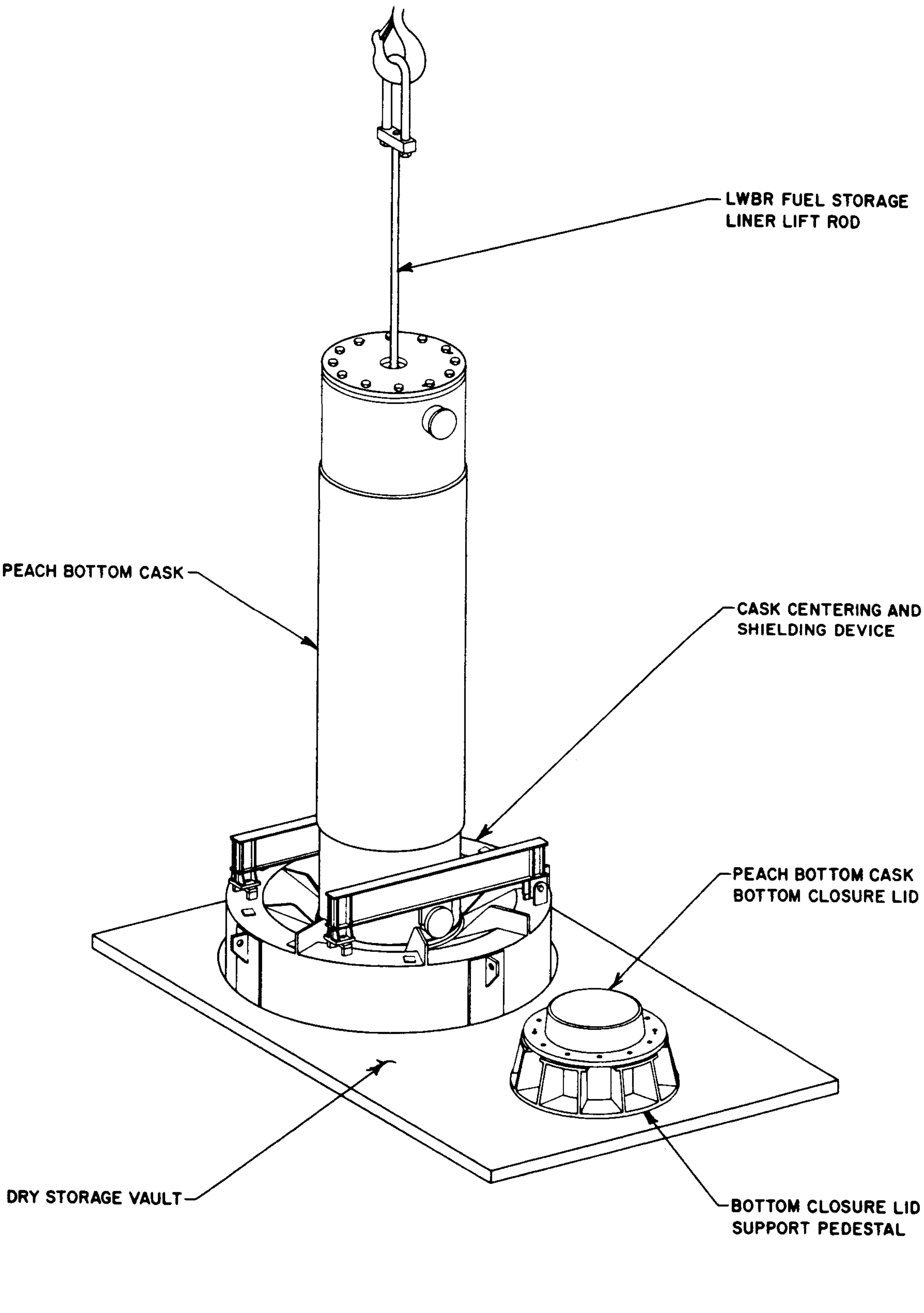


Figure 3-35: LWBR Storage Liner Installation at ICPP

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SECTION 4

SUMMARY AND CONCLUSIONS

Fuel disposal was the last major phase of the LWBR Development Program. The objective of fuel disposal was to package, process, and transport all LWBR fuel for long term underground storage. The fuel disposal process was comprised of the following operations: (1) Peach Bottom cask receipt and water pit installation; (2) fuel storage liner transfer to the liner closure station; (3) fuel storage liner closure; (4) fuel storage liner drying, inert gas backfill, and leak testing; (5) fuel storage liner loading into the Peach Bottom cask; (6) Peach Bottom cask removal from the water pit; and (7) Peach Bottom cask shipment. These processes and their associated equipment satisfied all of the LWBR fuel disposal requirements.

Fuel disposal operations began in December 1985 with the shipment of an as-received blanket fuel module. The smooth start-up was a direct consequence of an extensive training program. All 48 fuel disposal shipments were accomplished on time and safely.

