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# LIGHT WATER BREEDER REACTOR FUEL MODULE DISASSEMBLY AT THE SHIPPINGPORT ATOMIC POWER STATION

(LWBR Development Program)

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## FOREWORD

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

Subsequent to development and successful operation of the Pressurized Water Reactor in the Atomic Energy Commission (now Department of Energy, DOE) owned reactor plant at the Shippingport Atomic Power Station, the Atomic Energy Commission in 1965 undertook a research and development program to design and build a Light Water Breeder 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 examination, further disassembly, and final disposal. Fuel modules were partially disassembled at Shippingport. Seed module support shafts, reflector module seal blocks, and blanket module support tubes, seal blocks, and guide tube extensions were removed. This partial disassembly was required to enable the fuel modules to fit in M-130 shipping containers. No significant problems occurred during disassembly operations. Radiation and personnel exposure levels were carefully controlled.

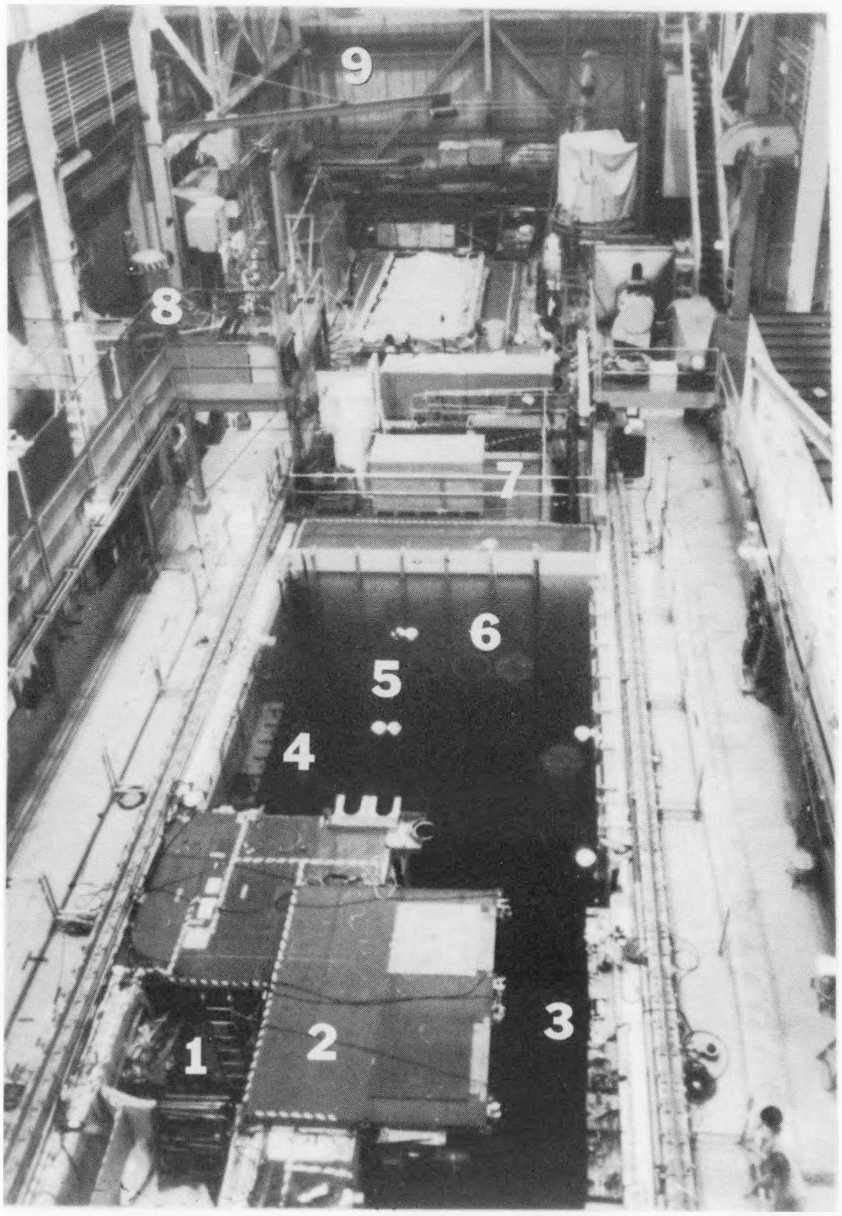
# LIGHT WATER BREEDER REACTOR FUEL MODULE DISASSEMBLY AT THE SHIPPINGPORT ATOMIC POWER STATION

