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SHIPMENT OF THE LIGHT WATER BREEDER REACTOR FUEL ASSEMBLIES FROM THE SHIPPINGPORT ATOMIC POWER STATION TO THE EXPENDED CORE FACILITY (IDAHO)

(LWBR Development Program)

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Contract DE-AC11-76PN00014

October 1987

Printed in the United States of America
Available from the National Technical Information Service
U. S. Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22161

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FOREWORD

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

Subsequent to development and successful operation of the Pressurized Water Reactor in the Atomic Energy Commission (now Department of Energy, DOE) owned reactor plant at the Shippingport Atomic Power Station, the Atomic Energy Commission in 1965 undertook a research and development program to design and build a Light Water Breeder Reactor 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. After end-of-life core testing, the core was removed and the spent fuel shipped to the Naval Reactors Expended Core Facility for detailed examination to verify core performance including an evaluation of breeding characteristics.

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

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

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

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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 Atomic Power Station. All nuclear fuel and much of the reactor internal hardware was removed from the reactor vessel and prepared for shipment to disposal sites or to the Naval Reactors Expended Core Facility in Idaho for testing or further disassembly. Three M-130 shipping containers were modified to accept LWBR seed, blanket, and reflector fuel modules for rail shipment to the Expended Core Facility. Thirty-nine LWBR fuel modules were transferred in 10 shipments. All shipments were completed successfully, without significant problems. Radiation and personnel exposure levels were carefully controlled.

SHIPMENT OF THE LIGHT WATER BREEDER REACTOR FUEL ASSEMBLIES FROM THE SHIPPINGPORT ATOMIC POWER STATION TO THE EXPENDED CORE FACILITY (IDAHO)

(LWBR Development Program)

SECTION 1 - INTRODUCTION

The Light Water Breeder Reactor (LWBR) core was totally defueled after successfully operating for 29,047 effective full power hours (EFPH). This report describes equipment and operations required to ship the partially disassembled fuel modules from the Shippingport Atomic Power Station to the Naval Reactors Expended Core Facility (ECF) in Idaho for further disassembly and testing of the breeder design concepts.

A brief introduction to fuel shipping operations is presented in this section, along with a brief description of the Fuel Handling Building and site facilities available to aid in the fuel shipping effort. Operations to remove fuel modules and other reactor components from the reactor are detailed in Reference 1. Partial disassembly of fuel modules was required to enable them to fit into shipping containers. These operations are detailed in Reference 2. Section 2 of this report presents detailed accounts of M-130 container loading and handling operations to prepare the irradiated fuel for shipment to ECF. The main emphasis is on operations, but tools used and problems encountered are also described. Detailed descriptions are provided in the Appendices of the M-130 shipping containers, the support system for filling and draining the containers, and the anticontamination enclosures which protected the containers from radiological contamination while they were submerged in the Shippingport canal.

In compliance with the Code of Federal Regulations, Title 10, Part 71 (10 CFR Part 71) and to ensure safety of the shipments, Bettis prepared Safety Analysis Reports for Packaging (SARPs) for the fuel shipments, and Certificates of Compliance for the shipments were issued by both the Nuclear Regulatory Commission and the Department of Energy. Many of the design modifications to the M-130 containers, including energy-absorbing material internal and external to the containers, were required to demonstrate compliance with 10 CFR Part 71 accident conditions.

1.1 - LOADING AND SHIPPING OPERATIONS

Shipping operations started with receipt of an M-130 container on its railcar at Shippingport. Personnel from the Duquesne Light Company prepared the container for receiving fuel.* Preparations included off-loading the container from the railcar, hooking the container up to its support system for initial filling with borated water, attaching an anticontamination enclosure around the outside of the container, submerging the protected container into the canal at the loading area, and removing the closure head. Personnel from the Bettis Atomic Power Laboratory (Westinghouse Electric Corporation) loaded fuel modules into the container and secured them. In the case of reflector modules, disassembly operations were performed after inserting the modules into the M-130 container. Reflector disassembly operations are detailed in

*All fuel movement and fuel disassembly operations, including loading fuel modules into M-130 containers, were the responsibility of Westinghouse/Bettis Defueling Operations, whereas all other M-130 operations were the responsibility of Duquesne Light Company. See Reference 1 for organization charts.

Reference 2. Final preparations, performed by Duquesne Light Company personnel, included reinstalling the closure head, removing the loaded container from the canal while decontaminating the exposed surfaces, reinstalling the container onto its railcar, and performing several operations using the support system to ensure that the fuel shipment was in compliance with Federal Regulation 10 CFR Part 71. Fuel shipped from Shippingport was escorted by couriers from the Department of Energy.

1.2 - FACILITIES

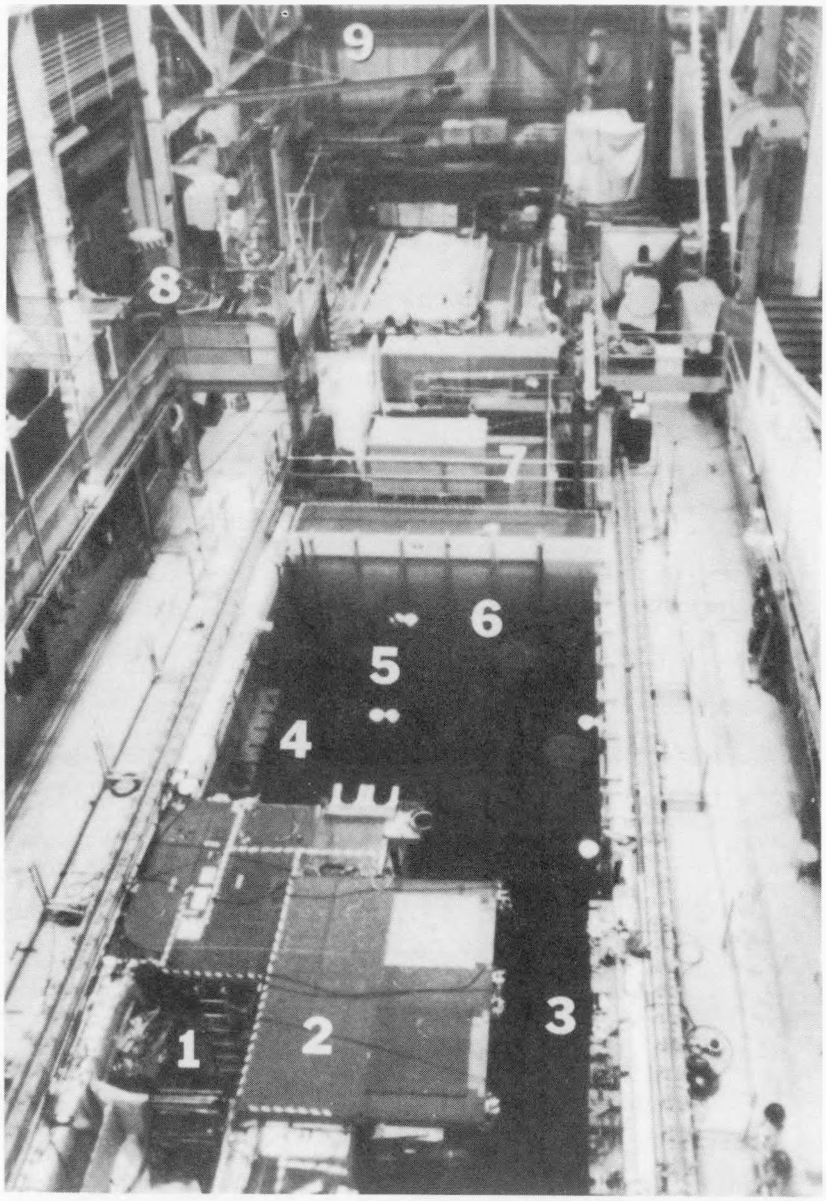
Facilities required to support shipping operations are illustrated in Figure 1B. Shipping operations centered around the M-130 fuel shipping container and its support equipment. This included a railcar, installed at the south end of the Fuel Handling Building; the M-130 support system, installed in a modified, dry fuel storage pit just north of the railcar; and the M-130 loading area in the deep pit. Fuel modules to be loaded into the containers were transferred under water from fuel storage racks, the seed/blanket disassembly stand, or directly from the reactor vessel (Figure 1A).

The Fuel Handling Building was serviced by an overhead bridge crane with single 125- and 25-ton capacity hoists. Several 3/4-ton capacity boom-type jib cranes attached to the building columns were available also. A new 2 1/2-ton capacity jib crane was installed at the south end of the Fuel Handling Building specifically to support fuel shipping operations. Access to tools and work areas for most shipping operations was provided by temporary work platforms installed over the deep pit or around the M-130 railcar as required.

Tools for shipping operations, including those needed for installing fuel modules into the M-130 container and for working on the M-130 container itself, were located in racks attached to the west and south walls of the deep pit.

1.3 - SAFETY AND TRAINING

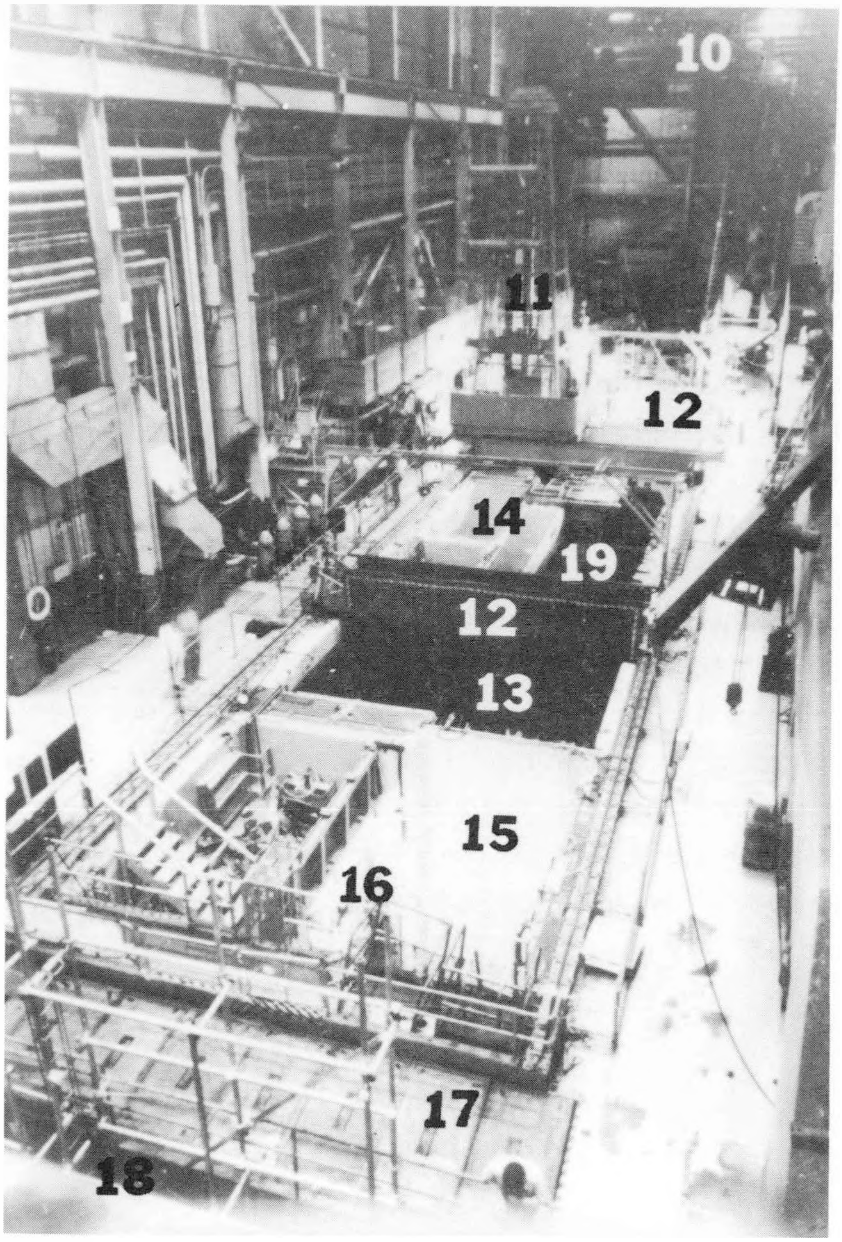
Throughout LWBR defueling, a prime consideration was personnel safety, both for the technicians performing the defueling operations and for the general public outside of the defueling area. Safety features included



LEGEND:

Item	Description	Item	Description
1	Tool Storage	5	Reactor Pit
2	Seed/Blanket Disassembly Stand (DAS)	6	CNS 3-55 Liners and Rack
3	Disassembly Tools	7	Closure Head Storage Pit
4	Seed Support Shaft Storage Rack	8	Bolt Cutting Machine Air Compressor
		9	Jib Crane

Figure 1A. The Fuel Handling Building During Refueling (Disassembly Stand and Reactor Pit)



LEGEND:

Item	Description	Item	Description
10	Main Crane	15	Dry Area (M-130 Support)
11	Extraction Crane	16	M-130 Support System
12	Movable Work Bridge	17	Cask Pit No. 4 (Motor Tube and Compression Sleeve Storage)
13	M-130 Loading Area (Deep Pit)	18	M-130 Shipping Area
14	Dry Pit (Training Area and Bolt Cutting Machine Support)	19	Fuel Storage Racks (Underwater)

Figure 1B. The Fuel Handling Building During Defueling (Fuel Shipping Facilities) careful control of personnel radiation exposure, protection against both nuclear criticality and spread of radioactive contamination, and use of specially designed and tested defueling equipment to protect personnel from injury and fuel from damage. The safety aspect was an inherent feature of equipment and facility designs and was further enhanced by an extensive program of personnel training and check-out of equipment and procedures prior to beginning defueling operations. Concern for public safety was demonstrated in the design of the shipping container and compliance with Federal regulations covering irradiated fuel shipments. As a direct result of the emphasis placed on safety, all defueling operations, including disassembly of fuel modules after removal from the reactor and subsequent shipping to ECF, were completed with no injury to personnel, no damage to fuel or equipment, and no release of radioactive contamination to the environment. Defueling was completed with total personnel radiation exposure of 76.2 man-rem; no individual worker received more than 10 percent of the 5 rem annual limit. Nuclear safety was assured through several features of the defueling program discussed in Reference 1. Shipments of irradiated fuel to ECF were accomplished without significant problems.

SECTION 2 - FUEL SHIPPING OPERATIONS

Fuel modules from the LWBR core were installed in shipping containers and transferred from Shippingport to the Expended Core Facility (ECF) in Idaho in 10 shipments. Shipment was via rail using three specially modified M-130 shipping containers to accommodate three geometrically different fuel module types used in the LWBR design. There were four shipments of blanket modules, two shipments of seed modules, and four shipments of reflector modules.

2.1 - M-130 SHIPPING CONTAINER OPERATIONS

The M-130 irradiated fuel shipping container is standardized to the extent that it can accommodate many fuel module types by using removable module holders designed by different reactor projects under the cognizance of Naval Reactors. A detailed description of the M-130 containers used for LWBR irradiated fuel shipments is presented in Appendix A1. Prior to first use of the three shipping containers, the container design was reviewed by the Nuclear Regulatory Commission (NRC) and a Certificate of Compliance was issued.

Operations to prepare an M-130 container for receiving fuel modules and for shipping after fuel module loading were essentially the same for all three containers and for all 10 shipments. There were two differences in operations using the M-130 support system (described in Appendix A2) that were dependent upon the type of fuel being shipped:

1. All loaded containers were flushed with nonborated water to reduce boron residue, but it was necessary to add a surfactant to the water used to flush the seed module container to enhance drainage from horizontal surfaces which were not present in other containers.

2. Decay heat generation values for the seed shipments and for the first blanket shipment were obtained by performing a calorimetric test. This was required to confirm calculations of fuel and cladding temperatures and to compare them to specified limits. A calorimetric test was not required for reflector shipments.

The discussion that follows describes operations on M-130 shipping containers beginning with off-loading of the empty container from the railcar, through loading of fuel modules and shipment of the loaded container to ECF.

2.1.1 - Preparations Before Placing the M-130 into the Loading Area

For off-loading and on-loading the M-130 container, the railcar was jacked up high enough to unload the truck springs, then lowered onto cribbing to provide stability. All accessible areas of the container were cleaned to remove road dirt which had accumulated in transit from ECF.