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SECTION 5

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SECTION 6

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Messrs. W. J. Babyak, J. E. Bayer, A. R. Beale, D. G. Bruhn, R. J. Greenberger, M. A. Hennessy, R. L. Matchett, E. L. Miller, C. A. Pruss and P. K. Stirn for their efforts in the design, assembly and testing of the LWBR Fuel Disposal Equipment.

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APPENDIX A

FUEL STORAGE LINER

Two types of fuel storage liners were fabricated for the LWBR fuel disposal program: fuel rod storage liners and fuel module storage liners. The exterior of all storage liners was a cylindrical shell. The interior of the rod storage liners had tube bundle inserts to house the individual fuel rods. The interior of the module storage liners had features configured to the various module cross sections. A typical LWBR fuel module storage liner is shown in Figure 3-1. Each module type had a corresponding storage liner type because of the vastly different sizes and cross-sectional shapes of the LWBR fuel modules. Module storage liner internals were fabricated to accept both as-received and COS, Cut Off System, prepared modules.

All storage liners were constructed from stainless steel materials. The main body of the storage liners consisted of a 25.50 inch outside diameter cylindrical shell. The module cavity in module storage liners was formed by an upper girth ring and axial runners fastened to the girth ring. The outside of the girth ring was welded to the storage liner body shell. These axial runners guided the module into the storage liner during vertical insertion and supported the module during horizontal shipment. For rod storage liners a tube bundle was fastened to the girth ring in place of the module cavity axial runners.

The bottom of the storage liner was a circular plate welded to the storage liner body shell. This plate in module storage liners had "torque blocks" which interfaced with the top mounted axial runners and prevented them from torsionally skewing within the liner. Resting on the bottom plate was a landing base and an energy absorber. The energy absorber was a honeycomb unit which protected the fuel module in the event of a drop accident. In the case of reflector module storage liners and all rod storage liners, the energy absorber was replaced with a simple spacer. LWBR seed and blanket fuel modules contained sufficient fissile material such that if the fuel rods were ruptured, optimally rearranged, and moderated, criticality could potentially occur. This was not the case for reflector modules or individual fuel rods. The bottom of the fuel module or the ends of the fuel rods seated on the landing base. The landing base was captured in position by the axial runners in the module liners and by the tube bundle in the rod liners. All storage liners had a drain line which extended from the top girth ring to the bottom plate. This drain line was used during the dewatering blowdown cycle to expel the water from the storage liner cavity.

All storage liners had a removable external guide pin in the girth ring that interfaced with the fuel storage racks, the vertical and module disassembly stands, and the closure head installation port of the liner closure station. The guide pin positively aligned the storage liner when installed in the work or storage locations listed above.

The closure head, closure bolts, drain fitting, vent fitting, and silver-plated, nickel o-rings sealed the LWBR fuel within the storage liner. The metal o-rings provided a seal which would not deteriorate with age or exposure to radiation. After fabrication and final assembly, each storage liner was individually leak tested to confirm its sealing capability. The leak test included a hydrotest at 125 psig and a helium test at 55 psig.

Features integral to the liner closure head included identification markings, alignment features, and threaded holes which allowed the installation of the liner lifting head assembly. This head assembly was used to lift and transport the storage liner once the closure head had been installed. A large reinforced threaded hole at the center of the storage liner closure head was used when the sealed storage liner was lowered out of the Peach Bottom cask shipping container for final disposition at ICPP.

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APPENDIX B

MODULE TRANSFER CAGE AND FUEL GRAPPLE

The Module Transfer Cage (MTC) was used for all transfers of vertically oriented LWBR fuel assemblies. The basic function of the MTC was to preclude an unacceptable fuel assembly drop accident. This was accomplished by providing a "basket" to catch the fuel and keep it from falling to the water pit floor during transport of the fuel from one work station to another. The MTC, shown in Figure B-1, consisted of a structural cage which was independently suspended from the bridge crane trolley at a fixed elevation by wire rope cables. The LWBR fuel was grappled using the fuel handling grapple tool and was suspended from the bridge crane hook inside the MTC during a transfer. The cage bottom had an opening which was closed by hydraulically operated aluminum doors through which the fuel was raised and lowered. The MTC was sized to accept all fuel module types, all cut-off modules prepared for fuel rod removal operations, and all fuel storage liners.

The vertical fuel handling grapple within the MTC latched onto the modules by engaging a lift adapter that was installed on the modules at initial ECF receipt. The grapple design had a cam activated lift pin head. Three lift pins were radially driven outward into the corresponding adapter plate lift holes. These lift pins had an outer lip which would not allow the lift pins to be withdrawn under load. The grapple activating tool was captured by a grapple guide until rotated to the fully engaged or fully disengaged position to prevent partial engagement or disengagement.