(LWBR Development Program)

## SECTION 1 - INTRODUCTION

The Light Water Breeder Reactor (LWBR) core was defueled after successfully operating for 29,047 effective full power hours (EFPH) at the Shippingport Atomic Power Station. This report describes operations to partially disassemble the fuel modules removed from the reactor to prepare them for shipment to the Naval Reactors Expended Core Facility (ECF) in Idaho. Partial disassembly was required to permit fuel modules to fit into the shipping containers. At Shippingport, only those items that inhibited installing the fuel modules into the shipping containers were removed from fuel modules.

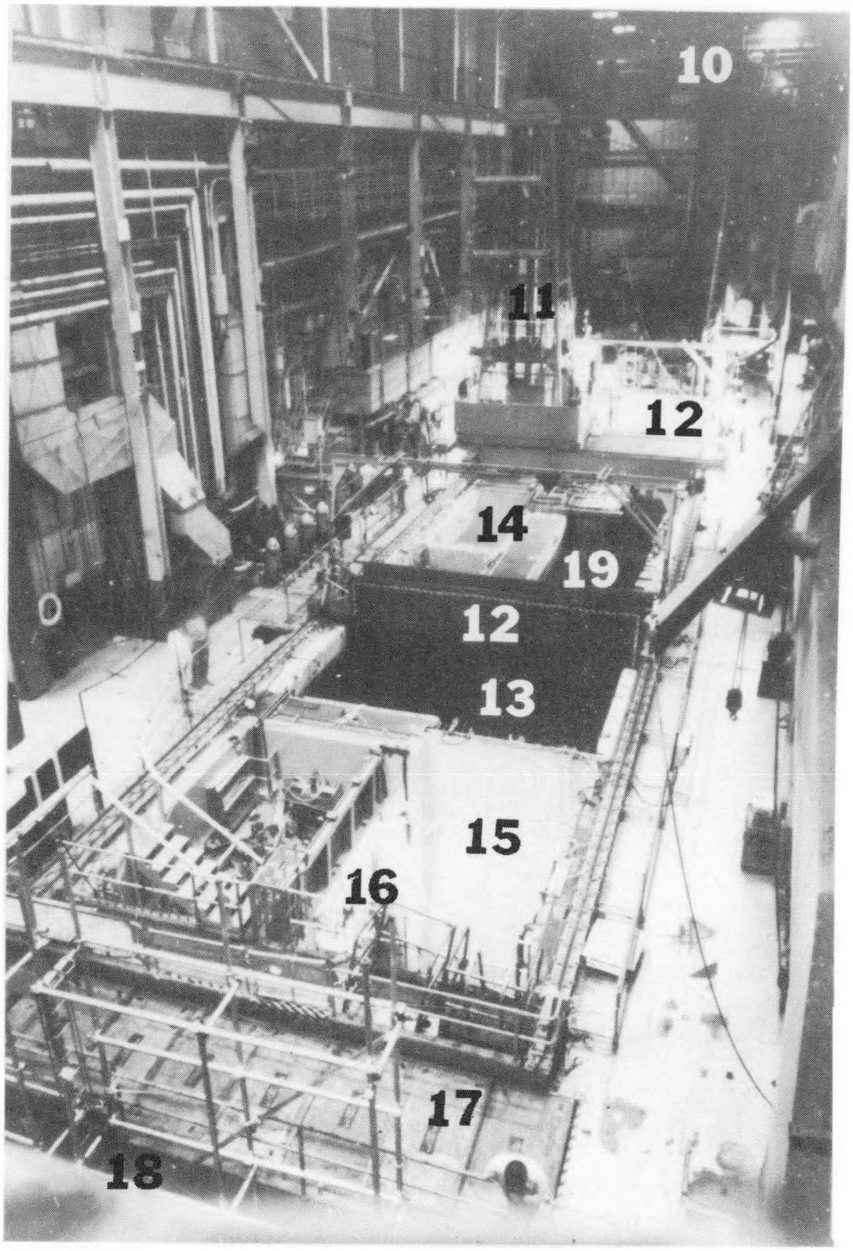
Facilities to support fuel module disassembly operations are illustrated in Figures 1A and 1B. All disassembly operations were conducted either at the seed/blanket disassembly stand or in the M-130 shipping containers (reflector disassembly only). Storage racks for fuel modules removed from the reactor




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) vessel were installed in the deep pit area south of the disassembly stand. All 12 seed modules were placed directly into the storage racks after removal from the reactor. Several of the blanket modules were also placed directly into storage, but most were disassembled directly upon removal from the reactor to avoid extra fuel handling.