Toe jacks were used under the container on the railcar to support the weight of the container and to reposition the container while the A-frame support structure was disassembled and removed from the railcar. The A-frame support structure had to be removed to permit removal of the M-130 container from the railcar because the existing maximum crane hook height was not adequate to withdraw the container from the assembled support structure and lift it over the A-frame. Each A-frame, consisting of two struts and one upper side plate, was removed as an assembly by removing the bolts securing the lower end of the struts to the lower support structure and the bolts securing the upper side plate to the M-130 lifting lugs. Upon removal of the A-frame assemblies, the M-130 lifting plate assemblies were bolted to the M-130 lifting lugs, and four links were disconnected from the holddown ring near the bottom of the M-130 container.

An anticontamination enclosure (ACE bag) was used to enclose the exterior of the M-130 containers to simplify the decontamination efforts after removing the loaded containers from the canal. The ACE consisted of a strong, double bag which was sealed to the M-130 container. An inner bag of heavy polyvinylchloride provided a leak-free cover, while an outer bag of nylon-reinforced polyvinylchloride provided strength. Uncontaminated borated water was circulated in the volume between the ACE and the M-130 container to prevent radioactive contamination of the finned container surface. A description of the ACE system is presented in Appendix A3. Preparations for attaching an ACE bag to an M-130 container were made while the container was on the railcar. Twelve seal plate gasket alignment pins were installed in 12 tapped holes in the top horizontal surface of the M-130 container to hold the seal plate gasket in position during installation of the seal plate. The seal plate was positioned on the gasket to provide a place for attaching the anticontamination bag. The seal plate was a flat ring with a cylindrical flange welded to the bottom for attaching an ACE bag. Two pipes penetrated its top surface; one was used as a vent for the ACE water supply system, while the other provided a location for one of the M-130 container support system hoses to penetrate the ACE bag. A short hose was connected from the underside of this pipe to the quick-disconnect fitting in the container side penetration. The inner and outer ACE bags were preassembled as much as possible and positioned for subsequent installation onto the M-130 container.

The trunnion assemblies, another part of the M-130 lifting rig, were lowered through rectangular openings in the seal plate and bolted to the M-130 lifting plates with shoulder bolts. A rectangular boot provided a seal between the trunnion assembly and the seal plate. The M-130 support system hoses were connected to the quick-disconnect fitting on the seal plate and to the access plug in the closure head. The support system (Appendix A2) was then used to fill the container with canal water.

Two sets of closure head bolts were used with each container. One set was installed in the closure head prior to shipping and remained uncontaminated. This set of 56 bolts was removed from the closure head before the container was put into the Shippingport canal. A separate set of bolts for use only during underwater operations was placed into a storage rack on the closure head, to be used after the container was loaded.

Two closure head alignment pins were installed into two predetermined closure head bolt holes, and match marks were painted on the closure head. The two alignment pin locations were chosen so that they were not 180 degrees apart, would not interfere with fuel transfer into the container, and would not interfere with a contingency tool that was designed for remote removal and installation of a flexitallic gasket which provided container sealing. Alignment pins and markings were used to ensure that each closure head was always placed on its M-130 container in the same orientation. Misorientation was not a major concern for the seed or reflector module M-130, although earlier checkouts showed that there could be difficulty inserting some of the closure head bolts if particular alignments were not maintained. It was also desirable to keep the closure head penetration in a certain orientation to permit easier hookup to the M-130 support system. Orientation of the closure head on the blanket module M-130, however, was important. Three recesses were machined into the underside of the closure head at 120 degree intervals. These recesses provided space for module holddown equipment. Because of the spacing of the bolt holes, there was only one closure head position in which both the bolt holes and the recesses would be properly aligned.

Three lifting brackets were bolted to the closure head and wire rope slings were attached to the brackets for underwater removal of the closure head. The remainder of the M-130 container lifting rig, consisting of two 5 1/2-inch diameter slings and a spreader beam, was attached to the trunnion assemblies. Sling restraints were installed in the lower loops of the slings to prevent them from disengaging from the trunnions when the container landed in the canal and the rigging slackened.

The M-130 container was raised and transferred from the railcar to the south canal walkway (Figure 1B), where an ACE bag was raised over the sides of the container and banded in place on the ACE seal plate. A series of hose clamps, rather than one large clamp, was used to band the ACE bag in place so that adjustment of the band could be made at several locations around the circumference to achieve a better seal. The container was transferred to the deep pit and positioned over the M-130 bearing plates, which were 30 feet below the canal water surface. The M-130 container was lowered into the canal while the ACE bag was simultaneously filled with uncontaminated, borated water. After seating the container, a positive pressure was established within the ACE bag and maintained during the entire period that the container was in the canal.

2.1.2 - M-130 Operations in the Loading Area

After the M-130 container was seated in the deep pit, the closure head rigging was attached to the crane and the closure head was removed from the M-130 container. An inspection of seal gaskets in the closure head and M-130 container was performed to ensure that there was no damage, then the head was stored under water on an elevated rack located over the PWR lower core barrel. When these preparations were complete, the M-130 container was loaded with fuel modules. Details of module loading will be discussed in succeeding sections for each module type.

After loading the irradiated fuel modules in the container, extensions were installed on the closure head alignment pins. The alignment pin extensions were of sufficient length to extend above the canal water surface to provide easier engagement of bolt holes in the closure head. The closure head was removed from its storage location, raised above the canal water level, and positioned above the closure head alignment pin extensions, where the closure head was rotated as required to engage two specific closure head bolt holes. A minimum of 39 closure head bolts were then remotely installed and torqued to 300 ft-lb underwater. It was possible to install only 42 of the 56 closure head bolts under water because lifting brackets and rigging made several bolt holes inaccessible. Installation of a minimum of 39 bolts was required to ensure hermetic closure of the container. After the bolts were installed, the support system was used to lower the water level inside the container and to pressurize the container to perform a closure head leak test. Upon completion of the leak test, the container was refilled with water to enhance the conduction of decay heat from the fuel modules.

The M-130 container was rigged and slowly raised from the water pit to avoid rupturing the ACE bag by a sudden displacement of water within the bag. Work platforms, installed around the M-130, provided access to the container surfaces while the container was being raised above the canal water surface. The lifting rig was decontaminated as it was withdrawn from the canal. When the top of the container was at the canal water surface, the flow of water into the ACE bag was stopped and the inlet and the outlet lines were disconnected. The ACE bag was self-draining as the container and ACE bag were elevated to a working level. The top of the M-130 container was decontaminated as much as possible at this time, and the ACE bag was disconnected from the seal ring in a manner that maintained exclusion of canal water from the M-130 surfaces. The M-130 was then slowly withdrawn from the canal while being surveyed for radiological contamination, then it was transported to the railcar. The ACE bag was cut up and scrapped as low specific activity waste. Final decontamination of the closure head was performed after the container was returned to the railcar, where the surfaces to be decontaminated were more accessible.

2.1.3 - Final Preparations for Shipping

Once reinstalled on the railcar, operations to prepare the M-130 container for shipment were continued. This included support system operations (described in Appendix A2) such as calorimetric measurements to confirm that decay heat generation was within specifications, flushing the container with fresh water to dilute residual boron, and filling the container with neon gas. Other operations included reinstalling the M-130 container support structure, changing out the closure head bolts, and installing the wooden energy absorber. A three-axes impact recorder was secured to a mounting plate located near the bottom of the container. A clock mechanism drove a strip chart which was installed to monitor shocks to the railcar and container during transit from Shippingport to ECF. After completing security checks and radiological surveys, the fuel-loaded M-130 container was certified for shipping.

Impact recorders attached to each M-130 container indicated maximum shock loads of 2.5 g vertically and 0.5 g longitudinally. The 2.5 g vertical recording occurred on only one shipment, and only after arrival at ECF. One other shipment experienced an impact of 1.0 g vertically enroute but, in general, shock loadings experienced by fuel modules enroute were lower than 0.25 g, the lower limit of recorder readability. All shipments were completed successfully, with no damage to fuel modules.

2.2 - SEED MODULE LOADING

After the seed module M-130 container was seated under water on the canal floor and the closure head was removed, additional container preparations were necessary before modules could be loaded. Using remote handling tools, the six top holder/support assemblies (Appendix A1, Figure A1-3) were removed from atop the seed module holders and stored.

With the container prepared, the seed modules were grappled in the fuel storage rack or disassembly stand using the seed handling tool (Figure 2). The rigging attached to the seed handling tool, which was standard for all fuel handling operations, included the fuel handling flexible link (Reference 1) and chain hoist. The grappled module was then transported under water to the shipping container and positioned above one of the module holders. After careful alignment, the module was slowly lowered into the module holder until it seated on the seed holder bottom support (Appendix A1). The maximum allowable weight dropoff during module lowering was established at 500 pounds to protect the seed module from structural damage should the module hang-up during loading. The seed module weight in water was approximately 1500 pounds. Once the seed module was seated on the module bottom support, the seed handling tool was ungrappled from the module and removed. The loading sequence was then repeated until all six seed modules were installed in the M-130 shipping container.

After the seed modules were installed in the shipping container, the Shippingport lifting adapters, which were installed during disassembly operations (Reference 2), were unbolted and removed from the modules using remote operating and handling tools. This left the ECF lifting adapters still attached to the modules, ready for ECF use in module handling. Next, the top holder/support assemblies were installed over the seed modules and fitted into mating counterbores in the module holders using a remote handling tool. Each of the top holder supports housed two spring-loaded jack pads, which were driven radially inward to contact the seed module using a remote operating tool. Thus, each module was forced into contact with the module holder and restrained from moving laterally during shipment. Vertical holddown forces on

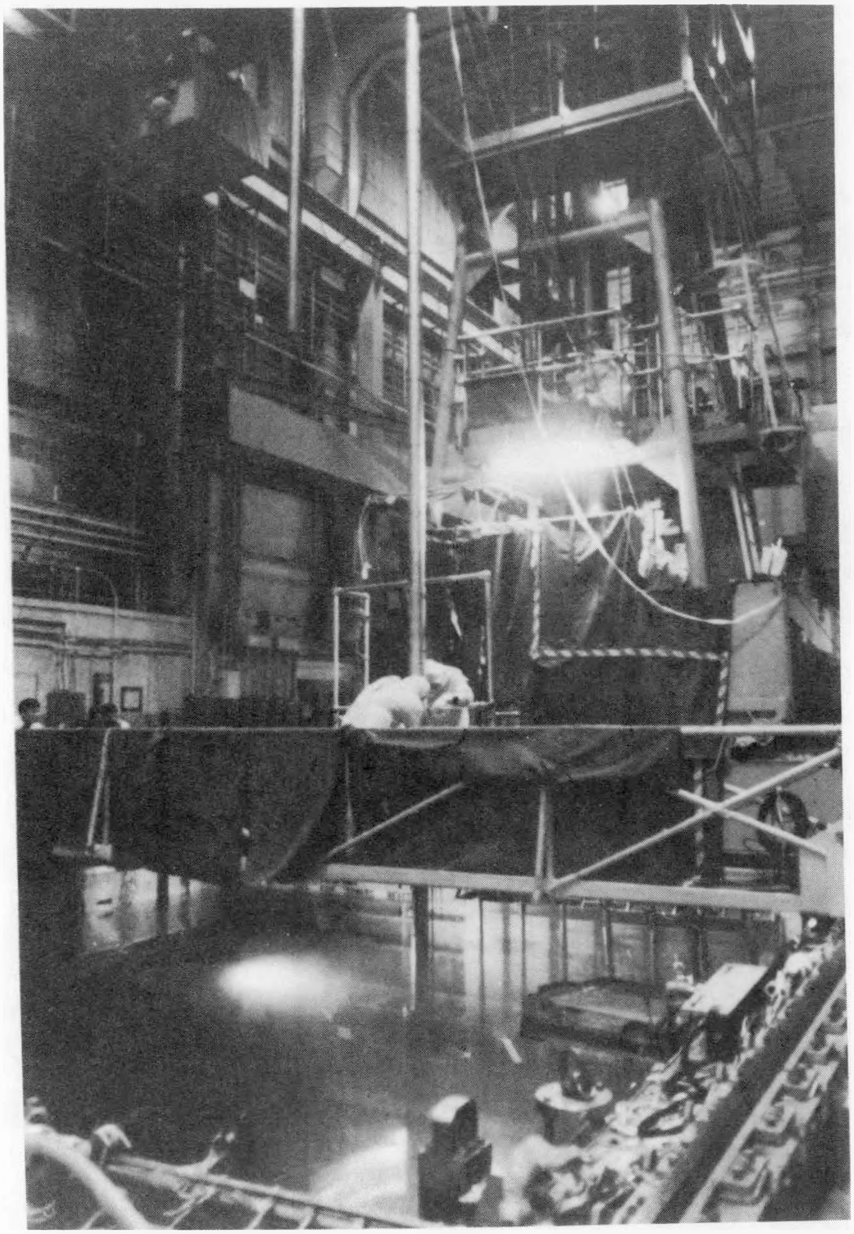


Figure 2. Seed Module Being Transported to M-130 Container

the seed modules were obtained by springs which were compressed between the seed top supports and the M-130 container closure head. Holddown spring height adjustment was necessary because a single, preset spring height could not take into account module-to-module variations in length due to dimensional tolerances and radiation-induced growth. Measurements were taken remotely to determine the correct height at which to set the module holddown springs, then the seed top supports were installed on the modules using a remote handling tool. This completed seed module loading operations.

2.3 - REFLECTOR MODULE LOADING

After the reflector module M-130 container was seated on the canal floor and the closure head was removed, a check was made to ensure that the module holders were adjusted properly to accommodate the mix of Type IV and Type V modules to be loaded. A remote handling tool was used to install or remove an insert from the module holders as required to accommodate the specific mix of modules designated for shipment.

The four reflector modules which were to be loaded into the shipping container were transferred under water from the fuel storage rack or directly from the reactor vessel. Reflector modules from the reactor vessel were transported to the module visual inspection station (Reference 1) for a complete visual inspection, then transferred to the shipping container. Reflector modules from the fuel storage rack were inspected prior to insertion into the fuel storage rack; therefore, they were transported directly to the shipping container. The visual inspection performed on all modules removed from the reactor vessel showed the modules to be in excellent condition.

A reflector module was installed in the shipping container by carefully positioning the module just over the module holder, then slowly lowering the module until it seated on the bottom of the module holder. The defueling procedure for reflector module loading limited the maximum allowable weight dropoff during lowering of the modules into the module holder to 600 pounds. The reflector module weight in water was between 4000 and 5000 pounds. This load limit for lowering was selected because it would limit forces on the modules and prevent structural damage if the module hung up on the module holder. Ample clearance was designed into the module holders to accommodate calculated radiation-induced growth and bowing. Module dimensional changes were not as great as calculated so there were ample clearances between fuel modules and the walls of the module holders; hence, none of the modules hung up during M-130 container loading. Once the reflector was seated in the module holder, the reflector handling tool was ungrappled and removed. The loading sequence was then repeated until four reflector modules were installed in the shipping container. There were a total of 15 reflector modules to ship and four available locations per shipment; hence, there was an available holder location in the fourth shipment. A special container was designed to fit the holder and was used to ship a highly irradiated seed support shaft, a bypass inlet flow supply tube, and two flux wire thimbles to ECF for examination as part of the LWBR End-of-Life Examination Program.

Each reflector module installed in the shipping container was fully assembled. Seal block removal was performed after container loading to reduce the length of the modules to fit the shipping container. Details of the operations necessary to remove the reflector seal block and hardware are provided in Reference 2. Following module disassembly, a reusable holddown spring (Appendix A1, Figure A1-5) was installed on a shipping plate for each module, and this assembly was then bolted to a reflector module using remote operating tools. The shipping plate was used to secure the reflector top baseplate to the reflector shell (a requirement for shipment) and to provide a means for handling the reflector module at ECF. The holddown springs were compressed by the shipping container closure head to provide vertical holddown force on the module during shipment (Appendix A4).