In preparation for transfer, the LWBR fuel was raised into the MTC by the bridge crane and the MTC doors were closed by actuating the door hydraulic cylinders. The fuel elevation above the doors, approximately 1 inch, was controlled by a limit switch on the crane hook travel. If the fuel was dropped from the grapple, the cage doors would prevent it from falling to the water pit floor, a distance of almost 16 ft. The resulting impact loads on the fuel from a drop to the MTC doors would be insufficient to rupture the fuel rods. Besides limiting the forces on the fuel due to the postulated drop accident, the cage was also designed to retain the fuel assembly after the drop accident.

The MTC/bridge crane electrical interlocks were designed so that when the MTC electrical cables were connected into the MTC control console on the bridge crane trolley, the crane operated only in the micro-mode (jog). The MTC doors had to be locked in the closed position to take the crane out of the micro-mode and allow it to operate at full speed. This would provide an indication to the operators that the doors were not locked in the closed position.

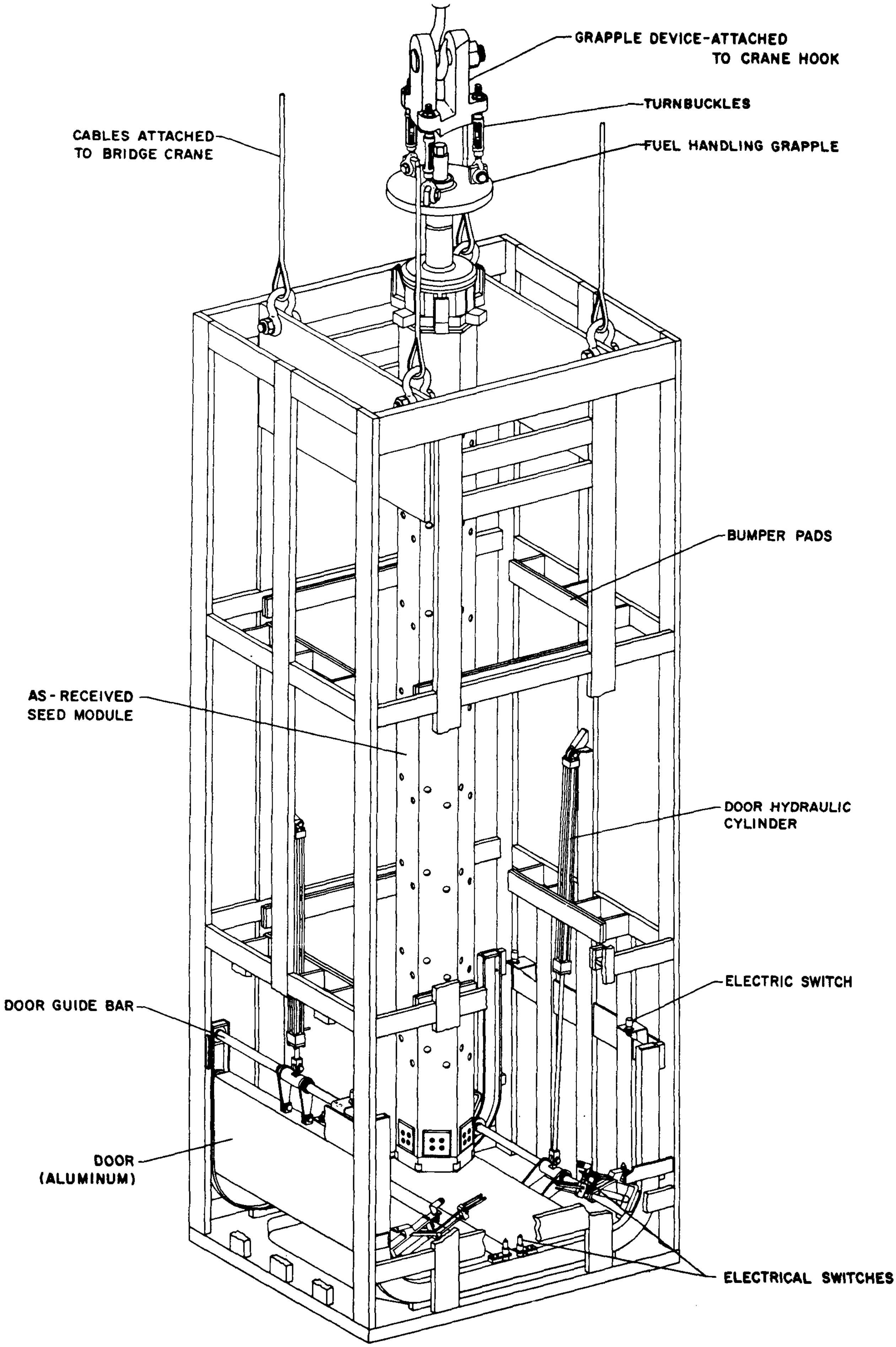

Figure B-1: LWBR Fuel Module Transfer Cage (MTC)

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APPENDIX C

LINER CLOSURE STATION

The Liner Closure Station (LCS) was part of the water pit equipment required to process the LWBR fuel for disposal. The LCS was a LWBR fuel storage liner storage rack which was modified to the requirements needed for closure head installation and dewatering processing.