Each M-130 shipping container was installed under water on a ledge at the south end of the canal. Reflector module disassembly was performed after the modules were installed in the container since only one component (the top seal block) had to be removed from the top of each module, and special facilities were not required to accomplish this operation.

The Fuel Handling Building was serviced by an overhead bridge crane having one 125-ton capacity hoist and one 25-ton capacity hoist. Several 3/4-ton, boom-type jib cranes attached to the building columns were available also. One of these was moved to a more strategic location near the disassembly stand. A new jib crane was installed at the south end of the Fuel Handling Building to support fuel shipping operations. Access to tools and work areas was provided by two work bridges and a movable extraction crane. The extraction crane was equipped with a jib crane and modified to contain personnel work platforms, which were added specifically for the defueling work.

Tools for disassembly operations were located along the east wall of the canal and the south wall of the reactor pit. For easy access, many tools were stored on the disassembly stand itself. Storage receptacles and racks to receive items removed from the fuel modules were located around three walls of the reactor pit. The PWR-2 lower core barrel, which was a portion of the internal structure of a previous core installed at Shippingport, was being stored in the deep pit. Several LWBR fuel module components removed during disassembly operations were loaded into the core barrel for disposal.

A prime consideration throughout LWBR defueling was personnel safety, both for the technicians performing the defueling operations and for the general public outside of the defueling area. Safety features included careful control of personnel radiation exposure, protection against 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 enhanced by an extensive program of personnel training and check-out of equipment and procedures prior to beginning defueling operations. 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 serious injury to personnel, no damage to fuel or equipment, and no release of radioactivity to the environment. Defueling was completed with total personnel radiation exposure of 76.2 man-rem and no individual worker exceeded 10 percent of the permissible yearly dose of 5 rem. Nuclear safety was assured through several features of the defueling program. Protection against nuclear criticality was obtained by heavily borating the reactor vessel and canal water to ensure a minimum margin to criticality of 10 percent under worst-case accident conditions. A detailed discussion of boration as a means of criticality control is presented in Reference 1.

To prepare personnel for defueling and disassembly operations, an extensive training program was initiated several months before the anticipated reactor shutdown. Training was conducted using actual tools, fuel module mock-ups, and systems designed to simulate actual conditions as nearly as possible. The major objective of the training program was to familiarize personnel with tools and methods so that actual defueling (including disassembly and shipping operations) would proceed smoothly, safely, and with radiation exposure minimized. This objective was realized; defueling was completed with no major problems and with total personnel radiation exposure significantly less then predicted.

A brief introduction to disassembly operations has been presented in this section, along with a description of the Fuel Handling Building and the site facilities. Section 2 provides a summary of the operations performed to remove fuel from the reactor. Section 3 provides detailed accounts of operations performed to partially disassemble the fuel modules. The primary emphasis is on component removal, but tools used and problems encountered are also described. Descriptions of the seed/blanket disassembly stand and the guide tube extension bolt cutting machine are presented in Appendices A1 and A2, respectively. Disassembly operations and the equipment used for these operations were relatively trouble-free. Significant problems encountered during disassembly are discussed in the context of the operations in which they occurred.

## SECTION 2 - SUMMARY OF REACTOR DEFUELING OPERATIONS

Removal of nuclear fuel from the LWBR core, along with many nonfuel components, was the first stage of total decommissioning of the Shippingport Atomic Power Station. The objective was to remove the 39 fuel modules comprising the LWBR core and ship them to the Naval Reactors Expended Core Facility (ECF) in Idaho for examination to confirm the good performance of the thorium-based fuel cycle and to prove breeding. This section is a summary of reactor defueling operations detailed in Reference 1. Loading and shipping operations following module disassembly are detailed in Reference 2.

Defueling operations began in December 1982 with draining of the reactor pit and removal of the reactor dome. Before fuel could be removed, all of the hardware, instrumentation, and piping in the closure head area had to be removed.