Length variations among the reflector modules were not as large as they were for blanket and seed modules, primarily due to the lower radiation levels in the reflector region of the reactor during operation. The loads generated by the holddown springs over the range of reflector module lengths were within the established range required for shipping. Therefore, adjustment of holddown spring height was not required for reflector module shipments.

The final operation for loading reflector modules in the shipping container was to engage the reflector lateral restraints (Appendix A1). Using a remote operating tool, spring-loaded jacks were sequentially driven against the reflector shipping plates (Figure 3), positioning the reflector modules radially outward from the center of the shipping container and into the module holders. This arrangement prevented module motion during shipment.

2.4 - BLANKET MODULE LOADING

After the blanket module M-130 container was installed in the canal and the closure head was removed, additional container preparations were necessary before modules could be loaded. First, the three blanket plugs (Appendix A1) were removed from the module holders and stored. Each of the plugs contained two fixed extension arms and a third, adjustable, spring-loaded arm, which was expanded to contact the module holder to prevent plug motion during empty container shipment from ECF to Shippingport. Remote operating tools were used to retract the plug adjustable arm, remove the plug from the module holder, and retract the plug fixed extension arms prior to plug storage.

Next, the blanket lateral restraint was removed from the shipping container and stored using a remote handling tool. Lateral restraint removal was necessary because of a requirement to visually inspect the blanket module holder locking wedge, which was located directly below the blanket lateral restraint. Each of the module holders in the shipping container could hold any of the three types of blanket modules by adding or removing aluminum inserts (Appendix A1, Figure A1-4) to make the holder conform to the shape of the module to be loaded. These adjustments were made as needed to prepare the holders for the particular assortment of Types I, II or III blanket modules being loaded. Finally, a blanket loading guide (Figure 4) was installed over the first module holder to be loaded with a blanket module. The loading guide was used to prevent hangup of the delicate blanket grid structure (Figure 5), which protruded almost to the periphery of the module and was not protected by Zircaloy shells (as those in seed and reflector modules were).

The three disassembled blanket modules to be shipped were removed from the fuel storage rack or the disassembly stand using the blanket handling

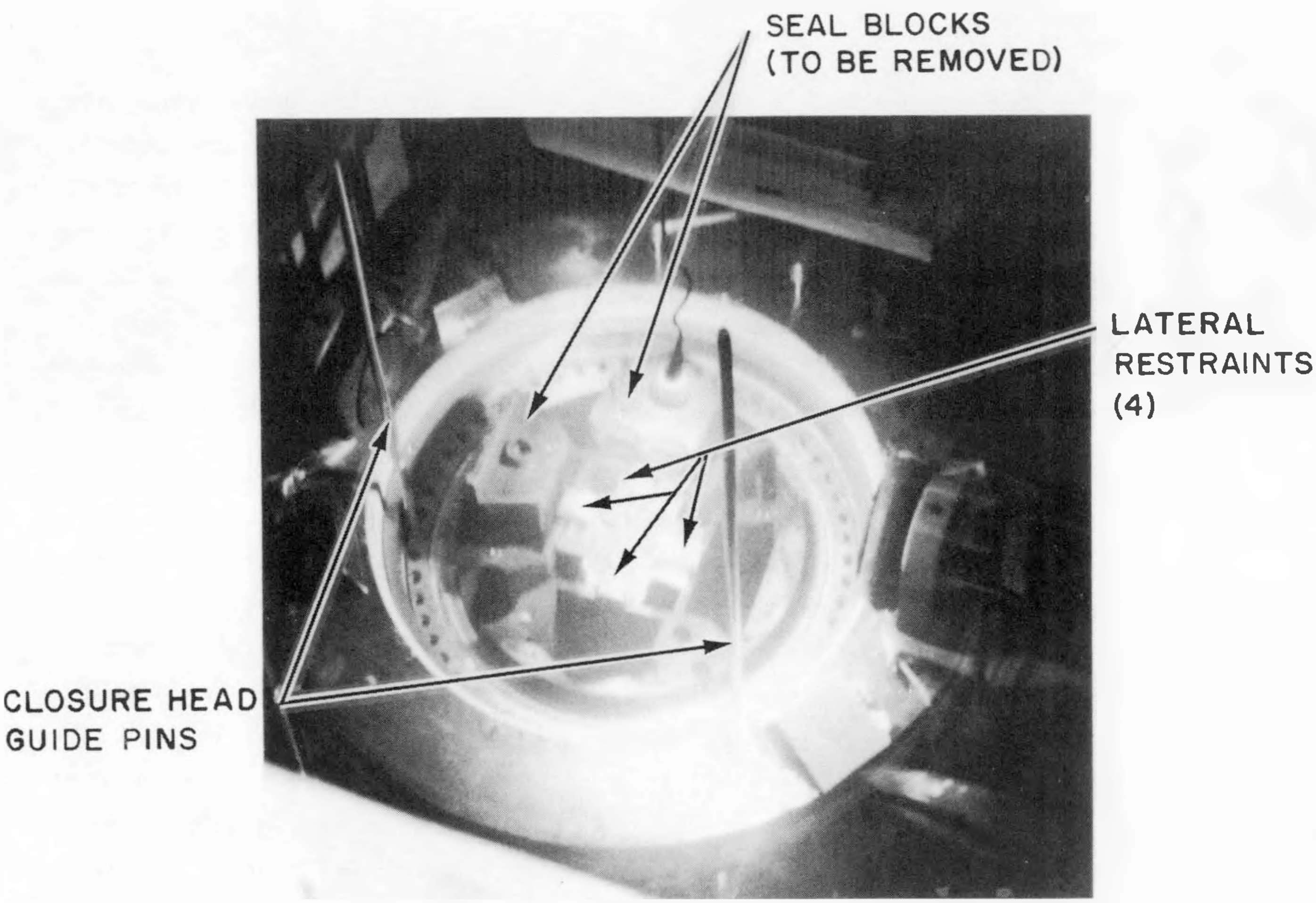


Figure 3. Reflector Modules in M-130 Container
(Not Disassembled)

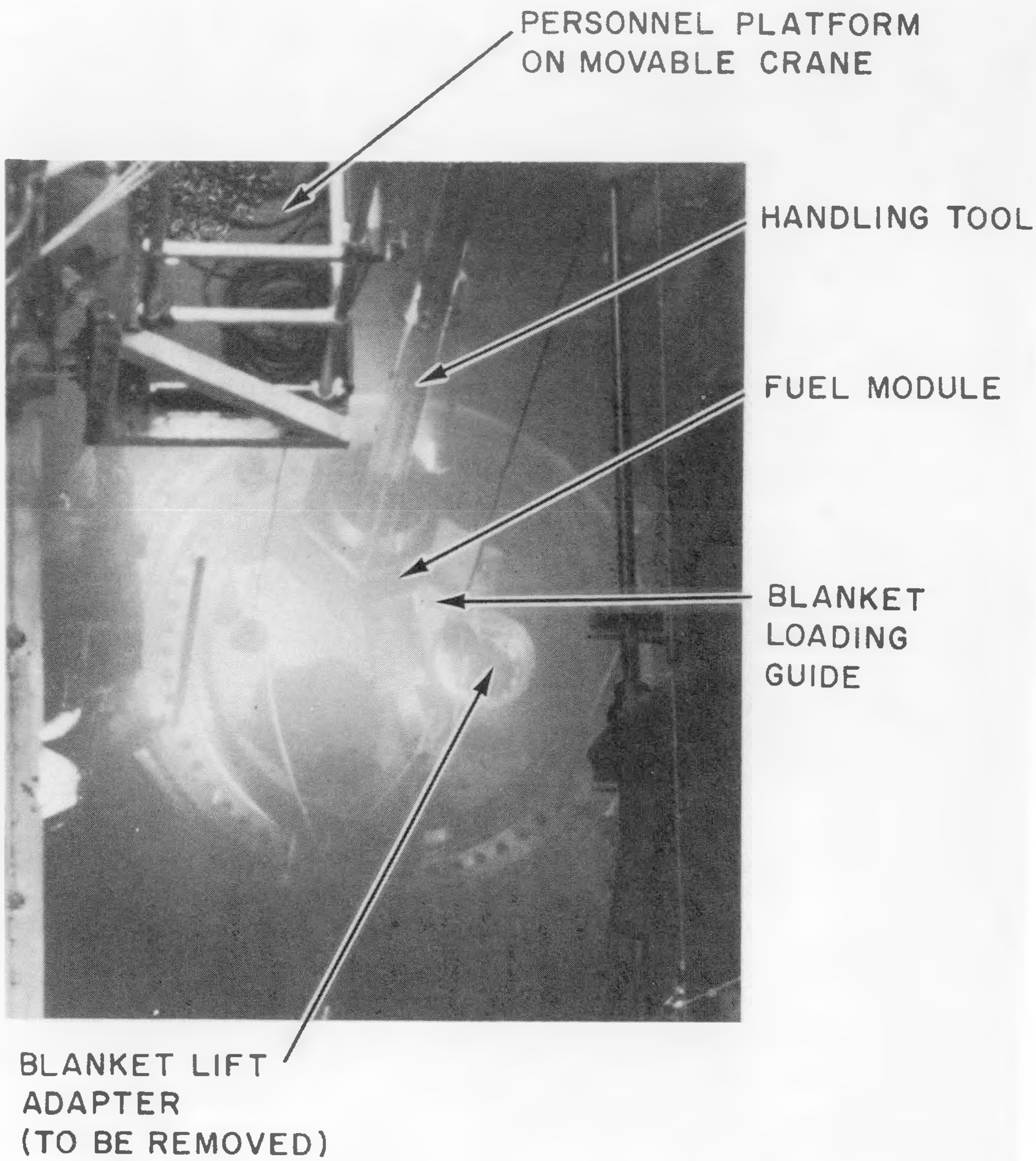


Figure 4. Installing a Blanket Module in the M-130 Container Using the Blanket Loading Guide

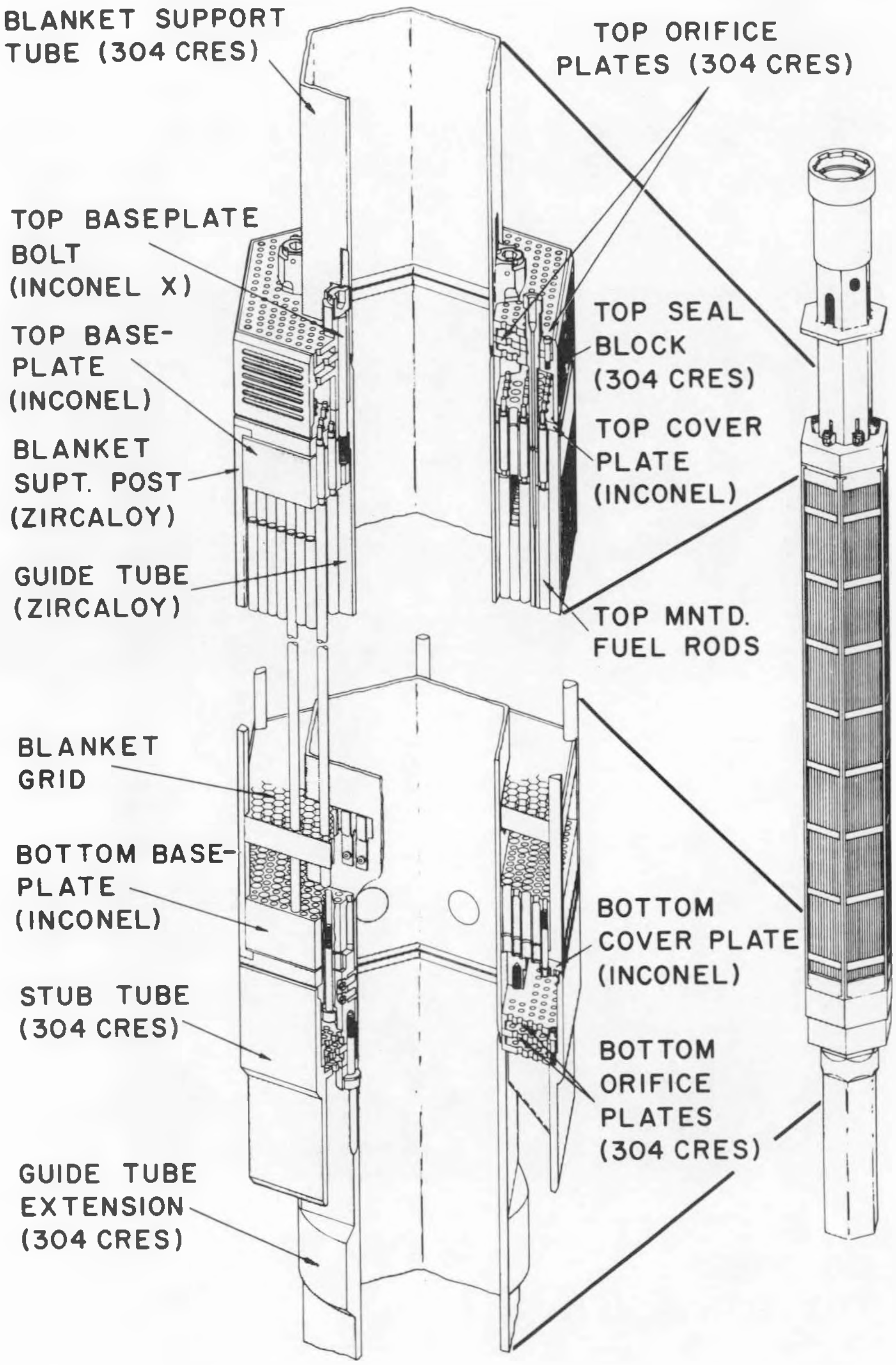


Figure 5. Type I Blanket Module Showing Exposed Grid Structure

tool. The rigging attached to the blanket handling tool, which was standard for all fuel handling operations, included the fuel handling flexible link (Reference 1) and a chain hoist. After rigging and removing a blanket module from its storage location, the module was transferred to a position just above the module holder and nearly in contact with the blanket loading guide. Pads on the loading guide protruded upward to approximately 14 inches above the top of the module holder on two adjacent sides of the module. The module was manually held in contact with the loading guide pads and lowered, using the chain hoist, until it seated at the bottom of the module holder. During lowering, the loading guide pads contacted the module support posts (which spanned the length of the module), providing a smooth, continuous surface. The defueling procedure for blanket loading limited the maximum allowable weight dropoff to 300 pounds during lowering into the module holder. Although this weight limit would not, by itself, have protected the blanket grids during a direct hangup, it was selected because the blanket loading guide provided assurance that there were no surfaces on which the grids could hang-up, and this load dropoff limit was judged to be the smallest that could be reasonably monitored, considering that the Type III blanket module weighed approximately 6000 pounds in water.

After a blanket module was loaded into the M-130 container, the blanket handling tool was removed and transported to grapple to the next module. In parallel, the loading guide was relocated to the next module holder location. This loading sequence was repeated until all three blanket modules were seated in the M-130 container.

After the three blanket modules were loaded into the M-130 container using remote operating tools, the Shippingport blanket lifting adapter (Reference 2) was removed from each module and replaced with an ECF blanket lifting adapter, which was bolted to the blanket top baseplate. The ECF lift adapters were installed at Shippingport as a time-saving operation for ECF inasmuch as installation of the blanket top baseplate bolts, which passed through and held down the ECF adapter, was required for blanket module shipment to ECF.

Two blanket spacers were installed between each blanket module and module holder at the elevation of the blanket top baseplates using a remote handling tool. The spacers centered the module in the module holder and provided bearing pads against which the blanket lateral restraint would later react. Next, using a remote operating tool, the blanket lateral restraint was installed in the center of the M-130 container at the elevation of the blanket top baseplates. The lateral restraint was adjusted to apply a lateral load to the three blanket modules, forcing the modules radially outward into contact with the spacers. The resulting three-point loading provided sufficient force to prevent the module from shifting laterally within the module holder during shipment.

Three blanket plugs were then installed, one in each blanket module. The plugs were solid, hexagonal aluminum bars of approximately the same cross section as a seed module. They were inserted into the guide tube of the blanket module, which had been occupied by a seed module during reactor operation, and extended the full length of the blanket module. In the event of a container drop accident, the plugs would prevent collapse of the blanket module into the region then occupied by the plug, ensuring that the nuclear fuel within the shipping container could not be arranged into a critical configuration.