The storage rack was fabricated from 304 stainless steel box beams and sheet metal which formed a container 136 inches long, 74 inches wide, and 172.50 inches high. The rack was divided into eight individual compartments for secure storage of eight fuel storage liners. The storage rack was designed to withstand the loads generated at ECF during a design basis seismic event or due to equipment dropped from 20 ft. above.

The LCS, shown in Figure 3-3, used six of the eight available storage locations for liner fuel processing. The remaining two storage ports were preserved for intermediate storage locations if needed. Of the six compartments used, two were for closure head installation, two for storage liner dewatering, one for the filtration system, and the last for the blowdown holding tank.

The four ports which were used for storage liner dewatering and closure head installation had spacers installed into the bottoms of the ports. These spacers raised the storage liner being processed to a height which provided ready access for the processing operations. The two dewatering positions were raised by 12.25 inches which simplified the attachment of the dewatering equipment to the storage liner fittings. The two head installation positions were raised by only 8.62 inches. This allowed the head installation locations to be secured by closing the port cover while still allowing unhindered access to the top of the storage liner. These four ports had guide plates installed which were designed to: (1) guide and maintain the position of a liner during installation and removal; and (2) minimize the clearance between the circumference of the liner and the LCS. The reduction in clearance was necessary to prevent any tooling from falling into the LCS during closure head installation and storage liner dewatering operations.

The filter assembly was an industrial cartridge filter. This assembly, shown in Figure 3-3, was connected downstream of the storage liner and before the blowdown holding tank. This unit provided filtration of the particulates in the effluent being discharged from the storage liner down to 1 micron.

The holding tank was a right circular cylinder, 25.50 inches in diameter, 161.50 inches in height, and fabricated from 304 stainless steel. The capacity of the holding tank was larger than the nominal water volume that could remain in a fuel loaded storage liner. All of the bulk water was removed from the storage liner by pumping more compressed air into the storage liner than water available. This holding tank collected the excess compressed air preventing the release of potentially contaminated air.

The LCS, by the addition of leveling screws to each corner of the station, was positioned on the water pit floor so that the storage liners were aligned and maintained in a true upright position. This permitted the closure head and dewatering tooling to perform their function without built-in misalignments occurring.

Mounting plates were added to the side of the LCS to support the piping rack and dewatering tool rack. When fully assembled, the modified storage rack provided a work station to install a storage liner final closure head and remove the bulk water while maintaining the position of the storage liner and fuel during processing.

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APPENDIX D

STORAGE LINER DEWATERING DEVELOPMENT AND METHOD

Spent LWBR fuel, sealed in storage liners, is being stored in underground silos at the Idaho Chemical Processing Plant (ICPP) for an extended period of time. Over this time it is necessary that the condition (viz., the cladding integrity) of the fuel not be degraded. For this reason, the environment in which the fuel is being stored must be inert; hence, all liquid water must be removed from the storage liner and be replaced with an inert gas, in this case neon. Neon was chosen as the inert gas because it is a relatively good heat conductor and because of the acceptable previous experience with neon gas during LWBR fuel shipments from Shippingport to ECF in the M-130 containers.

Water in the storage liner could be deleterious for one or more of the following reasons. The decay heat from the fuel could potentially cause evaporation, thereby increasing pressure within the storage liner. Secondly, the presence of water can cause degradation of the Zircaloy cladding through oxide corrosion and hydriding processes. Additionally, water may hydrolize, under irradiation, i.e., the water may break down into gaseous hydrogen and gaseous oxygen. Therefore the fuel must be dry and must be stored in a dry storage liner. At ECF, each fuel module was kept underwater in a storage liner for several years. In order to dry a storage liner the following procedure was used. First, the liner head was bolted onto the storage liner. Compressed air at 35 psig was then forced into the liner, forcing the water out. Once this bulk amount of water was removed from the liner, only droplets of water remained on all of the fuel and liner surfaces. Tests showed that the surface water remaining totaled no more than five pounds (water within the crud layer on the fuel rods may contribute additional residual moisture).

Before proceeding with design of a drying method, it was first necessary to establish the technical requirements. It was determined that the removal of all liquid water from the storage liner was required. The amount of water vapor within the storage liner was limited by the vaporization pressure, 12 millibar, of water at the 50°F temperature of the ECF waterpits.

The presence of liquid water is temperature dependent. If all liquid water was removed and the liner was saturated with water vapor, then cooling down the liner would result in the condensation of water. In a like manner, liquid water may be left in the liner at one temperature, and this water would evaporate to water vapor if the liner temperature was raised to a higher value. Hence, when stating that all liquid water is to be removed from a liner, it is essential to specify the temperature of the process.

The method for removing the residual water (the drops of liquid water) from the storage liner was to establish a vacuum within the liner. A vacuum pump could reduce the pressure within the liner to a value below 12 millibar, the vaporization pressure of water at the 50°F temperature of the ECF waterpits. The water then vaporizes and exits the liner via the vacuum pump. In actual fuel disposal operations the vacuum pump reduced the pressure within the liner to less than 3 millibar.