During LWBR operational lifetime, reactivity control was obtained by axial movement of seed modules within the surrounding blanket modules. Positioning of the seed modules was accomplished by connecting the support shaft of the seed module to a translating assembly, essentially a threaded rod which penetrated the closure head and entered a motor tube mounted on top of the closure head.

Blanket fuel modules were supported by attachment to the closure head. Reflector modules formed the periphery of the core. The reflector modules were suspended within the core barrel by a ledge on their top structural member (seal block), and were locked in place against coolant flow forces by a holddown barrel extending from the top of the reflector modules to the underside of the closure head. Performance of emergency shutdown (scram) required a flow pressure equalization system consisting of a piping network connecting the top of the movable seed module to the coolant inlet. Removal of all the support system components was necessary to accomplish fuel removal from the reactor.

After removal of instrumentation and control drive mechanism stators from the top of the closure head, the reactor primary system was breached by cutting a weld and removing a vent plug at the top of two motor tubes; then, other primary system seals were cut at the base of the motor tubes, at the closure housing of the bypass inlet flow pressure equalization system, at instrumentation penetrations surrounding the motor tubes, and at the base of the closure head. The motor tubes and translating assemblies, the pressure equalization system piping, and the flux wire thimbles, thermocouples, and pressure taps which comprised core internal components of the instrumentation system were then removed.

To gain access to the blanket module support system, the guide tubes which provided a path for seed module vertical motion were removed. This was followed by a complex series of operations to detach the blanket modules from the closure head and lower them, along with the mating seed modules, about 3 inches to seat on the core barrel bottom plate. This operation was performed incrementally and simultaneously on all 12 fuel assemblies because dimensional changes occurring within the blanket modules as a result of radiation effects presented a very high potential for module-to-module interference and hangup of the exposed grids. The operations were accomplished successfully.

After the removal of all items connected to the closure head, the head itself was removed and placed in storage.

All of the preceding operations did not involve fuel movement and were performed primarily in air using local containments to prevent spread of radiological contamination. Borated water filled the reactor vessel to ensure that the reactor would remain shut down and to provide shielding during head area disassembly operations. After the head was removed, the reactor pit was flooded to provide containment and shielding for the highly radioactive materials which were to be removed from the reactor vessel. After flooding the reactor pit, the first component removed was the reflector module holddown barrel, which was installed into a shielded shipping container and shipped to a disposal site. At this point, all of the fuel modules were accessible for removal.

The first fuel modules removed were the seed modules. All 12 modules were removed and placed in a storage rack (Figure 1B) for later disassembly. Removal of blanket and reflector modules from the reactor was dependent on available storage space, fuel shipping schedules, and requirements that certain modules be removed before others due to accessibility considerations. Thus, after seed modules were removed, eight reflector modules were removed, of which four were stored in the fuel storage racks and four were loaded into an M-130 shipping container, disassembled, and shipped to ECF. Blanket shipments were prepared by removing modules from the reactor and partially disassembling them. Some were placed in the fuel storage racks before or after disassembly; however, to reduce fuel handling, most blanket modules were disassembled and stored in the disassembly stand, then moved directly to the M-130 container for shipment. The remaining seven reflector modules were loaded into the shipping container directly from the reactor.

The last fuel module was removed from the reactor on May 16, 1984. The final disassembly operation was completed on August 17, 1984. Shippingport defueling was completed with the last shipment of fuel modules on September 6, 1984.

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## SECTION 3 - DISASSEMBLY OF LWBR FUEL MODULES

Disassembly of LWBR fuel modules at Shippingport was limited to removal of support and/or extension components which made the fuel modules too long to fit into the M-130 shipping containers. In each case, a lifting adapter had to be installed in place of the removed component to permit handling with the same equipment that was used to remove the fuel modules from the reactor. Disassembly of seed and blanket modules was performed in the seed/blanket disassembly stand, a large framework structure designed to clamp and support a fuel module during disassembly operations. A detailed description of the stand is presented in Appendix A1. Disassembly of reflector modules was performed after the modules were loaded into M-130 shipping containers.

Detailed descriptions of components removed from each type of fuel module and the tools used to accomplish each task are presented in the following sections.

### 3.1 - SEED MODULE DISASSEMBLY

To reduce the length of the seed module to fit in the M-130 shipping container, the seed support shaft (Figure 2) was removed. After removal of the support shaft, an adapter was installed onto the remaining portion of the fuel module to allow handling using the existing module handling equipment at Shippingport.