A hexagonal-shaped plate containing blanket top crush blocks and holddown springs (Appendix A1, Figure A1-4) was installed and seated on the blanket top cover plate using a remote handling tool. During shipment, the holddown springs were compressed by the M-130 container closure head to provide vertical holddown force on the blanket modules. The crush blocks remained passive during module shipment and would have been necessary only in the event of a shipping container drop accident. Prior to installation of the crush block/holddown spring plate, measurements were obtained, a spring height was calculated for each module position, and the spring height was adjusted. This positioned the crush blocks at a controlled distance from the closure head and correctly set holddown spring compression. Crush block and holddown spring assembly height adjustment was necessary for each blanket module because a single, preset height could not be effective for the entire range of possible assembly heights. The primary contribution to the range of possible assembly heights was radiation-induced growth of the blanket modules. Once the crush block/holddown spring plates were installed on each of the blanket modules, loading operations were completed. The container was turned over to Duquesne Light Company personnel to install the closure head and to complete shipping preparations.

2.5 - PWR-2 LOWER CORE BARREL LOADING AND SHIPPING

The lower core barrel from the PWR-2 reactor (the reactor core which preceeded LWBR at Shippingport) was stored under water in the canal near the fuel storage racks (No. 19 in Figure 1B). It remained there during LWBR operations and was adapted as a receptacle for highly radioactive LWBR components which were to be shipped to a disposal site. Figure 6 shows the support structure that was placed into the lower core barrel to adapt it for use. The support structure consisted of two pieces, a baseplate and an upper framework. Six blanket support tubes were installed on the baseplate (Reference 2). Then the upper framework was added and additional LWBR components were installed into the lower core barrel, including 11 (of 12) seed support shafts, five (of six) bypass inlet flow tubes, and all flux thimbles.

After the lower core barrel was filled with scrap components, the inner cylinder of a two-piece shipping container was placed into the canal in the M-130 loading area (Figure 1B). Figure 7 shows the inner container wrapped in its anticontamination enclosure (ACE) being readied for underwater placement. The closure head of the inner container was remotely removed after the container was placed under water. The filled lower core barrel was then raised and placed into the container without raising any portion of it above the water.

The inner container closure head was then replaced onto the container and the closure head bolts were installed. The container was slowly raised out of the water as the ACE was stripped away and the water inside the container was allowed to drain out through two small drain holes near the base of the container. After the water was drained, the drain holes were sealed by welding plugs into the holes.

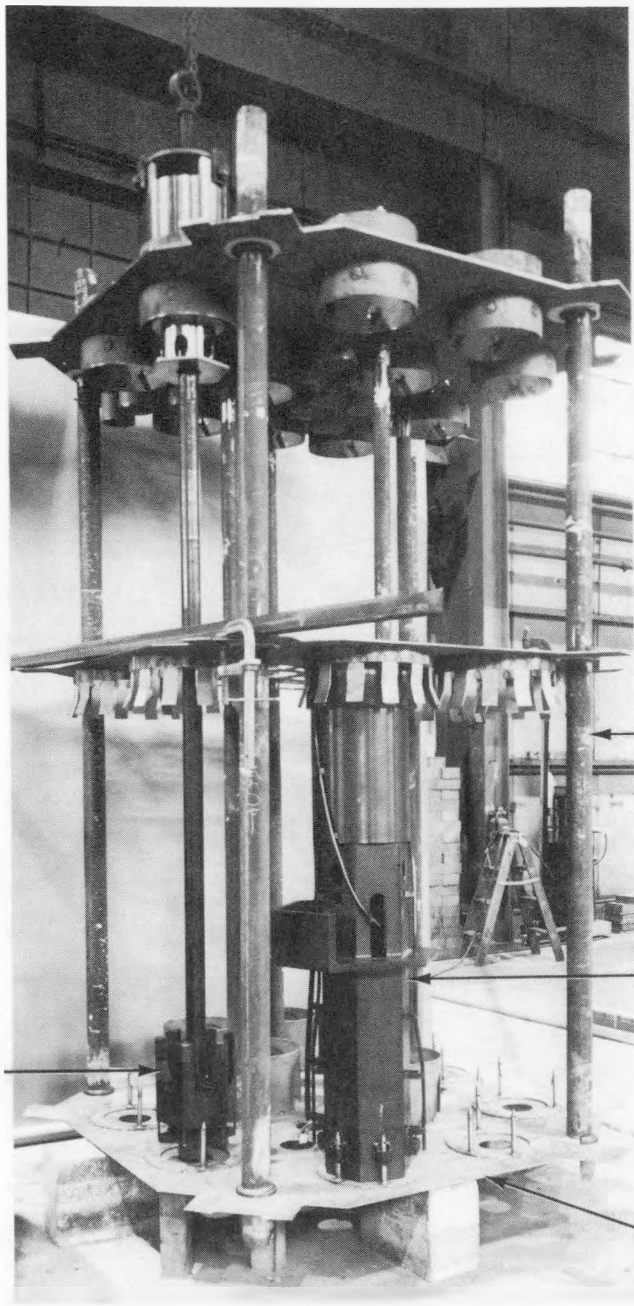


Figure 6. Lower Core Barrel Support Structure for Disposal of Reactor Components

Figure 7. Lower Core Barrel Inner Shipping Container

The sealed inner container was then placed into a larger shipping container on a railcar in the M-130 shipping area (No. 18 in Figure 1B). Because of the height of the shipping container, the shipping container was rotated to a horizontal position for shipping.

SECTION 3 - SHIPPING SUPPORT

Loading fuel modules into M-130 shipping containers and preparing the containers for rail shipment to the Expended Core Facility (ECF) were the objectives of the third phase of defueling operations. The first- and second-phase objectives were removing fuel modules from the reactor and partially disassembling them to fit into the shipping containers. Details of these other operations are presented in References 1 and 2. A discussion of support activities required to accomplish the defueling objectives is presented in Reference 1. Defueling organization, support groups, radiation and contamination control, facility preparations, and reactivity control are discussed in the context of the entire program.

Planning and training activites, however, can be discussed as they apply to the objectives of each phase of the program. These activities will be discussed here as they apply to fuel loading and shipping.

3.1 - PLANNING AND SCHEDULING FUEL SHIPMENTS

The Duquesne Light Company Master Activity Schedule for the Light Water Breeder Reactor (LWBR) defueling identified dates for ten M-130 container shipments and the PWR-2 lower core barrel shipment. The schedule was based on the LWBR Defueling and Shipping Operational Plan issued in mid-1982. This original plan (listed in Table 1) had the first seed shipment as Shipment No. 7 and the PWR-2 lower core barrel as Shipment No. 10. The first seed shipment was scheduled this late to allow 500 days for reduction in the decay heat generation rate. The PWR-2 lower core barrel was Shipment No. 10 because the last fuel module structural component to be disposed of in the lower core barrel would not be ready until then. After defueling had progressed and operations had slipped approximately 2 months behind schedule, it became apparent that the first seed shipment could be made 500 days after shutdown, but as the fifth shipment instead of the seventh. This permitted earlier shipment of the PWR-2 lower core barrel, loaded with scrapped fuel module structures, to a disposal site and also permitted earlier clearout, draining, and decontamination of the reactor pit. Table 1 also presents the revised shipping sequence.

Table 1 - M-130 Container and PWR-2 Lower Core Barrel Shipping Sequence

Shipment No.	Original Plan	Revised Plan	Final
1	1st Reflector	1st Reflector	1st Reflector
2	1st Blanket	1st Blanket	1st Blanket
3	2nd Reflector	2nd Reflector	2nd Reflector
4	2nd Blanket	2nd Blanket	2nd Blanket
5	3rd Reflector	1st Seed	1st Seed
6	3rd Blanket	PWR-2 LCB	3rd Blanket
7	1st Seed	3rd Blanket	PWR-2 LCB
8	4th Reflector	3rd Reflector	3rd Reflector
9	4th Blanket	2nd Seed	2nd Seed
10	PWR-2 LCB	4th Blanket	4th Blanket
11	2nd Seed	4th Reflector	4th Reflector

Once fuel handling operations began and several M-130 shipments were completed, the final change in the shipping sequence was developed. Because three blanket modules were disassembled and three more were to be disassembled to complete loading of fuel module structural components to be scrapped into the PWR-2 lower core barrel, defueling mainline time could be saved by shipping an additional blanket module M-130 container ahead of the PWR-2 lower core barrel. The sequence was changed accordingly. The final M-130 container and PWR-2 lower core barrel shipping sequence is also listed in Table 1.

The composition of each fuel shipment also changed over the course of defueling. The only shipment not revised from the original plan was the first blanket shipment; each of the others was revised for various reasons. Table 2 lists the original M-130 container shipment composition, the revised plan, and the actual mix of each shipment.

Table 2 - Composition of M-130 Container Fuel Shipments in Final Shipping Sequence

M-130 Container Shipment No.	Original Plan	Revised Plan	Final Composition
1st Reflector	IV-3, IV-4 V-3, V-4	IV-1, IV-3 V-1, V-4	IV-1, IV-3 V-1, V-4
1st Blanket	I-3, II-1 III-6	I-3, II-1 III-6	I-3, II-1 III-6
2nd Reflector	IV-1, IV-7 V-2, V-5	IV-4, IV-7 V-2, V-5	IV-6, IV-7 V-5, V-6
2nd Blanket	I-1, II-3 III-4	I-1, II-3 III-4	I-1, II-3 III-3
1st Seed	I-2, II-1, II-2 III-1, III-2, III-6	I-2, II-1, II-3 III-1, III-2, III-5	I-2, II-1, II-3 III-1, III-2, III-5
3rd Blanket	I-2, II-2 III-1	I-2, II-2 III-1	I-2, II-2 III-4
3rd Reflector	IV-6, V-1 V-6	IV-6, IV-9 V-3, V-6	IV-2, IV-5 IV-8, V-2
2nd Seed	I-1, I-3, II-3 III-3, III-4, III-5	I-1, I-3, II-2 III-3, III-4, III-6	I-1, I-3, II-2 III-3, III-4, III-6
4th Blanket	III-2, III-3 III-5	III-2, III-3 III-5	III-1, III-2 III-5
4th Reflector	IV-2, IV-5 IV-8, IV-9	IV-2, IV-5 IV-8, Exam Components	IV-4, IV-9 V-3, Exam Components

The majority of the changes were made to save fuel handling and defueling mainline time. Each change was dictated by the circumstances at that time, and each change received the concurrence of cognizant personnel at Bettis Laboratory and at ECF. Factors involved in determining shipment composition changes included main crane availability, fuel storage rack configuration, and minimizing handling of fuel modules. Early in the fuel handling operations, main crane time was at a premium. Crane availability had to be used properly; one shift misspent could cause a 1-day delay in M-130 container shipments. Transfer of a blanket module from the fuel storage rack to the disassembly stand could be accomplished more quickly than blanket removal from the reactor vessel and inspection at the module visual inspection station. This option affected the second and third blanket shipments where modules in the fuel rack were substituted for the planned modules, which were still in the reactor vessel.

Storage space in the fuel storage rack was limited to six ports for either blanket or reflector modules. At the start of defueling operations, the six ports were adapted to accept two Type IV reflector modules, two Type V reflector modules, one Type II or Type III blanket module in the fully assembled state, and one Type II or Type III blanket module that was disassembled (see Reference 2 for details of disassembly operation). This distribution of storage rack capabilities was planned because eight reflector modules were to be removed from the reactor before removing the first blanket module. Four reflector modules were placed directly into the reflector module M-130 container and the remaining four were placed into the storage rack for later shipment. Adapters were used to change storage rack port configurations so that it was possible to change any port over from one type of module to another, but the change-over operation was complex and time consuming. Rack port configuration changes were avoided after the start of defueling operations by scheduling the shipment composition such that available and accessible modules were substituted for assigned modules. The seed/blanket module disassembly stand and the reactor itself were acceptable storage locations for blanket and reflector modules, respectively. Using these facilities for storage minimized fuel handling (the module did not have to be transferred to and from storage). Thus, after fuel module shipments began, modules were placed into the storage rack only if not doing so would delay operations.

Figure 8 presents a comparison of the time originally scheduled for preparation of each of the ten M-130 container and the PWR-2 lower core barrel shipments versus the time actually taken. Without question, the first M-130 operation required the most time to complete, going over schedule by about 3

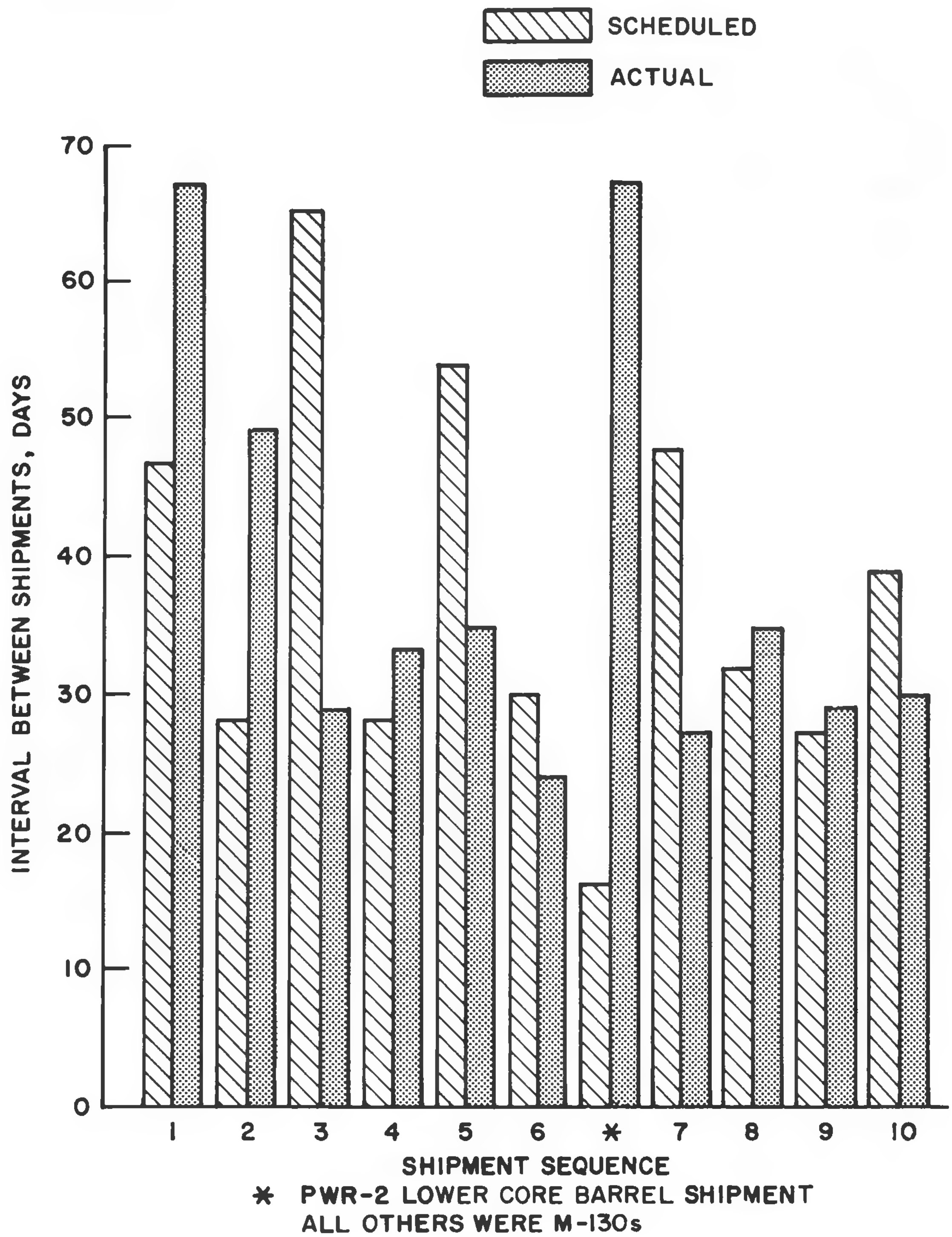


Figure 8. Loading and Shipping Intervals for Fuel and Reactor Components

weeks. The second shipment (first blanket shipment) was over schedule by about the same amount of time. This was typical of most first-time operations; delays were not unexpected. None of the delays which affected schedules was serious. Most were related to small differences between training methods and actual practice which affected written procedures. In a few cases, tools that worked properly during checkout did not function properly in use and required repairs before shipping operations could be completed. During preparation of the first shipment of reflector modules, a tangled wire rope sling on a disposal tray for reflector seal blocks caused a three-shift delay in disassembly operations. None of the problems involved personal injury or the spread of radioactive contamination. Later shipments required less time to prepare and complete because of experience and fewer problems. Note that the first seed module shipment (fifth shipment) was prepared in less time than was scheduled. The largest difference between scheduled and actual time occurred for the PWR-2 lower core barrel shipment, which was originally significantly under-scheduled, allowing only 16 days to complete a new operation with unfamiliar equipment.