Utilization of a vacuum system for drying the storage liners had the following benefits: 1) a vacuum system can dry the storage liners at the waterpit temperature - theoretically no heating is required; 2) a vacuum system does not involve a large quantity of effluent gases; 3) while narrow gaps present some difficulty, a vacuum system is much more reliable (than other drying systems) in pulling water out of small crevices; and 4) capability to hold a vacuum provides positive proof that all liquid water has been removed.

The following disadvantages were incurred by use of a vacuum system. The principal problem with a vacuum system is maintaining seals. On the storage liner there were many seals and it was imperative that each seal withstand a vacuum. (Note that these seals must also withstand overpressurization with neon.) There was concern that heat transfer within a vacuum might not be sufficient to preclude reaching excessively high temperatures within the fuel due to inefficient decay heat removal. Finally, pressure varies significantly from the vacuum pump to the liner, to the extent that water vapor may undergo extensive expansion in traveling to the vacuum pump. In expanding, the vapor will absorb heat for this expansion, and water might be frozen in either the liner or the vacuum line. Time would be lost in evaporating this ice, and the ice could possibly block the transfer of water vapor to the vacuum pump.

The resulting dewatering system, shown in Figure 1-6, was a fluid processing network with its own dedicated mechanical tooling subsystem. The mechanical tooling provided the means to remotely couple the fluid processing network to the fuel storage liner in order to access the fuel storage liner internals.

The fluid processing network handled contaminated effluent (water or gas) from the fuel liner and supplied the dewatering processing media, i.e., high pressure dry air, water, vacuum capable of handling high moisture effluent, and neon gas. All process changes were accomplished through manual valves and gages located above water in the dewatering system control panel. This control console is shown in Figure D-1.

The mechanical tooling included the drain and vent umbilical tools, the funnel latch plate, and the funnel latch plate tools. The umbilical tools connected the process piping to the fuel liner via the self-seal fittings. These remote connections are illustrated in Figures 3-12 and 3-13. These tools contained inner volumes (plenums) to channel the processing media to and from the fuel liner plus inner spindles to manipulate the closure features of the self-seal fittings. These inner spindles were manually operated and were able to thread the fitting caps on or off and to lift or insert the fitting drain plug. The umbilical tools used Buna-N O-rings to establish a seal with the outside diameter of the self-seal fittings and between the inner spindles and the tool housing internals. The inner spindle seal allowed for translation and rotation of the spindle for self-seal fitting manipulation without the loss of process pressure or vacuum. This design allowed final closure to be made while the process pressure and media were active in the system. Intrusion of water during final closure was prevented since the process lines were not uncoupled until sealing was completed.

The funnel latch plate, shown in Figure 3-14, was installed on the fuel liner head and served three functions. The funnel latch plate guided the umbilical tools to their required positions above the self-seal fittings in order to prevent O-ring damage. Once installed, two remotely operable latches secured the umbilical tools to the fuel liner to prevent tool blowoff due to the high pressure in the umbilical tool's plenum region during liner blowdown.

The funnel latch plate contained a clear Lexan plate located directly above any region on the liner from which an air leak could emanate. The leak test of the liner relied on the accumulation of air bubbles. The lack of air bubbles indicated an acceptable seal. A special Lexan plate for the drain fitting was on a swivel which allowed remote operation. Engaging the holddown bolts to secure the funnel latch plate to the liner closure head, actuation of the latches to secure the umbilical tools, and rotation of the Lexan plate for drain fitting leak test were all performed by use of the funnel latch plate reach tools.

The dewatering system tool rack, shown in Figure 1-6, housed the umbilical tools and stored the funnel latch plate reach tools. The tool rack provided a structure on which the weight of the umbilical tools were counterbalanced in order to ease usage. The tool rack, mounted to the south wall of the dewatering pit S4-39, rotated on a bearing at its lower end, and was guided by a radial bearing at the top. This rotational flexibility allowed the tool rack arm to access either of the two liner dewatering ports as well as a "home" position. Features were provided to lock the tool rack and the umbilical tools into a stationary position during liner processing to preclude inadvertent movement which could have resulted in loss of process pressure or vacuum.

The submerged portion of the dewatering fluid system consisted of a "blowdown" tank, a filter system, piping to the umbilical tools, piping joining the filter to the "blowdown" tank, piping for "blowdown" tank effluent and backfill, piping to allow sampling for fuel cladding breach assessment, a volumetric flow meter and a diverter valve. See the fluid processing schematics on Figures 3-11, 3-15, 3-16, and 3-18. Umbilical tool piping included sections of flexible hose to allow freedom of movement of the tools via the support system tool rack. The volumetric flow meter measured the total flow of water during blowdown. The diverter valve controlled the direction of water flow to allow flow to the flow meter during liner blowdown or flow to backfill the "blowdown" tank after liner blowdown.