The seed support shaft was the major link connecting the fueled portion of seed modules to the control drive mechanism. The support shaft was approximately 10 feet long, with a hexagonal-shaped bottom end having the same cross section as the seed shell. Its bottom end was bolted to the fueled region at the top baseplate with six bolts. The top end was connected to a balance piston inside a buffer cylinder. During reactor operation, the balance piston provided a downward force on the movable seed assemblies when connected to the bypass inlet flow system (Reference 1) and balanced the upward hydraulic force on the seed fuel assemblies. The support shaft, balance piston, and buffer cylinder were removed as an assembly after uncrimping locking cups and removing bolts which connected the support shaft to the fuel module.

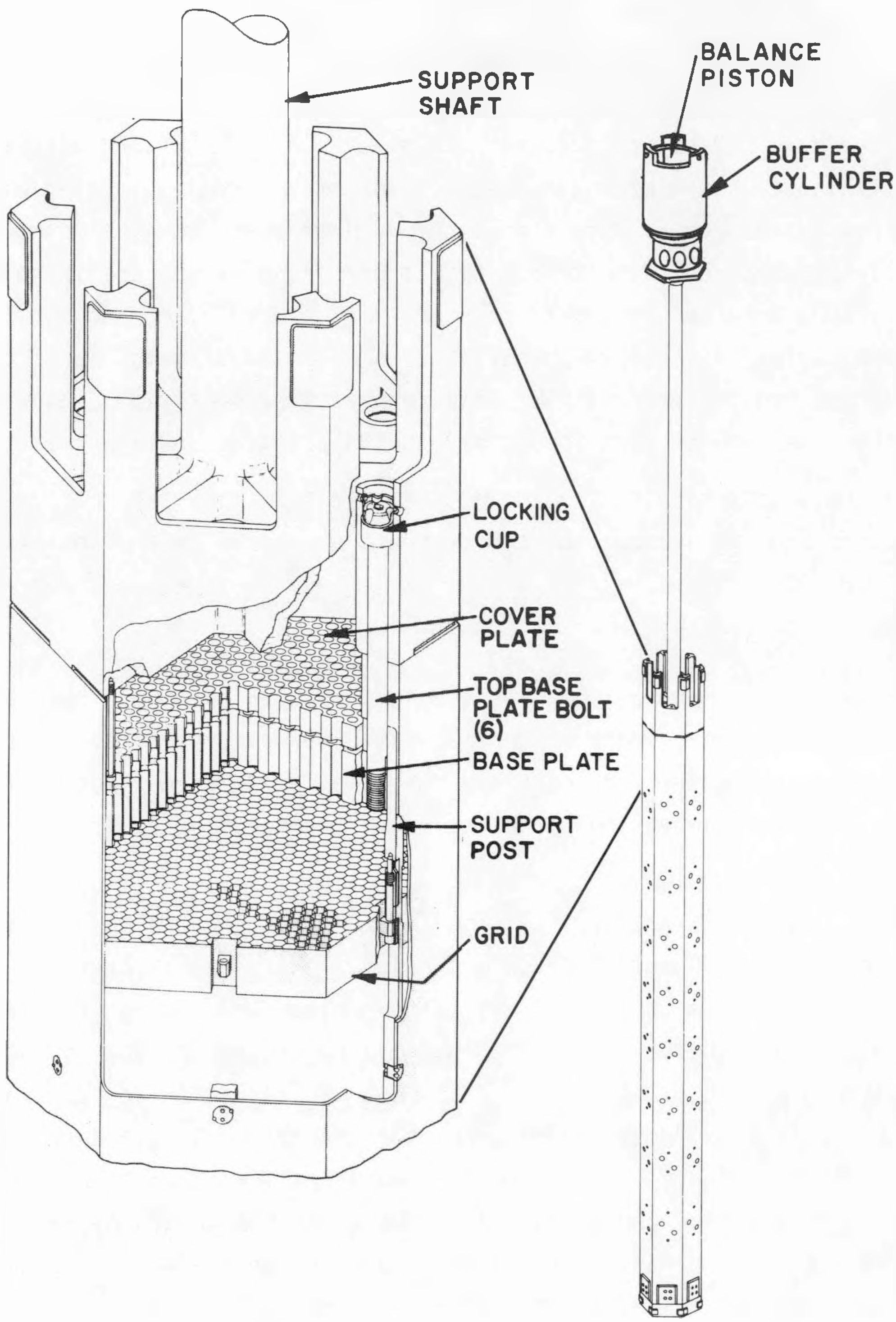



Figure 2. Seed Fuel Assembly

### 3.1.1 - Top Baseplate Bolt Uncrimping

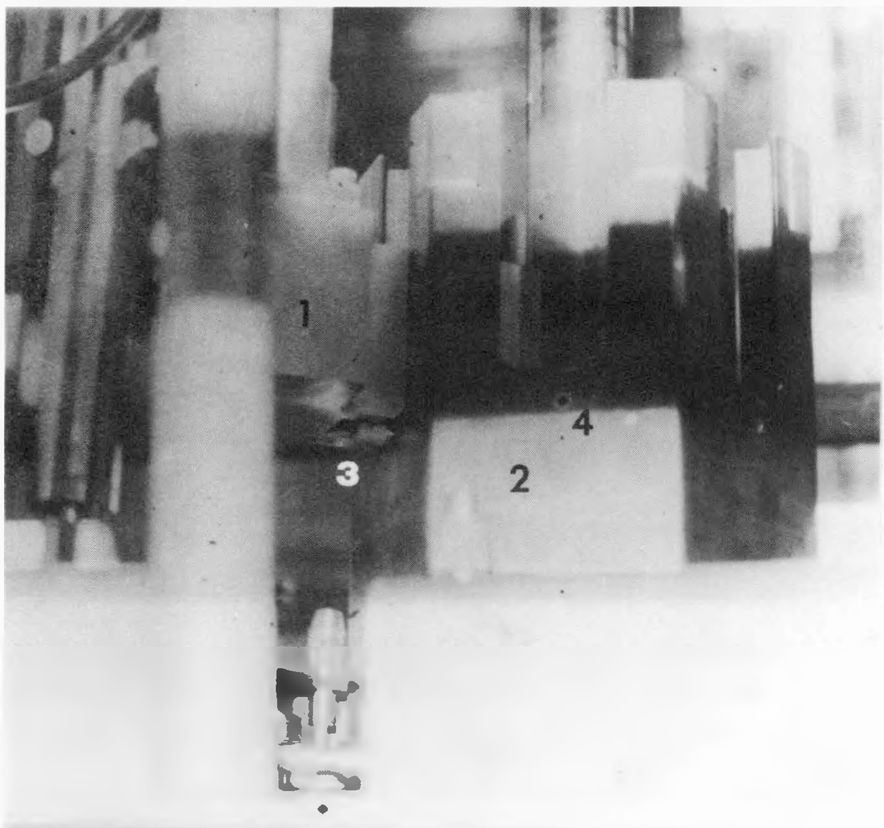
A locking cup was used as the method of capturing top baseplate bolts. Captivation was required to prevent bolt rotation or the generation of loose debris in the reactor in the event of bolt fracture. During seed module assembly, each locking cup was deformed (crimped) outward into two holes in the support shaft and crimped inward into the recessed area on the bolt head. The simplest uncrimping method considered was to provide enough torque to override the crimps during bolt unthreading operations. Testing showed that the torque needed to override the crimps could range from 50 to 125 ft-lb. However, the yield point of the bolt shank could be exceeded at about 100 ft-lb applied torque. Thus, there was no certainty that high torques were due to locking cup resistance rather than to a stuck bolt and there was a danger of shearing the bolt. Direct removal of the outward crimp on the locking cup was the method selected.

The top baseplate bolts were located about 12 feet below the surface of the water. The locking cup uncrimping tool was 21 feet long. This length provided comfortable access to the tool operating components by workers on the disassembly stand.

The uncrimping mechanism of the tool shown in Figure 3 consists of two high-strength machined uncrimping pins attached to two threaded blocks which were translated by the shaft. The shaft had left- and right-handed threads to move the uncrimping pins inward in unison. The optimum uncrimping pin design was obtained as a result of testing performed on mock-ups (Figures 4 and 5). The results of the uncrimping operations on an LWBR seed module are shown in Figure 6.