Availability of M-130 containers was not a problem during the LWBR defueling. Return of empty containers from ECF was rapid enough to support the needs at Shippingport. No planning changes were required due to M-130 container availability.

3.2 - TRAINING PROGRAM FOR FUEL LOADING AND SHIPPING

To qualify personnel for fuel loading and shipping, the training program was structured with three goals in mind: (1) to ensure that all defueling personnel acquired a broad understanding of the operations and the sequencing of operations to conduct the defueling effort; (2) to teach personnel the manner in which defueling equipment would be operated, with special emphasis on the unique features associated with the equipment; and (3) to foster an understanding of the importance of strict adherence to procedures and the administrative controls necessary to ensure a safe defueling.

Training was administered and modified as much as was practical with consideration of each worker's previous refueling experience and the requirements of the trainee's job classification. For example, since Bettis defueling personnel had previously demonstrated an understanding of fuel handling moves and, in fact, completed several prior to loading the first M-130 container, training for loading of fuel modules into the M-130 containers was tailored to a review of the key operations in the fuel loading procedures. This was accomplished by use of videotaped lectures and detailed briefings that outlined the procedural steps required for loading fuel into the M-130 container. Also enumerated were the radiological, safety, and cleanliness requirements of each operation. After experience was gained in the loading of fuel into each M-130 container configuration, refresher training sessions were conducted which primarily focused on the lessons learned and procedural changes that were made following the first loading operations.

An operational approach was used to train both Bettis Laboratory and Duquesne Light Company personnel to operate the M-130 support system. Trainees were first introduced to the system by means of a videotaped lecture. This presentation discussed the purpose of the support system and its modes of operation, and outlined the procedural steps for operating the system. Following this introductory phase, trainees performed hands-on training on the system by physically operating the equipment under the supervision of a training instructor. The evolutions of M-130 container initial fill, closure head leak test, cooling water circulation, calorimetric, drain for flush, fill for flush, flush and drain, and pressurize for shipment were actually performed with the support system attached to an empty M-130 container in the dry fuel storage pit. Final qualification of supervisors on the support system required each trainee to satisfactorily demonstrate his ability to supervise operation of the support system for the key operations of initial fill, cooling water circulation, and drain down. Additionally, supervisors were required to pass a written examination on support system operations and plans for emergencies.

An extensive checkout program on the modified M-130 shipping containers (Appendix A1) provided significant opportunities to familiarize Duquesne Light Company operating personnel with handling requirements and preparations for shipping. Operational checks were performed on the M-130 container designated for shipping reflector modules. The checkout consisted of a step-by-step progression through the draft version of the M-130 operating procedure. In addition to revealing problems with the containers (as discussed in Appendix A5), operating personnel gained practice in attaching and removing rigging, removing and installing hoses and the closure head, and removing the container from the railcar and reinstalling it.

The success of the training program depended on each individual worker's attention to detail and ability to demonstrate proficiency at his assigned tasks during training. The defueling training program thus contributed significantly towards the successful completion of the LWBR defueling at Shippingport within the required time and quality constraints.

SECTION 4 - SUMMARY AND CONCLUSIONS

Three M-130 standardized fuel shipping containers were modified to support shipment of Light Water Breeder Reactor (LWBR) spent fuel from Shippingport to the Expended Core Facility (ECF) in Idaho. One container was adapted for each LWBR fuel type; namely, seed, blanket, and reflector.

As part of container preparation prior to placement under water in the Shippingport canal, the container was inserted into an anticontamination enclosure (ACE) to simplify decontaminating operations after loading the container with fuel modules. The ACE bag ensured that radiologically contaminated canal water could not contact the container surface by maintaining a layer of uncontaminated, borated water between the container and the ACE at a slight positive pressure with respect to the surrounding canal water.

All filling and draining operations involving fluids within the M-130 containers were handled through the M-130 support system. This system consisted of a network of pumps, valves, and filters that supplied canal water, fresh water, nitrogen gas, or neon gas as required to prepare the M-130 and contained fuel for shipment.

Fuel handling operations for loading the containers were basically the same for all three fuel types. Minor variations among the different fuel types included:

1. Seed and blanket modules were installed into the shipping containers after disassembly operations, whereas reflector modules were installed in the same condition they were in upon withdrawal from the reactor. Reflector seal blocks were removed at the M-130 container.

2. Blanket and reflector module ports in the shipping containers accommodated more than one shape of module through the use of removable inserts. There were three different envelopes for blanket modules and two for reflector modules, but all seed modules were the same shape.

3. The height of holddown springs for seed and blanket shipments was adjusted for each module because of variation in radiation-induced module growth during reactor operation.

4. A funnel-shaped guide was used to aid in loading blanket modules to reduce any potential for hanging up a module on the exposed grid structure during insertion. Seed and reflector rod bundles were enclosed in smooth shells, which prevented any potential for hang-up on grids.

A comprehensive operations checkout and personnel training program prior to initiating fuel shipment operation produced significant benefits in terms of reduced radiation exposure to personnel and fewer operational problems. Radiation and personnel exposure were much lower than predicted.

Ten fuel shipments were prepared at Shippingport and shipped to ECF. Also, the PWR-2 lower core barrel, which was loaded with scrap LWBR fuel module structures, was installed in a specially designed container and shipped for disposal. No significant problems occurred during any of the shipment evolutions. All shipments were completed successfully with no damage to fuel modules, no injury to personnel, and no release of radioactive contamination to the environment.

SECTION 5 - REFERENCES

1. I. A. Selsley, ed., "Defueling of the Light Water Breeder Reactor at Shippingport Atomic Power Station," WAPD-TM-1551, October 1987.

2. I. A. Selsley, "LWBR Fuel Module Disassembly at Shippingport Atomic Power Station," WAPD-TM-1552, October 1987.

APPENDIX A1 - M-130 SHIPPING CONTAINER FOR SHIPPING LWBR FUEL MODULES

The purpose of this Appendix is to describe the M-130 shipping containers used for Light Water Breeder Reactor (LWBR) irradiated fuel shipments. The major assemblies of an M-130 container included the container itself, a closure head, module holder assemblies, a support structure mounted on a railcar, and an energy absorber (Figure A1-1).

A1.1 - M-130 CONTAINER

The M-130 container is an upright, right circular cylinder, with outside dimensions of 84 inches in diameter by 158 inches high and with inside dimensions of 55 inches in diameter by 132 inches high. An empty M-130 shipping container as modified for use for LWBR irradiated fuel shipments is shown in Figure A1-2. In this condition, a container was ready to accept fuel module holder assemblies for a specific module type (seed, blanket, or reflector). Three M-130 containers were used in the LWBR shipping program, one for each module type. A quick-disconnect penetration near the top of each container connected with a tube inside the container, which ran to a sump in the container baseplate, thus providing an outlet path for container draining operations.

A1.2 - CLOSURE HEAD

A recessed head was used for LWBR shipping because of module length and the need for specified holddown devices required in the event of a container accident. The container used for shipping blanket modules required special modifications to the closure head. The closure head for the container used for blanket module shipping was modified by machining three recesses at locations that would be above the three contained modules to provide added clearance for the modules and holddowns. Each closure head included a penetration with a quick-disconnect coupling, which was the fill port for both water and gases added through the M-130 support system (Appendix A2).

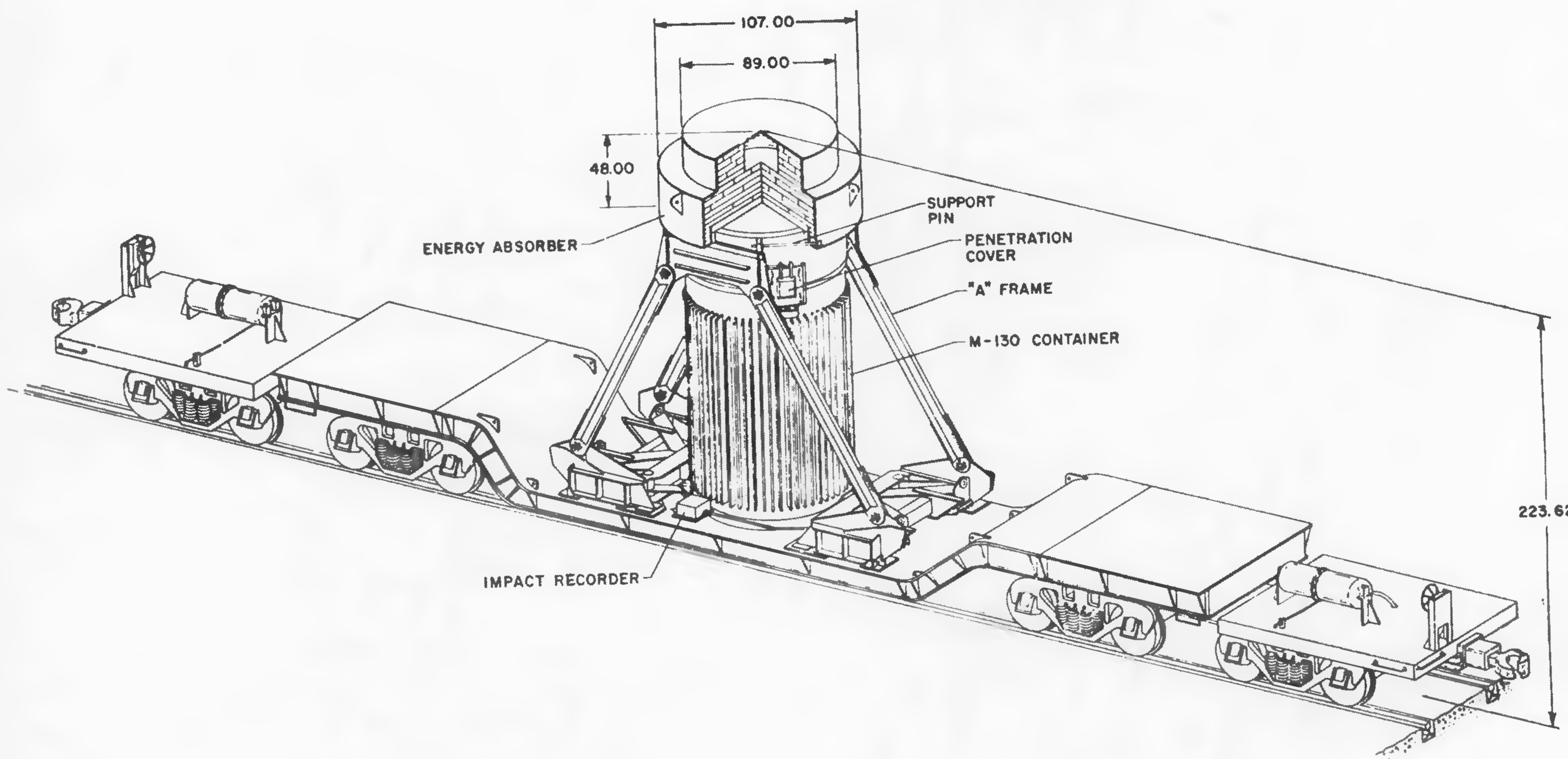


Figure A1-1. M-130 Irradiated Fuel Shipping System

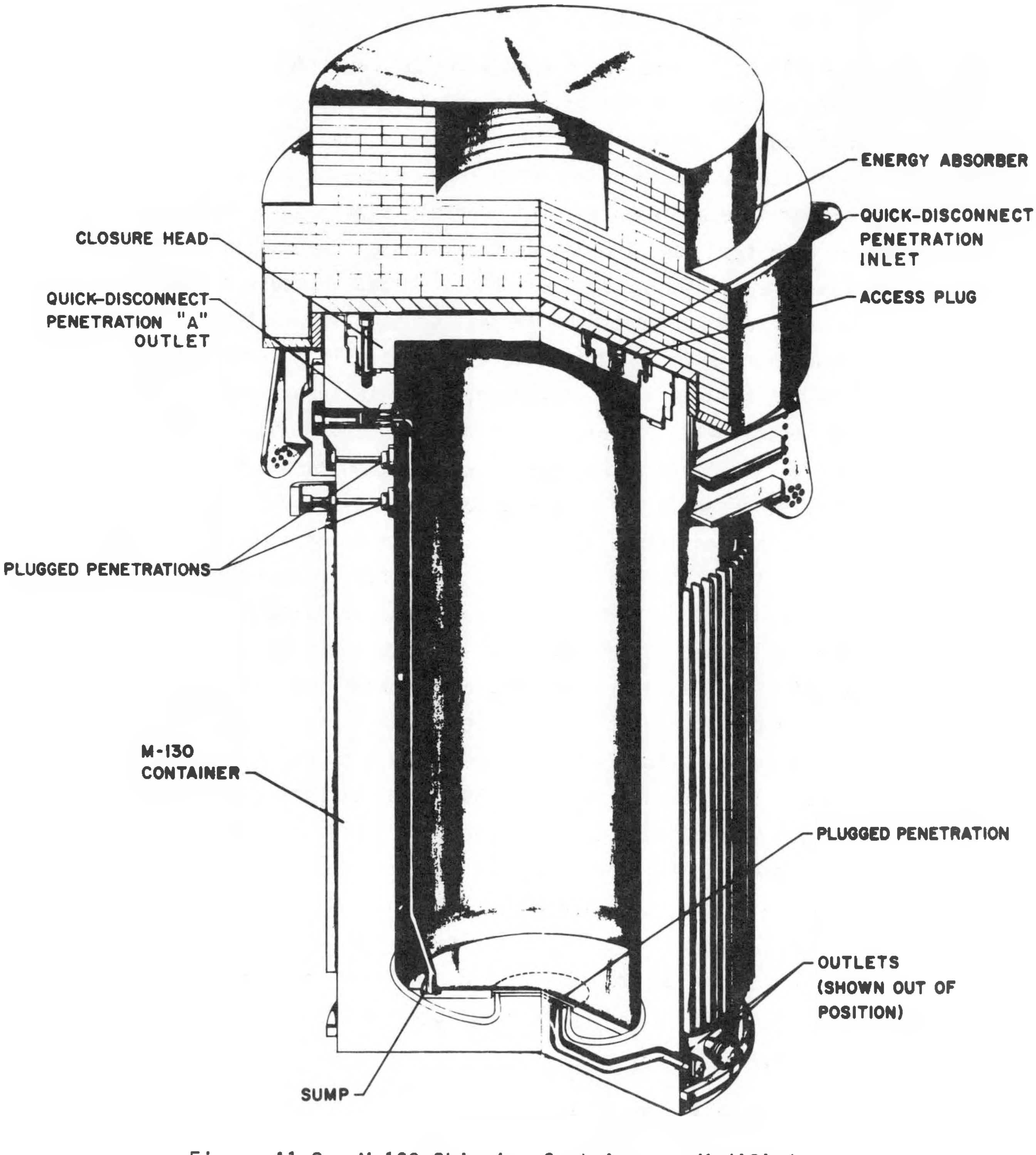


Figure A1-2. M-130 Shipping Container as Modified for LWBR Fuel Shipments

A1.3 - FUEL MODULE HOLDER ASSEMBLIES

Each of the M-130 containers was fitted with module holders with cavities of appropriate size and shape to fit specific modules. Details of module holders for seed, blanket, and reflector modules are shown in Figures A1-3 through A1-5, respectively. Each holder consisted of a bottom support for a fuel module, aluminum lateral supports with channels sized to receive the largest module of each type, and a wedge device to force the module holders against the container walls for better heat dissipation. Because the module holders were designed to accommodate the largest of each module type within the respective container, special inserts were used with Type I and Type II blanket modules in the blanket M-130 container, and with Type V reflector modules in the reflector M-130 container (Figures A1-4 and A1-5). The space envelope for all seed modules was the same, therefore, no adapters were needed. The top of each module holder was a holddown device. Seed and blanket holddown devices had height-adjustable springs to accommodate fuel module length changes that occurred as a result of irradiation-induced growth. The holddown device for reflector modules was of fixed height as length changes for reflector modules were small and could be accommodated by a single spring height. Extensive use was made of expanded metal honeycomb structures to provide cushioning of fuel modules in the event of an accident during transit. Figure A1-6 shows the seed fuel module holders installed in the M-130 container. The choice of which M-130 container became the seed or reflector M-130 was arbitrary because the holders would fit in any of the three containers. However, the blanket module holders had to be placed into the container fitted with the closure head containing additional recesses. During shipment, decay heat was transferred from the fuel modules, through the aluminum module holders, and to the wall of the container where it was dissipated to the atmosphere, aided by external cooling fins.