The above water portion of the fluid process system consisted of a control panel, pressurized neon tanks, 3 hp air compressors, 200 cfm vacuum pumps, a regenerative 35 cfm air dryer, piping to the water pit and piping to the ECF exhaust stacks. The control panel, shown in Figure D-1, contained five manual valves for air and neon gas supply, two system bleed valves, pressure and vacuum gages, pressure regulators for neon and air supply, and a batch controller to automatically track total flow of water during blowdown and then automatically shut off the air compressors. Switches were located on the control panel to operate the air compressors, vacuum pumps and the air dryer. Piping within the control panel connected to piping going into the water pit and also to piping ducting contaminated gases (air, neon, and vacuum effluent) to the ECF exhaust stacks.

A remote valve actuator handle was contained in the control panel to actuate the diverter valve. Redundancy in air compressors, vacuum pumps and neon tanks was used to preclude interruption of the processing of a liner. The air dryer was not critical since it could be totally bypassed with no significant effect on the liner being dried.

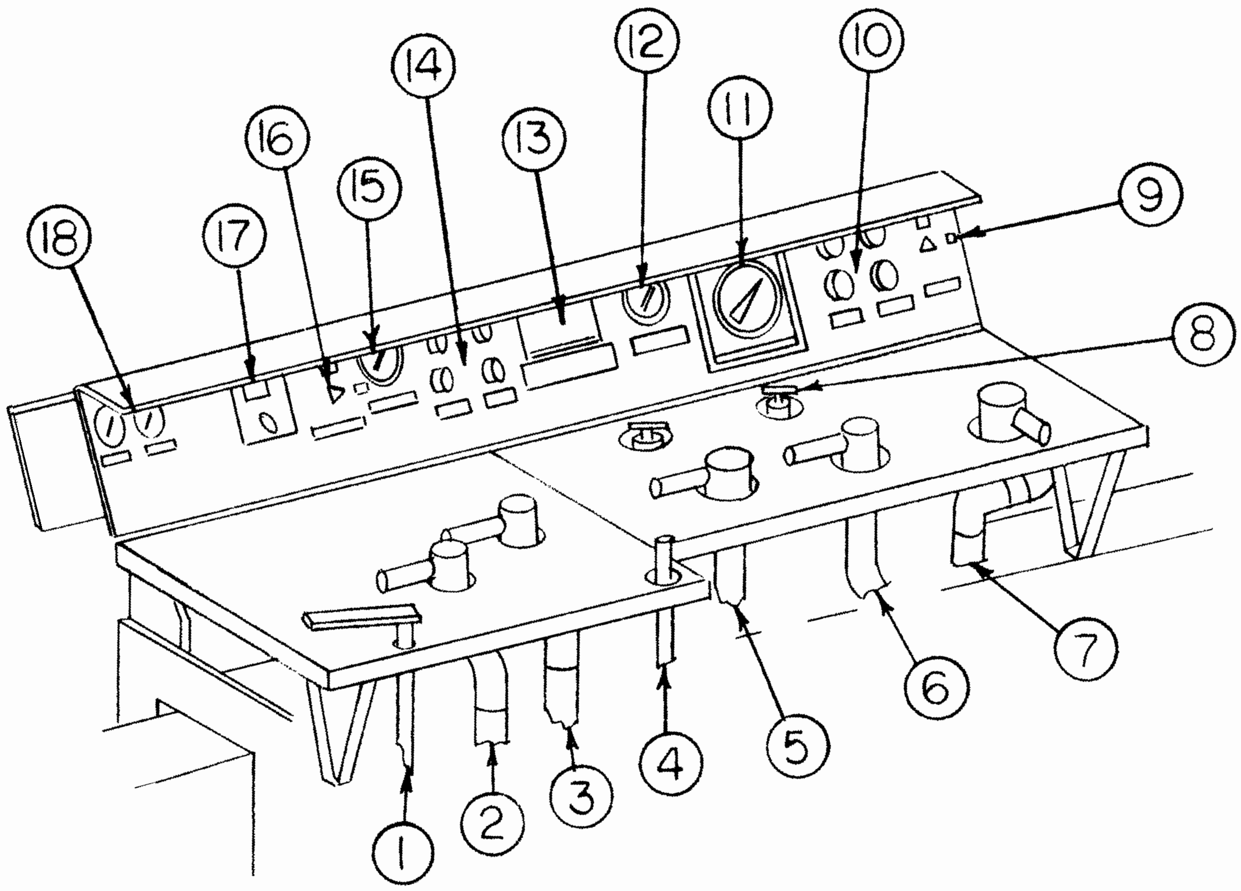

Figure D-1: LWBR Storage Liner Dewatering System Control Panel

Number	Function
1	Blowdown tank diverter valve
2	Blowdown tank vent
3	Spare
4	Sample line
5	Neon line
6	Air compressor line
7	Vacuum line
8	Neon pressure regulators
9	Vacuum bleed
10	Vacuum pump
11	Vacuum gauge
12	Pressure gauge (spare)
13	Batch controller
14	Air compressor
15	Pressure gauge (spare)
16	Air/Neon bleed
17	Relative Humidity monitor
18	Pressure gauge for neon regulators