### 3.1.2 - Top Baseplate Bolt Removal

Once the top baseplate bolt locking cups were uncrimped, the next operation was to untorque and unthread the bolts. The bolt unthreading tool, like the locking cup uncrimping tool, was operated from the disassembly stand and was about 21 feet long. To gain access to the bolts, which were blocked by the buffer cylinder, the tool body was offset to fit around the buffer cylinder and was equipped with a ratcheting device for bolt unthreading. The tool




1. Locking Cup Uncrimping Tool
2. Base of Support Shaft
3. Moving Uncrimping Pin
4. Access to Locking Cup

Figure 3. Locking Cup Uncrimping Tool

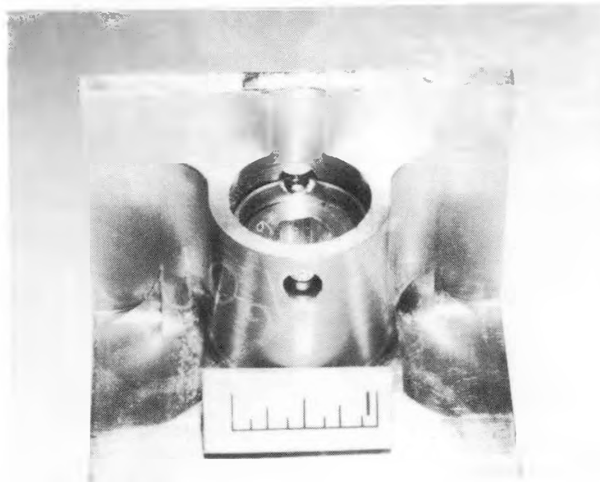


Figure 4. Mock-up of Seed Baseplate Bolt

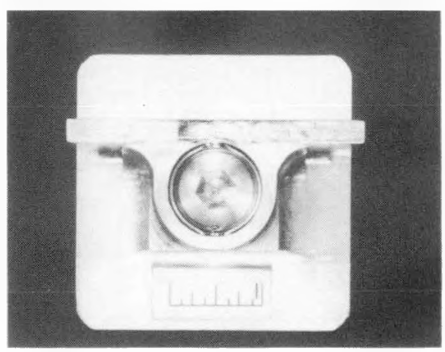


Figure 5. View Showing Outward Crimp of Locking Cup

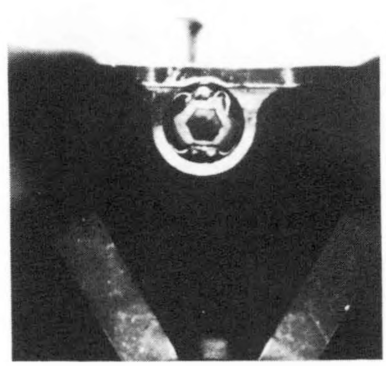


Figure 6. Locking Cups After Using Uncrimping Tool

was designed with the capacity to break the bolt if galling occurred. The hex key tip, which was the weakest part of the tool, was replaceable. When bolt unthreading was performed, an audible and tactile response (a "klunk" which occurred when the ends of male and female threads were reached and the bolt and tool dropped a distance equal to the thread pitch) indicated that the bolt was completely unthreaded. To prevent reengagement of the bolt into the top baseplate, the bolt was rotated approximately 180 degrees from the "klunk." This technique was used for all threaded connections in the seed, blanket, and reflector modules.

The bolts were removed from the assembly following unthreading. Because the buffer cylinder interfered with direct access to the bolt, a bolt removal tool was built with a bolt lifting device offset from the tool centerline. The bolt removal mechanism (Figure 7) consisted of a slotted spherical tip which expanded and retracted by movement of a plunger. The spherical tip was interchangeable with tips of different diameters. This feature allowed use of the removal tool for reflector flux thimble guide removal and fuel shipping container closure head bolt installation and removal (Reference 2) as well as for seed top baseplate bolt removal. The optimum tool design for removal of the top baseplate bolts would have combined the untorquing, unthreading, and bolt removal features but, because the tool had to be offset, this design was not feasible. Testing was also performed using a hex-shaped expandable tip. This tip, however, was more difficult to install into the bolt head, and the bolts fell off the tip when bumped.