A1.4 - A-FRAME SUPPORT AND ENERGY ABSORBER

The A-frame, shown in Figure A1-1, supported the M-130 container slightly elevated from the deck of the railcar. This functioned as a shock absorber in

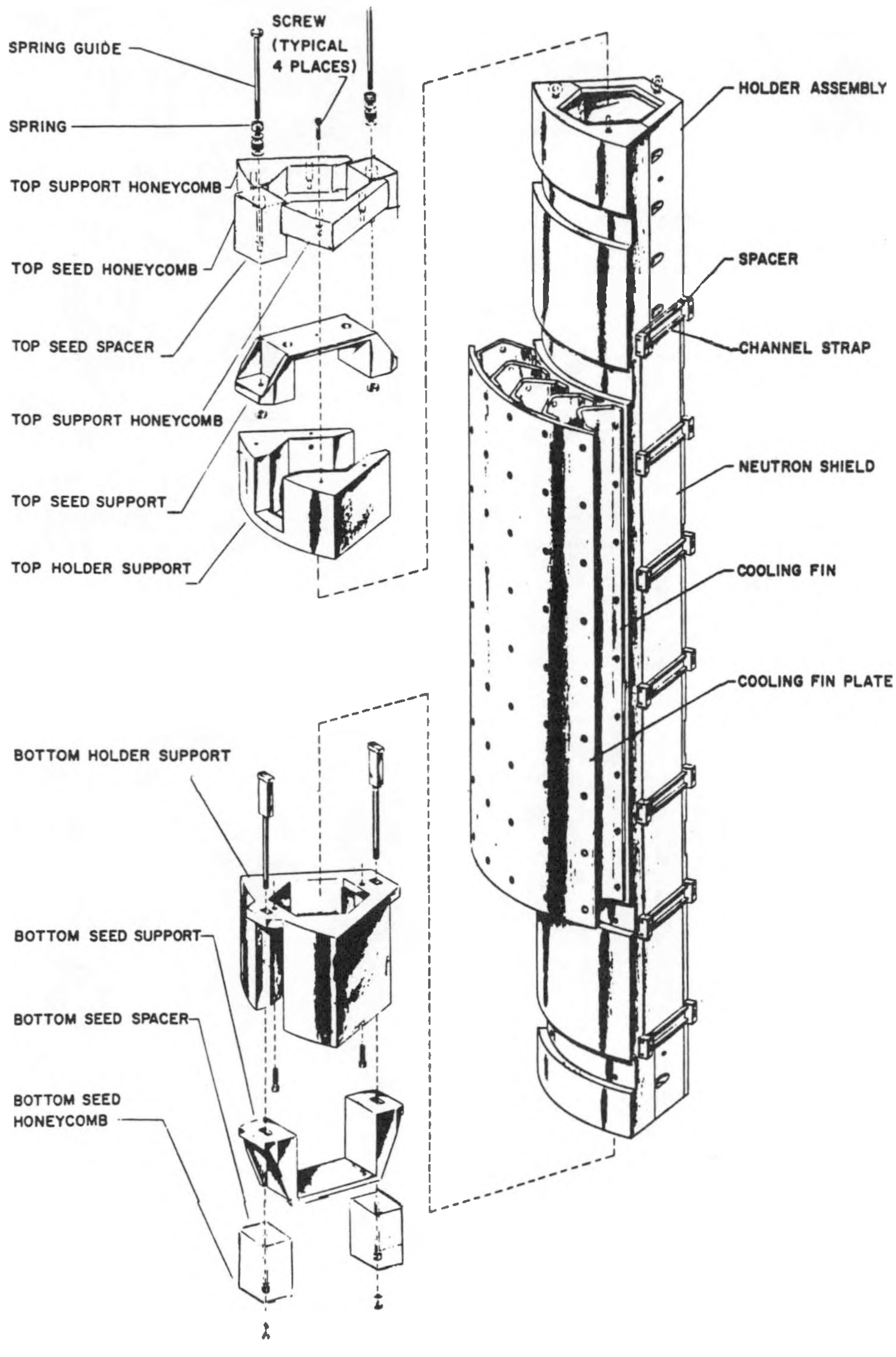


Figure A1-3. Module Holder for Seed Modules

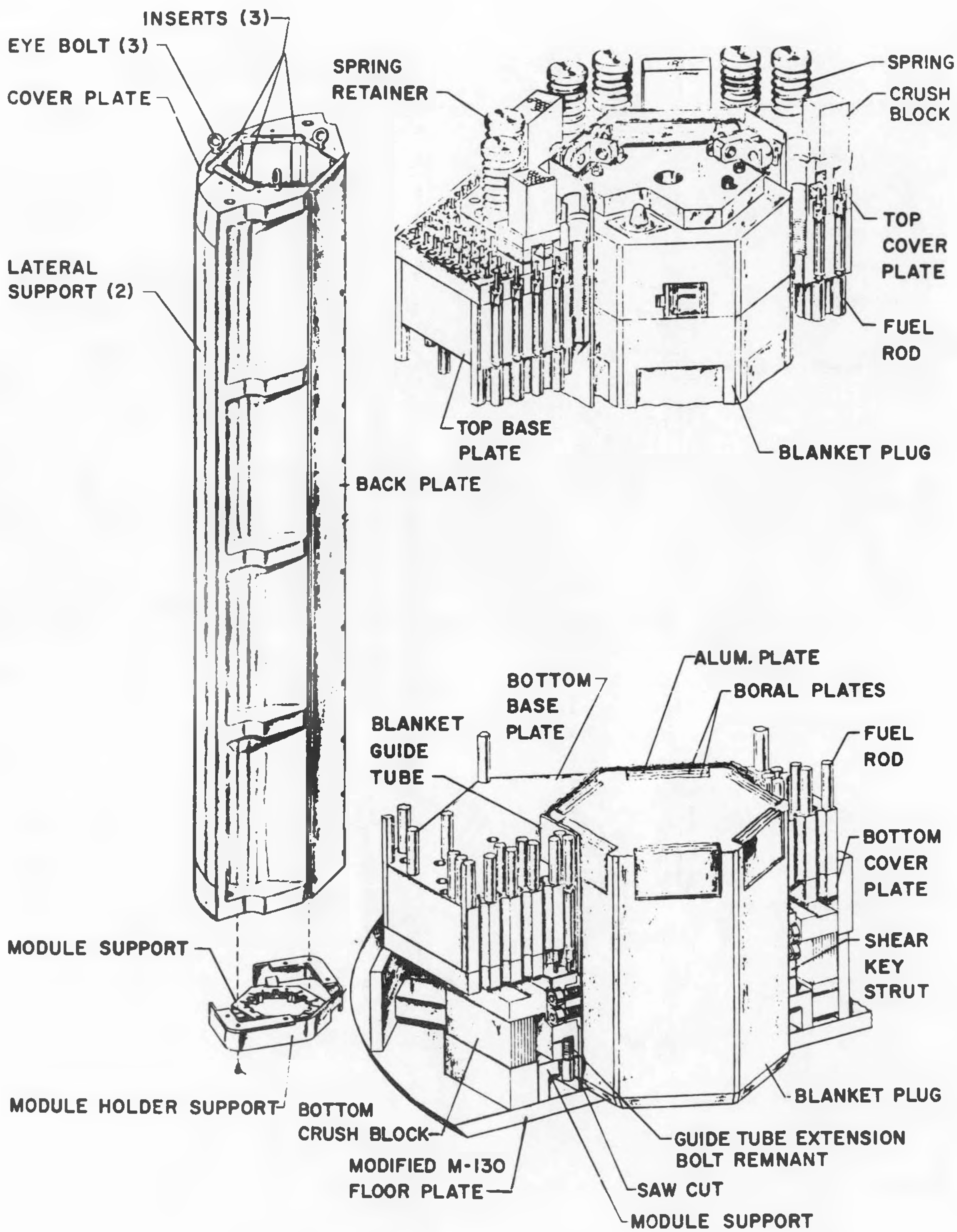


Figure A1-4. Module Holder for Blanket Modules

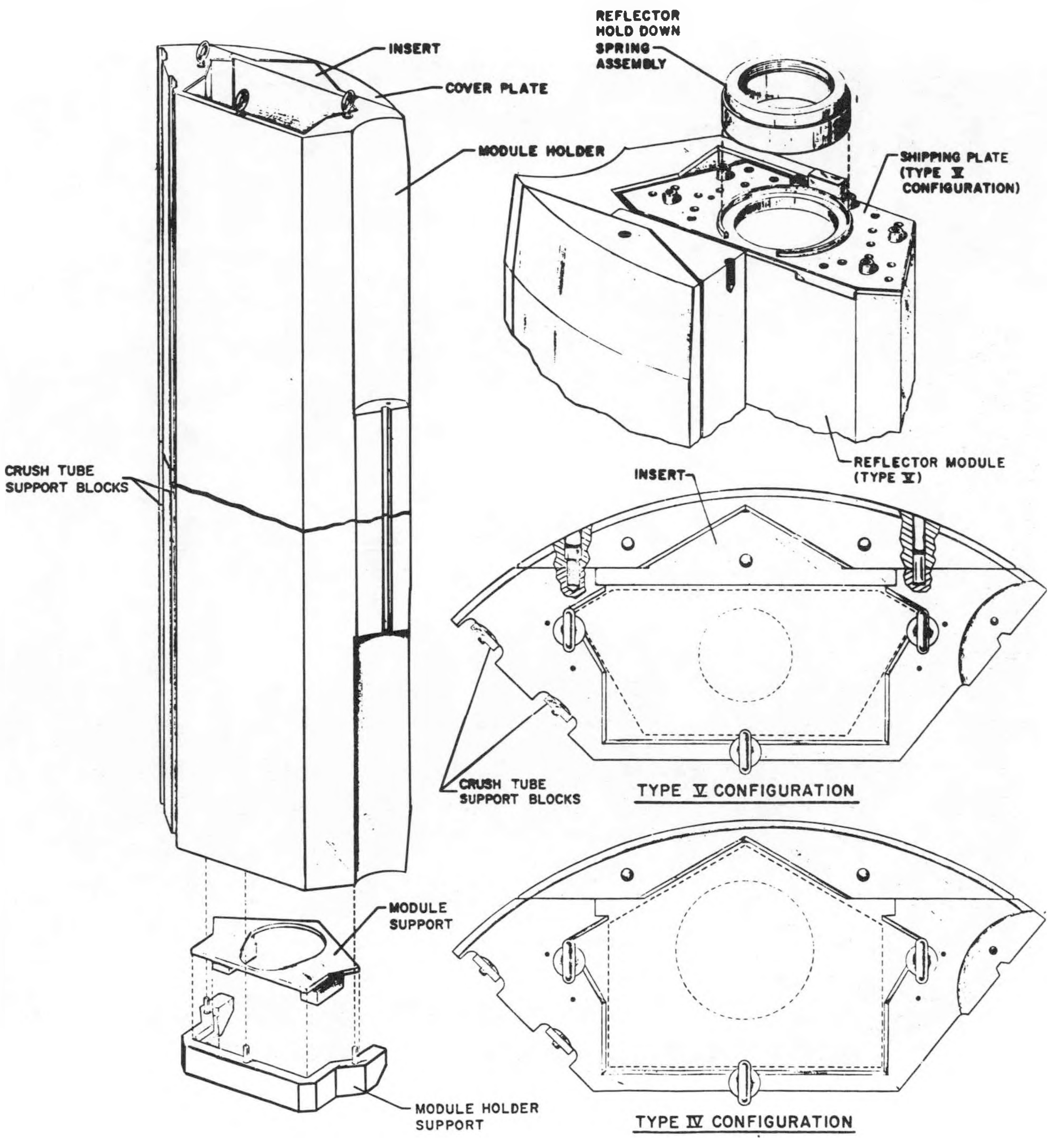


Figure A1-5. Module Holder for Reflector Modules

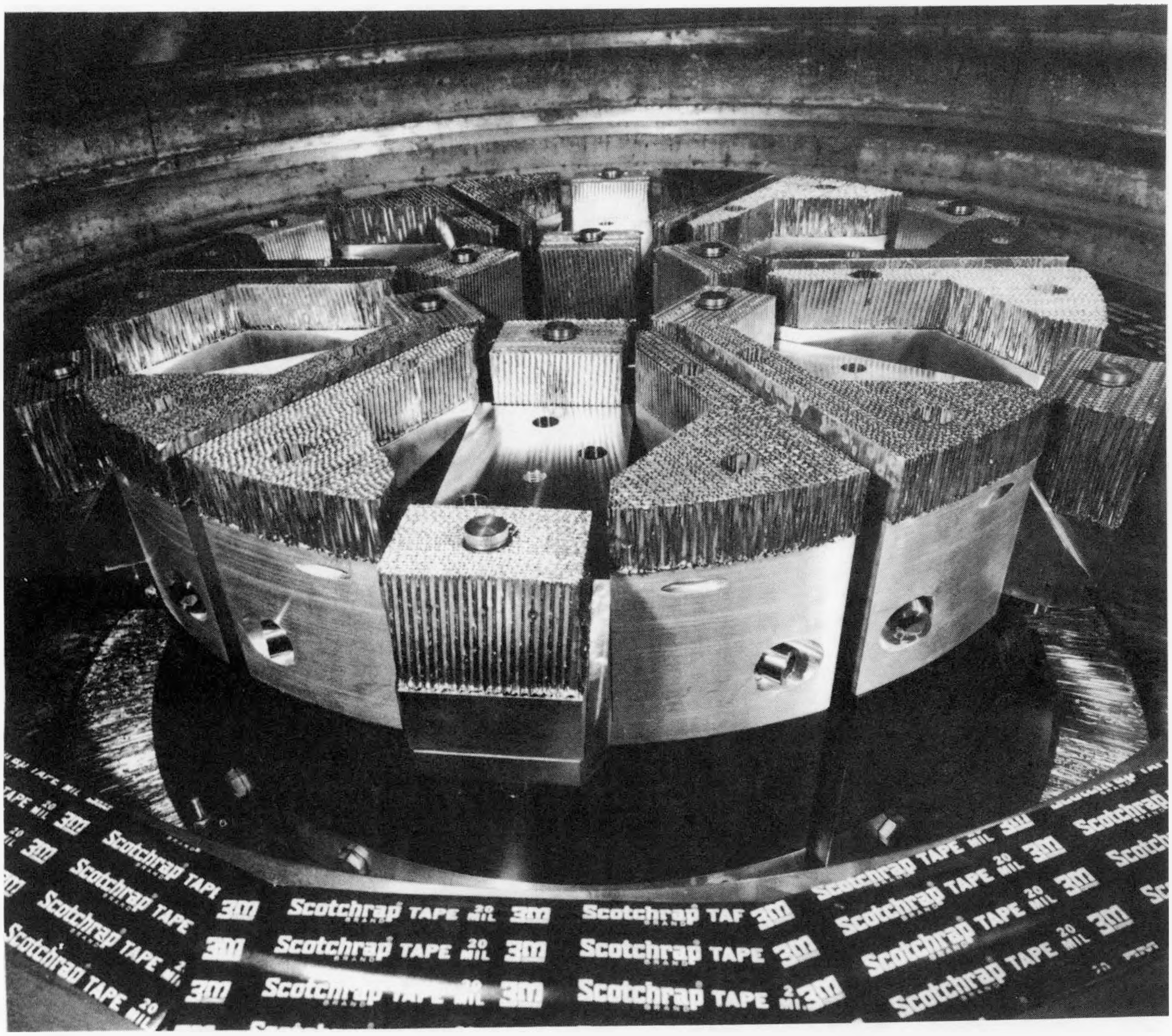


Figure A1-6. Seed Fuel Module Holders Installed in M-130 Containers [Visible are spring guides, top support honeycomb, top seed honeycomb, top seed spacer, top support honeycomb, top seed support, and top holder support (see Figure A1-3).]

the direction of travel and thus provided additional protection to the fuel modules during transit.