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APPENDIX E

PEACH BOTTOM CASK SUPPORT STRUCTURE

A Peach Bottom cask water pit support structure was required to provide a specific landing location at the bottom of the water pit for the Peach Bottom cask, to provide vertical stability for the cask during liner loading operations, and to prevent cask overturn during a design basis seismic event. The underwater cask support structure, illustrated in Figure 3-25, consisted of a weldment with wall bracing fabricated from 6 inch x 6 inch stainless steel square tubing. The center of the support structure was configured to accommodate the Peach Bottom cask's two lower trunnions. The support structure extended vertically to the center of gravity of the cask. A storage location for the cask top closure lid was provided on the west end of the support structure.

Chamfered lead-ins were provided on the top of the support structure to ease installation of the cask. The cask sat within the support structure resting on its bottom closure lid. Chamfered corners at the bottom of the support structure provided a positioning feature for the cask, and simplified construction by allowing use of less stringent tolerances during fabrication of the weldment. The main body of the support structure had four acme thread leveling pads that sat on the existing M-130 water pit floor bearing plate to support the full weight of the loaded cask. The leveling pads were required to obtain a plumb cask inner cavity for ease of fuel storage liner insertion.

A nominal radial clearance of only 0.25 inches existed between the storage liner and the cask inner cavity over the entire depth of the cask. Positioning the cask to within 0.50 inches of vertical ensured that the fuel liner entered the cask cavity without binding on the sides of the cask cavity. The cask and support structure were leveled so that the nominal elevation of the top of the cask, when within the support structure, was 183.12 inches. At this elevation, 1.88 inches of clearance existed to the bottom of the Module Transfer Cage (MTC) and all overhead building crane hoist hooks remained out of the water.

The Peach Bottom cask support structure was positioned within water pit N4-43 in order to utilize the existing M-130 work platform. The support structure's location was defined by 1) the north-south centerline of the N4-43 waterpit south gate to minimize bridge crane travel during fuel storage liner installation into the cask and 2) the southeast corner of the M-130 work platform opening to allow transfer of the redundant rigging A-frame and primary spreader beam for rigging attachment to the cask. The support structure wall bracing functioned to restrain the cask vertically and prevented overturn and translation in a design basis seismic event.

Leveling pads were provided on the wall bracings to ensure contact with the water pit floor regardless of the elevation of the main body of the support structure. Wall screws were provided on the wall bracings to simplify installation into the water pit.

APPENDIX F

PEACH BOTTOM CASK REDUNDANT RIGGING

LWBR seed and blanket fuel modules contained sufficient fissile material such that if the fuel rods were ruptured, optimally rearranged, and moderated, criticality could potentially occur. While it was highly unlikely that these fuel rod segments would ever be rearranged into this unsafe configuration, the LWBR/ECF safety posture was to prevent (i.e. render as implausible) fuel rod ruptures in postulated drop accidents. During loading of the fuel storage liners into the empty Peach Bottom cask, drop protection was provided by the Module Transfer Cage and the storage liner crushblock. Drop protection was also required for the remaining cask operations - 1) a vertical lift of the cask of approximately 38 feet from the bottom of the water pit to above the water surface, and 2) translation of the cask east to the cask downender. The redundant rigging concept discussed below was utilized to satisfy this drop protection requirement.

An implausible event is defined as an event which is sufficiently improbable that it can be dismissed from evaluation. The accidental drop of a loaded Peach Bottom cask back into the water pit was considered an implausible event with the following provisions:

(1) Redundant rigging was provided between the Peach Bottom cask and the overhead building crane trolley as shown in Figure 1-7. Primary rigging was attached to the auxiliary hoist and the redundant rigging was independently attached to the main hoist. Simultaneous operation of the two trolley hoists was required.

(2) The loaded fuel storage liner, Peach Bottom cask, plus both sets of handling equipment weighed 37 ton. The building crane auxiliary hoist was mechanically upgraded to a 40 ton lift capacity.

(3) In addition to scheduled periodic nondestructive inspection of lifting and handling equipment, the Peach Bottom cask primary and redundant rigging, and the overhead building crane main and auxiliary hoists were visually inspected prior to each use. Crane limit switches were verified operational to preclude accidental raising of the hook block into the hoist drum. These operational verifications were standard crane inspections at ECF prior to each use.

(4) Proper installation and fastening of all rigging was verified prior to each lift of the loaded Peach Bottom cask.

These actions, (1) upgrading the lift capacity of the building crane auxiliary hoist, (2) incorporation of redundant rigging, and (3) inclusion of the operational safeguards defined above, fulfilled the criteria of making the accidental drop of the Peach Bottom cask implausible and therefore satisfied the LWBR/ECF safety posture.

The design for providing redundant rigging for the fuel loaded Peach Bottom cask for use in the ECF water pit is depicted in Figure 1-7. Simultaneous operation of the two hoists on the building crane was required. The primary rigging utilized the building crane auxiliary hoist to attach rigging to the cask upper two lifting trunnions. The primary rigging, shown in Figure 3-22, consisted of a spreader beam, two pear links, and the two M-130 wire rope slings. The two pear links were locked to the upper cask trunnions with locking bars. The redundant rigging utilized the building crane main hoist to independently attach rigging to a lift adapter plate which was bolted to the top of the Peach Bottom cask. The redundant rigging, shown in Figure 3-30, consisted of an A-frame structure and a single wire rope sling that was attached, with slack, to the lift pin of the cask adapter plate with a hook. The hook was locked to the adapter plate lift pin with a safety latch. The A-frame was designed to (1) support the full load of the cask plus the two sets of rigging in the unlikely event of primary rigging failure, (2) prevent the auxiliary hoist block from dropping onto the loaded cask or impacting the redundant rigging sling in the unlikely event of crane hoist running rope failure, (3) couple the two hooks to maintain hook separation, and (4) allow a small degree of relative motion between the two crane hoist hooks to minimize side loading in the event the two hooks did not lift in unison.

The requirements of "redundant rigging" were satisfied because the rigging technique provided two independent sets of rigging that were attached to two independent lifting systems. The primary rigging utilized the upgraded auxiliary hoist to attach to the cask upper two lifting trunnions. The secondary (redundant) rigging utilized the main hoist to attach to the top of the cask body through the adapter plate. Both rigging attachments were locked to the cask. Each of the building crane hoists had its own independent hook, running rope, sheave assemblies, drum, drive motor, drive shafts, gear boxes, brakes, limit switches, electrical controls, and operating console. The only common electrical element was the bridge crane main power supply. The only common structural elements were the crane trolley and bridge box girders. The rated lifting capacities of the two hoists on the building crane were sufficient to satisfy the static load requirement (37 ton) for lifting the fuel loaded cask.

Simultaneous operation of both building crane hoists was required to lift the fuel loaded Peach Bottom cask out of the water pit. Simultaneous operation of two building crane hoists is not unique to fuel disposal operations. ECF handling of other shipping casks also requires simultaneous hoist operations. The rate of cask removal from the water pit was 5 ft/min or less because 5 ft/min was the maximum lift speed for the main hoist. This removal rate was adjusted lower to correspond with the ability to decontaminate the rigging wire ropes as they exited the water.

The amount of slack in the secondary rigging did not exceed six inches (i.e. the main hook six inches below the auxiliary hook) and at no time, except during an accident condition, could the secondary rigging carry any of the load (i.e. the main hook even with or above the auxiliary hook). In order to control the distance between the two hooks, and therefore the slack, an inclinometer was used to monitor the tilt of the redundant rigging A-frame and to shut off the hoist power automatically if either of the limits was reached. Electronic controls were used to monitor and display the cable slack. This aided the crane operator in adjusting the distance between the two hooks to be within the allowable range to avoid an automatic shutdown.

During preliminary equipment checkout, the crane operator was able to simultaneously control the two hoist hooks within ±1/2 inch of the pre-established slack operating goal of 2 1/2 inches. Based on these results, the upper slack alarm was set at 1 3/4 inches and the lower alarm was set at 3 1/4 inches. These alarm positions were used to signal the crane operator that adjustment in hoist speed was necessary to return to the desired slack operating goal of 2 1/2 inches. Automatic shutoff of the two hoists was set at one inch and four inches of slack for the upper and lower limits, respectively. The crane operator was able to handle the equipment checkout lifts without approaching the alarm limits.

The redundant rigging assembled the primary rigging to the auxiliary hoist for two reasons. First, the two Kranco hoist hooks are offset 51 inches with the auxiliary hook north of the main hook. In the unlikely event of a primary rigging failure, the Peach Bottom cask would swing south, in lieu of north, away from the water pit observation room window. Second, the dynamic loading resulting from this postulated failure would be reacted by the larger capacity 125 ton hoist. Under the postulated accident condition of primary rigging failure, a dynamic load of 242 tons (484,000 lbs) could be applied to the redundant rigging system which includes the 125 ton hoist. This loading force would result only from failure of the primary rigging system, either the auxiliary hoist running rope or the primary rigging itself, when 6 inches of slack existed in the redundant rigging. This 6 inches of slack could only develop in the unlikely event the 125 ton hook was allowed to reach an elevation 6 inches below the auxiliary hook. A decrease in the amount of slack, i.e., a reduction in the elevation difference between the two hooks, would result in a decrease in the dynamic loading and provide an added margin of safety to the calculated margin. Based on this analysis, the 2 1/2 inch operating slack goal was established with alarm limits of 1 3/4 and 3 1/4 inches and shutdown limits of one and four inches.

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