Energy absorbers, fastened to the top of each M-130 container prior to each fuel shipment, consisted of a 4-inch thick steel baseplate and a laminated stack of redwood, which was canned in a stainless steel cylinder for weather protection. The baseplate provided additional shielding to reduce the expected radiation levels at the top of the M-130 container to a level below that allowable for a radioactive shipment. The redwood provided a safe deceleration of a free-falling M-130 container in the event of an accident during rail transit. The energy absorber was designed to remain in place even during accident conditions.

APPENDIX A2 - M-130 SUPPORT SYSTEM

A2.1 - SYSTEM REQUIREMENTS

The M-130 support system was a piping system designed to service the M-130 shipping containers. Figure A2-1 shows the system installed at Shippingport. The system was designed to perform several functions to prepare the M-130 containers for loading with fuel and to prepare the loaded containers for shipment. These functions included:

1. Initial Fill. The M-130 containers were filled with canal water prior to immersing the container in the canal for loading with fuel.

2. Circulate Cooling Water. After loading fuel and reinstalling the closure head, canal water was circulated through the M-130 container to remove decay heat.

3. Calorimetric. After removing the M-130 container from the canal, cooling water was circulated at a lower, specified rate and the temperature was measured at the inlet and outlet of the container. Temperature data was used to determine the decay heat load in the M-130 container to verify that shipping requirements were met. This function was performed on the first blanket module shipment and on both seed module shipments. It was not required for reflector shipments because of the much lower decay heat levels for the reflector modules.

4. Drain for Flush. Upon successful completion of the calorimetric, the borated water was drained from the M-130 container using compressed nitrogen gas in preparation for flushing the container.

5. Fill for Flush. The M-130 container was refilled with radiologically clean, nonborated water. This operation diluted residual boron to ensure that it would not affect the results of nondestructive fuel assays that would be performed on the fuel rods at ECF. For seed

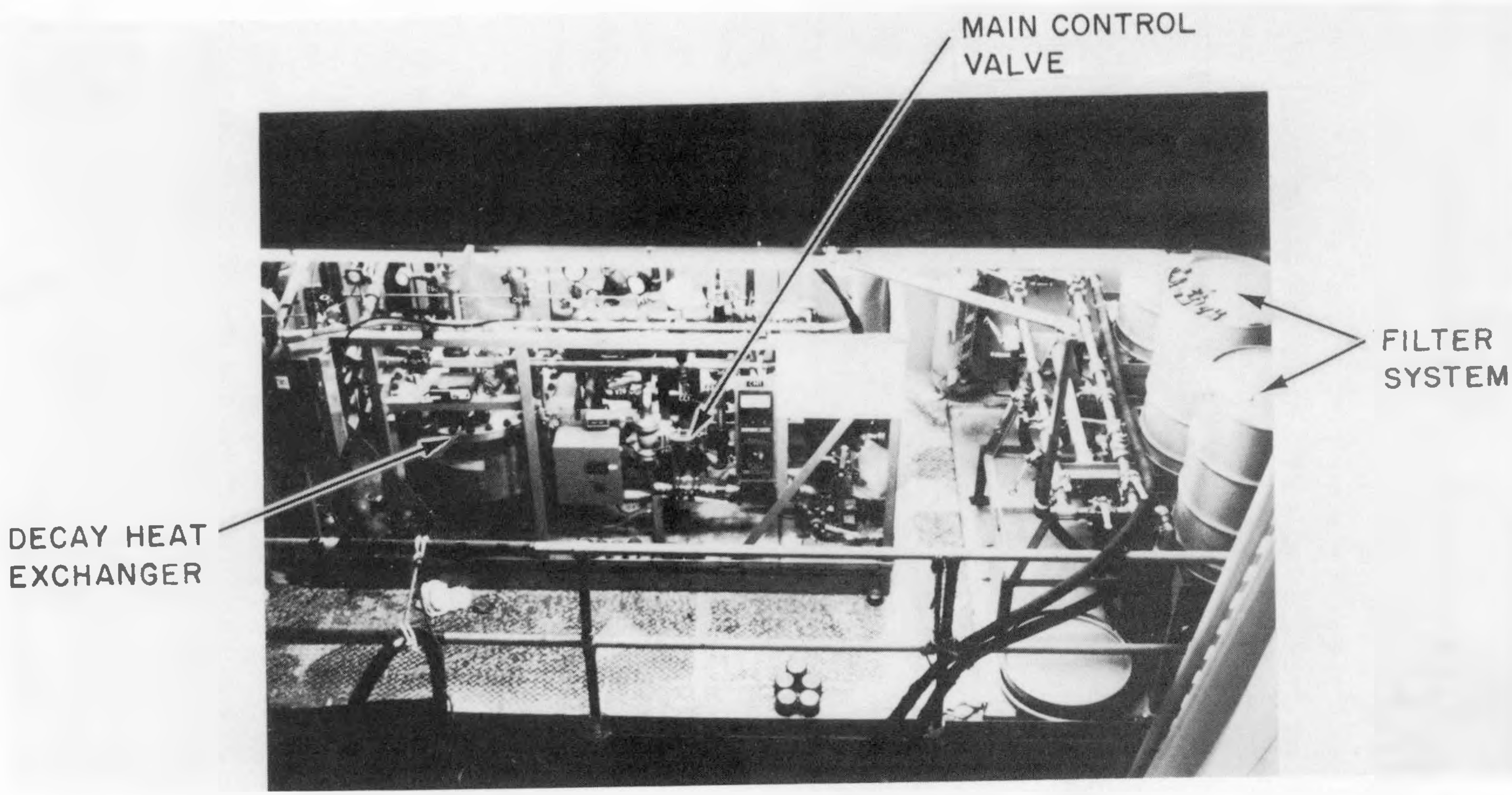


Figure A2-1. M-130 Support System Installed at Shippingport fuel shipments, a surfactant was added to improve water drainage from horizontal surfaces.

6. Flush. The nonborated water was circulated through the M-130 container to mix the water and thus reduce boron concentration.

7. Drain for Shipment. The nonborated water was drained from the M-130 container using compressed neon gas in preparation for shipment. Neon gas was used to enhance heat transfer from the fuel modules to the M-130 container wall, thus contributing to prevention of overheating of fuel elements while in transit.

The technical requirements for support system operation were determined based on the objectives of preventing overheating of the fuel elements and removing boron from the fuel rod surfaces. Excessive heating of fuel rods could have resulted in rod deformation, which would have compromised subsequent post-irradiation examination results, or failure of the fuel rod cladding. Excessive boron on the cladding surfaces would have adversely affected results of nondestructive assay tests, which were to be performed to confirm breeding of the LWBR core.

A2.2 - SYSTEM CONSTRUCTION

The M-130 support system was constructed from commercially available components which were assembled on a frame 111 inches long by 38 inches wide by 60 inches high. Most of the assembly consisted of welded fittings. Some of the major components of the system included a turbine pump; a float-type, low-range flowmeter; a venturi-type, high-range flowmeter; a heat exchanger; two water/gas separators; a submersible pump; and numerous valves and pressure gages. The system also included 1-micron shielded filters, which consisted of standard filter assemblies wrapped with lead and set in 55-gallon drums. Concrete was poured around the filters such that only the fittings and bottom end cap protruded from the concrete. This helped to minimize radiation exposures during operation and during preparations to dispose of the filters. Water and gases coming from the M-130 containers were directed through the filters prior to entering the support system in order to minimize crud buildup in the system.

A2.3 - SYSTEM OPERATION

The support system was connected to the M-130 container via flexible hoses which allowed moving the container while performing support system operations. The hoses were connected to the container using valved quick-disconnect couplings. The system was connected to several Shippingport plant systems to perform the following functions:

1. All gases vented from the M-130 container and support system were directed to the reactor plant container air cooling system, then to the plant stacks.
2. Nonborated water was supplied from the radioactive waste processing system.
3. Nonborated water was drained to the radioactive waste processing system during those times when it was not desirable to drain nonborated water into the canal.

APPENDIX A3 - M-130 ANTICONTAMINATION ENCLOSURE

A3.1 - GENERAL

The M-130 anticontamination enclosure (ACE) was a containment specifically designed to protect the M-130 container from becoming radioactively contaminated while submerged in the canal. This was achieved by completely enclosing the container in the ACE and filling the space between the ACE and container with clean water, free of radioactive contamination, at a pressure slightly higher than the surrounding canal water pressure. The slightly higher pressure ensured that any leakage would be out of, rather than into, the ACE.

A3.2 - DESCRIPTION OF THE ANTICONTAMINATION ENCLOSURE

The ACE consisted of a seal plate, an inner bag, an outer bag, various rubber gaskets and bands, a floating reservoir, and an independent piping system.

The seal plate was a flat ring with a cylindrical flange welded to the bottom near its outside diameter for attaching the anticontamination bags, an opening in the middle for removing the closure head under water, and two rectangular openings 180 degrees apart for trunnion assembly insertion (Figure A3-1). The seal plate also had two pipes penetrating its top surface; one was used as a vent for the ACE water supply system and the other provided an attachment point for one of the support system hoses (to avoid excess strain on the ACE bag). A short hose was connected to the underside of this pipe and to the support system quick-disconnect coupling in the container's side penetration. After installing and securing the trunnion assemblies, a rectangular boot seal was connected between each trunnion assembly and the opening in the seal plate to provide a contamination seal between the trunnion assembly and the seal plate.

The inner and outer anticontamination bags were preassembled as much as possible before positioning the bags for installation onto the M-130 container. The anticontamination bag assembly consisted of an inner polyvinylchloride (PVC) bag, an outer nylon-reinforced PVC bag, an inlet water pipe,

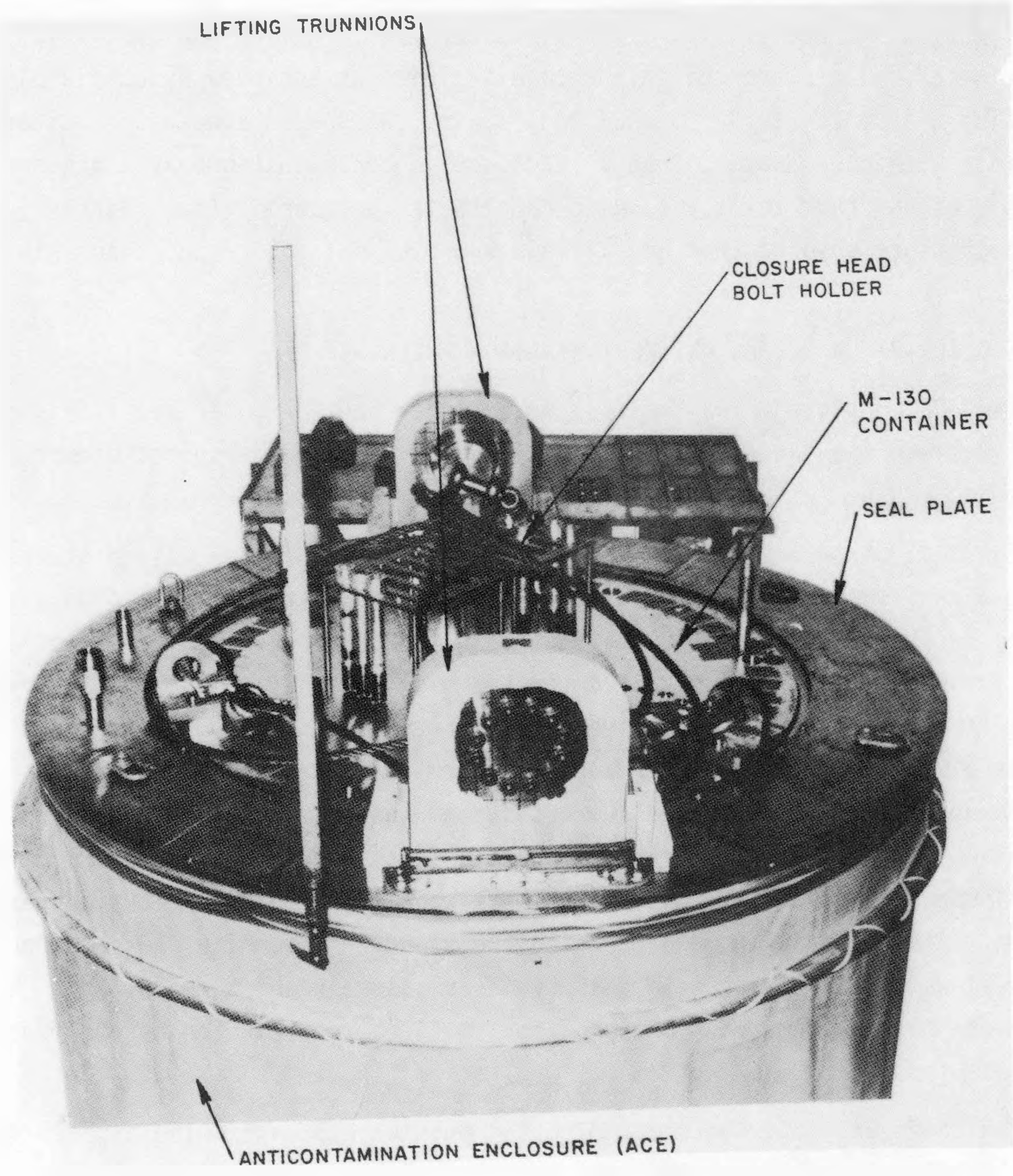


Figure A3-1. ACE Bag Seal Plate

and an aluminum handling ring. The inner bag provided the watertight seal, while the outer bag prevented the inner bag from expanding to its rupture point. The outer bag had four small holes near the top to allow air to escape from between the bags as the container was lowered into the water. The inlet water pipe was clamped to the inner bag on the inside of the bag and to the outer bag on the outside of the bag to provide a location to penetrate the bags for filling with water. The assembled bags were laced onto the handling ring to provide a means of handling the bag assembly and to help maintain the bags in a cylindrical configuration during installation onto the M-130 container (Figure A3-2).

A3.3 - ANTICONTAMINATION ENCLOSURE WATER SUPPLY SYSTEM

The ACE water supply system consisted of a predetermined amount of uncontaminated borated water, two flowmeters, a totalizer, an inlet line, an inlet relief line, an outlet line, and a floating reservoir. A measured amount of the water to be used in the ACE bag was stored in the reactor plant water storage tank, where it could be either pumped or gravity-fed into the bag. In the feed line from the tank, were two flowmeters in parallel and a totalizer. Either of the flowmeters could be valved into the system, depending on the desired flow. The high-range flowmeter was used during initial fill of the bag, at a rate of approximately 15 gallons per minute (gpm). After the bag was filled, the flow was reduced to approximately 0.25 gpm and the low-range flowmeter was valved into the system. The totalizer was used so that there was an indication of how much water remained in the water storage tank. Hose connections to the ACE bag are shown in Figure A3-3. On the inlet side were a hose for the inlet water supply and an inlet relief hose to protect the ACE bag if the outlet hose were to become blocked. The inlet relief was set at 10 inches above the canal water level. The outlet line was attached to the pipe nipple on the seal plate; the other end was attached to the bottom of the floating reservoir. The floating reservoir was a rectangular tank which floated on the canal, with a dry chamber at each end of the tank to provide flotation. Properly adjusted, the reservoir maintained a pressure head of 1 inch of water in the ACE bag, thus ensuring that only clean water contacted the surface of the M-130 container. Only enough water was

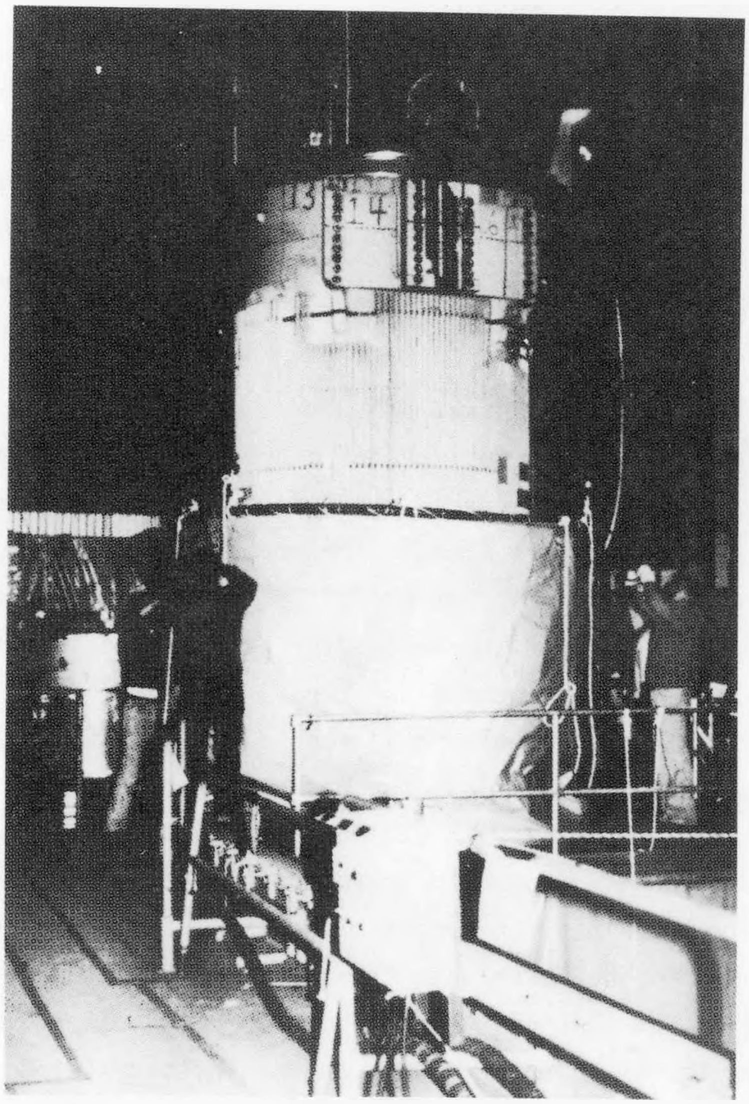


Figure A3-2. ACE Bag on Handling Ring

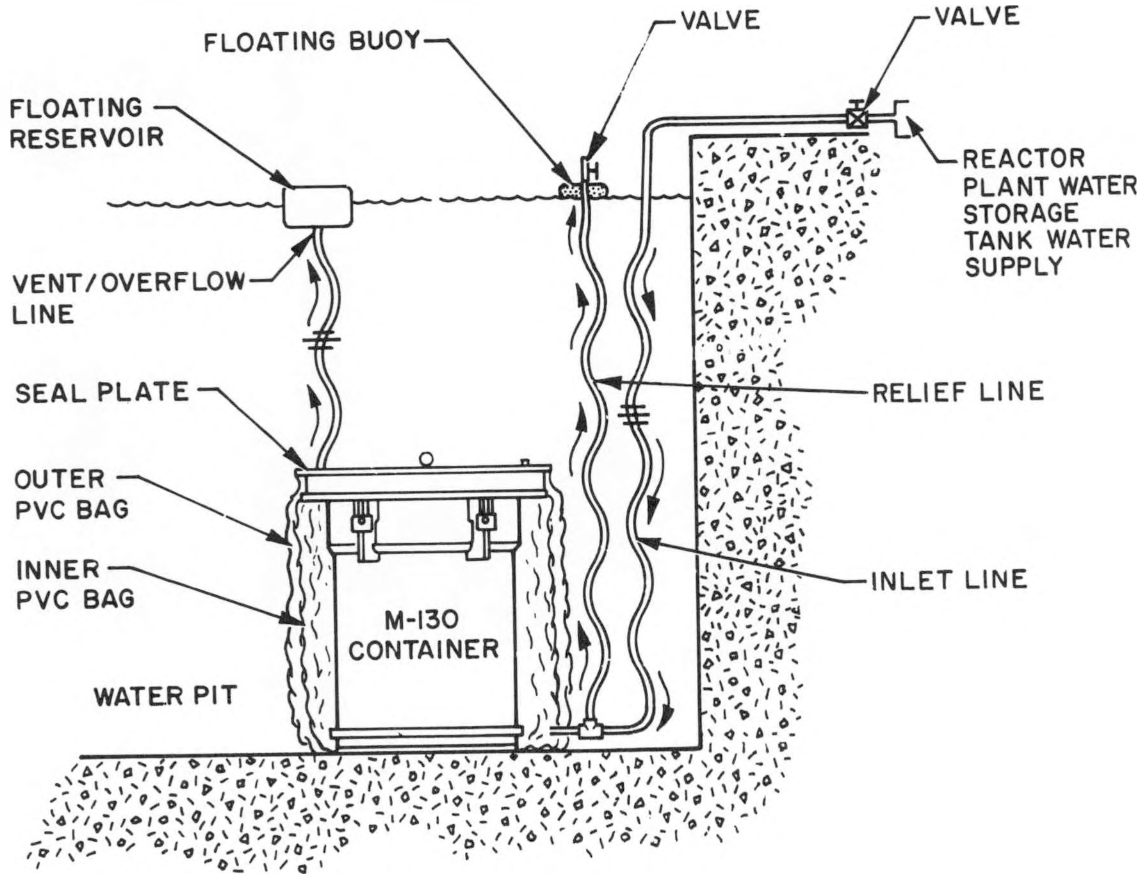


Figure A3-3. ACE Bag Hose Connections

supplied to the bag to replace any leakage which, in turn, minimized the amount of water added to the canal during underwater M-130 operations. The leakage rate was generally less than 0.50 gpm.

Anticontamination enclosures were used on all M-130 containers. They significantly reduced fuel module shipping preparation time and were relatively trouble-free. A few minor problems relating to ACE operation are detailed in Appendix A5. There were no major problems with this system.

APPENDIX A4 - FUEL MODULE MOTION RESTRAINTS FOR SHIPPING

A4.1 - GENERAL

Because transportation of fuel modules to the Expended Core Facility (ECF) was accomplished by railcar, nearly continuous shipping container shock loadings were expected during transport. Fuel module restraint was, therefore, necessary to prevent fuel damage which could potentially have resulted from modules impacting the module holders during shipment. To obtain a reliable estimate of container shipping shock loading, acceleration recorders were placed on two nuclear fuel rail shipments which were nearly identical to the shipping container and railcar arrangement to be used to transport Light Water Breeder Reactor (LWBR) fuel from Shippingport to ECF. An analysis of the shipping acceleration data showed that accelerations were typically far less than 1.0 g and that 99 percent of the shocks were less than 1.8 g in the railcar longitudinal direction, 0.99 g laterally, and 2.9 g vertically. Because the container shipments showed minimal accelerations, it was considered sufficient to require prevention of module vertical and horizontal motion resulting from accelerations up to 1.0 g in a horizontal direction. Effectively, the modules would not move until accelerations exceeded 1.0 g in <u>any</u> direction. The lateral restraint would prevent module motion in a horizontal direction, and an acceleration of greater than 1.0 g would be required to overcome module weight and move the module vertically. For the infrequent accelerations greater than 1.0 g, module motion would result, but displacement would be restricted by the shipping container module holders and module holddown devices.

A4.2 - MODULE MOTION RESTRAINT EQUIPMENT

For all three types of fuel modules, the module motion restraint equipment consisted of a vertical holddown spring and a lateral restraint mechanism. The holddown springs applied a downward force on the module through spring compression between the top of the module and the underside of a container closure head. Spring height was set such that installation of the closure head on the container resulted in compression of the spring and generation of a holddown force. The total force generated by holddown springs in each shipping container was limited by the weight of the closure head, approximately 10,000 pounds, inasmuch as exceeding this weight would prevent proper seating of the closure head on the container. Because container shipments were comprised of six seed modules (weighing approximately 1800 pounds each), four reflector modules (weighing as much as 5500 pounds each), or three blanket modules (weighing as much as 6200 pounds each), typical holddown forces per module were less than 1.0 g.

Each of the fuel lateral restraint mechanisms applied a horizontal loading near the top of a module of sufficient force to prevent module motion during lateral module acceleration of up to 1.0 g. The lateral restraints were sized to accommodate a worst-case scenario; that is, a module initially tipped away from the lateral restraint experiences acceleration directed toward the lateral restraint. The force necessary to restrain the modules under this condition was approximately half the module weight.

APPENDIX A5 - PROBLEMS DURING SHIPPING OPERATIONS

There were a few problems which affected preparations for shipping or loading operations. The following were the most significant problems.

A5.1 - SUMMARY OF PROBLEMS

A5.1.1 - Premature Draining of Shipping Container

During preparation of the loaded M-130 container for the first seed module shipment from Shippingport, several procedure steps were inadvertently skipped which caused the shipping container to begin to drain during operations to circulate cooling water. With no water cover over the fuel modules inside the container, a high radiation area (100 mr/hr) was produced over the container closure head with no proper markings (ropes and signs) or controls (area guards). Although the normal condition for shipping the fuel modules was in a drained container, in this case only initial fill and cooling water circulation steps had been performed (Appendix A2) and the draining was premature.

The event was discovered when a control room supervisor noted a 1/2-inch rise in the canal water level in a 25-minute period. No personnel were required for the operation in progress, hence, no workers received radiation exposure as a result of this event. Seed module shipping was scheduled to take place after decay heat levels of the irradiated fuel were low enough that the fuel could be shipped with only an inert gas atmosphere in the container relying on convection and conduction for heat dissipation. Hence, the short time that the modules were not covered with water was insufficient to cause any significant heat build-up within the container or to postulate any damage to the fuel rods.

An error in the valve lineup for the expected conditions was found and corrected. A contributing factor was multiple intra-procedure step referencing (i.e., a step in the procedure referenced another step elsewhere in the procedure which referenced yet a third step to perform an action). Several handwritten changes were incorporated into the first step called out by the time the event occurred, which led to confusion as to which step was to be performed. Subsequent to this event, a second issue of the procedure was prepared that clarified the sequencing and eliminated the confusion.

A5.1.2 - M-130 Container Quick-Disconnect Coupling Leaks

During M-130 operations for the first three shipments from Shippingport, leaks developed at the quick-disconnect couplings on the M-130 containers. The valved quick-disconnect fittings, which were used to connect the M-130 support system to the M-130 container, were threaded into the container using a metal O-ring for sealing. A crimping sleeve was incorporated to lock the quick-disconnect in position. Leaks were developing during operations due to the quick-disconnect fittings becoming loose. It was determined that the side loads on the fittings from the support system hoses were deforming the metal O-ring, causing a loss of preload in the quick-disconnect threads. Thus, even though the quick-disconnect coupling was locked in place, the loss of preload allowed water to leak out of the M-130 container. The situation was corrected by applying an anaerobic sealant to the threads, and torquing the quick-disconnect coupling to a higher value, which seated it on the crimp sleeve washer. In the original arrangement, the quick-disconnect coupling was seated only on the metal O-ring, thereby allowing additional deformation in the O-ring from the side loads. By increasing the torque to seat the coupling on the washer, the side loads were transferred through the washer, which prevented further deformation of the O-ring and subsequent loosening of the quick-disconnect fittings. Also, guides were attached to the M-130 container, which supported the hoses to reduce side loads on the quick-disconnect fittings.

A5.1.3 - Anticontamination Enclosure Clean Water Supply

Whenever the M-130 shipping container was placed in the canal water, the anticontamination enclosure (ACE bag; Appendix A3) was used to surround the container to avoid contaminating the outside of the vessel. Original plans specified that the ACE bag would be fed by demineralized (but borated) canal water at a controlled, low flow rate to provide a few inches of water head. When it was realized that radioactive antimony (Sb-125) could not be removed by the chelating-type canal water resin bed (Reference 1), the flow path to the ACE bag was changed to a nonradioactive borated water source. The new source selected was the reactor plant water storage tank, which was borated on August 18, 1983, to a minimum of 3800 ppm boron. The outflow from the water storage tank was routed through a 0.2-micron filter to remove any possible contaminants in the path to the ACE bag. The storage tank path to fill the ACE bag worked satisfactorily throughout defueling.

A5.1.4 - M-130 Container Checkout

Because extensive modifications were made on the M-130 containers for LWBR fuel shipments, an extensive checkout program was performed before the first use to ensure that all systems would function as intended. A number of small problems were uncovered that would have resulted in significant delays if they had not been found before shipping operations began. Problems were mostly of the type that are inherent in converting an existing system to a new application. Also found were deficiencies in design of certain tools, and operation of support systems for both the M-130 container and the anticontamination enclosure (ACE bag). In some cases, these problems required redesign or modification of tools or components; in other cases, simply rerouting hoses or resequencing operations was sufficient to overcome the problems.

Based on the number of small problems found that could have become major interferences to the smooth flow of defueling operations, the value of complete and detailed checkout of new systems was confirmed.

A5.1.5 - Anticontamination Enclosure Piping System Flowmeters

Two sight gage flowmeters were used in the anticontamination enclosure (ACE) bag water supply system to control flow to the ACE bag. Between the first and second M-130 container shipments, it was noted that the flowmeters were indicating flow, even though the system was shut down. A checkout of the gages revealed that boron crystals were clogging the internal surface of the gage. They were flushed with nonborated water, which restored operability. Flushing was performed as periodic maintenance for the remainder of defueling operation.

A5.1.6 - M-130 Container Threaded Connections

At various times during M-130 container preparations, there were problems with threaded connections. The seal plate attachment flange was being installed on the first M-130 container when two bolts gave indications of being stripped. Upon checking, the threads were found to be satisfactory. It was judged that the threaded holes in the container were at fault, and a tap was used in an attempt to clean and rethread them. When the tap was used, it was found that the holes contained threaded helical inserts which had loosened in the holes. Use of the tap damaged the inserts. Replacement of the inserts, however, corrected the slipping problem.

Another case of stripped threads in a bolt hole occurred on one A-frame lifting lug attachment point. The first several threads at the opening of the hole stripped. It was necessary to use a longer lug to ensure that sufficient threads were engaged.

Two sets of closure head bolts were used on each M-130 container; one set was kept radiologically clean for shipping, while the second set was installed to place the M-130 container in the canal water. This second set was cleaned in an ultrasonic decontaminating bath between uses, but was never permitted out of the controlled area. The decontamination bath contained citric acid, which was capable of removing chromium plating from the bolts, which was needed to prevent galling. One set was inadvertently left in the ultrasonic cleaner over a holiday shutdown. The citric acid bath damaged threads on the whole set of bolts, making them unfit for use.

A5.1.7 - Closure Head Leakage and Stuck Bolts

During the container leak test which was performed for the third shipment (second reflector) prior to removing the loaded M-130 container from the canal, leakage (in the form of air bubbles) was noted around the closure head. Thirty-nine bolts were installed and torqued to 300 ft-lb prior to the leak test. Another pass of torquing was permitted at slightly higher torque (325 ft-lb) but, upon retesting, the closure head still leaked. Approval was obtained to remove the closure head to determine if a foreign object was inhibiting proper sealing. During removal of the bolts, three of them could not be loosened at the 500 ft-lb upper torque limit. Bolts were replaced on either side of the stuck bolts in an attempt to relieve stresses in the stuck bolts. Reinstallation of all 39 bolts, plus three others, plus performance of several torquing and untorquing passes were required to finally loosen all bolts. During these operations, as many as eight of the bolts could not be untorqued at the 500 ft-lb limit at any one time. Three working shifts were required to remove the bolts and the closure head.

After all bolts and the closure head were finally removed, the seating surfaces were checked for foreign matter; none was found. The closure head was reinstalled using a specified torquing sequence to ensure uniform seal compression, and it passed the leak test.

*U.S. GOVERNMENT PRINTING OFFICE: 1988-505-001/80158