When the bolts were removed, the baseplate was held in place by the spring force provided by the top grid and the clamping force applied by the jacks on the seed/blanket disassembly stand at the baseplate elevation. A possibility existed that radiation-induced relaxation would cause the spring force of the grid against the outer shell to decrease to very low values. In this case, the baseplate would be supported only by the disassembly stand clamping force and could have dropped down onto the top of the bottom mounted rod ends, making installation of the grappling adapter very difficult. Another potential problem was that the remaining grid spring force and disassembly stand clamping force could have caused shifting of the shell, support

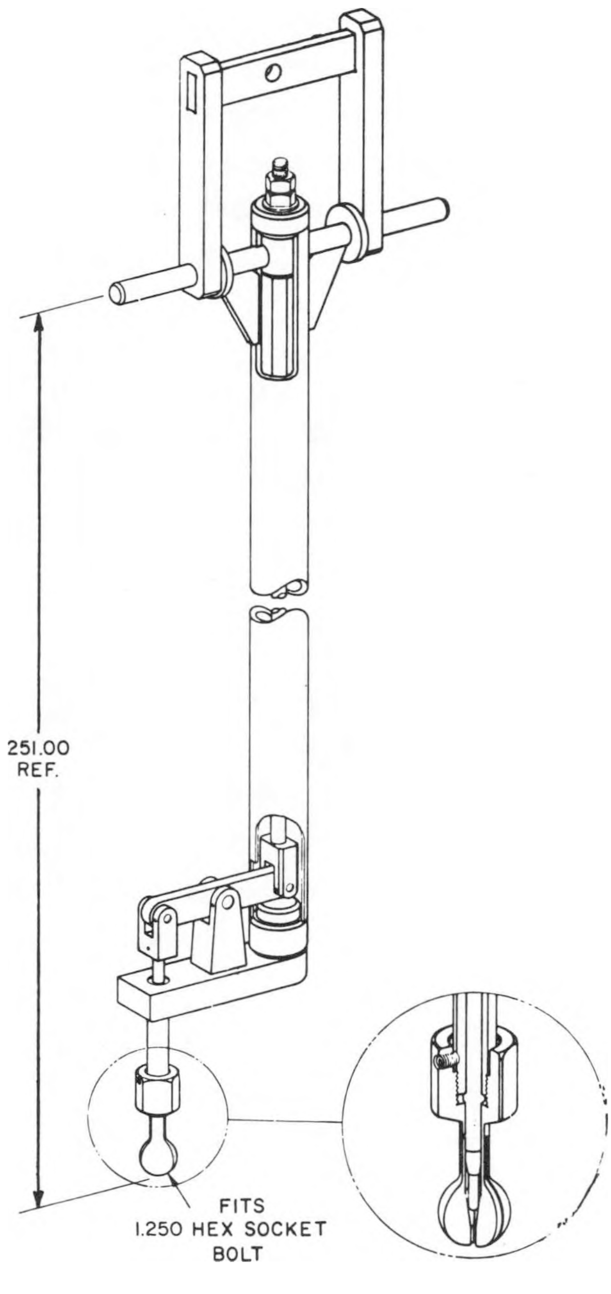



Figure 7. Typical Bolt Removal Tool

post, and baseplate when the support shaft and cover plate were removed. This shifting would misalign the holes, preventing access to the threaded hole in the baseplate (which was the only means of attaching the grapple adapter to the module). To minimize the chances that the baseplate would drop or the holes would misalign, bolt removal was sequenced such that only five of the six bolts were removed initially, leaving one to maintain the position of the baseplate. Five threaded studs were then installed into the baseplate. The disassembly stand clamping force was then increased to hold the baseplate in place. The sixth bolt was then untorqued, unthreaded, and removed; and the last stud was installed.

### 3.1.3 - Support Shaft Removal

Support shaft removal was performed using the seed module handling tool. The handling tool was engaged with the buffer cylinder, and the support shaft was raised from the module and transferred to a storage location prior to disposal (Figure 8).

### 3.1.4 - Grappling Adapter Installation

After removing the support shaft, the height of the installed studs was measured. The height of the six studs was limited to a maximum of 1 inch above the seed module shell to allow for installation of crush block material for shipping (Reference 2). The stud height measurement verified that the stud did not exceed the 1-inch requirement and also verified that the stud was high enough to provide sufficient thread engagement with the nuts which would secure the shipping plate to the module.

A means of grappling the seed module with the handling tool was required after removal of the support shaft. Because the seed module handling tools in use at the Naval Reactors Expended Core Facility (ECF) in Idaho were different from those used at Shippingport, two adapters (bolted together) were installed on the seed module top baseplate over the studs. The top part of the adapter assembly permitted use of the Shippingport seed handling tool for transfer of this module to the seed storage rack or the M-130 shipping container. After the module was installed in the M-130 container, the Shippingport portion of

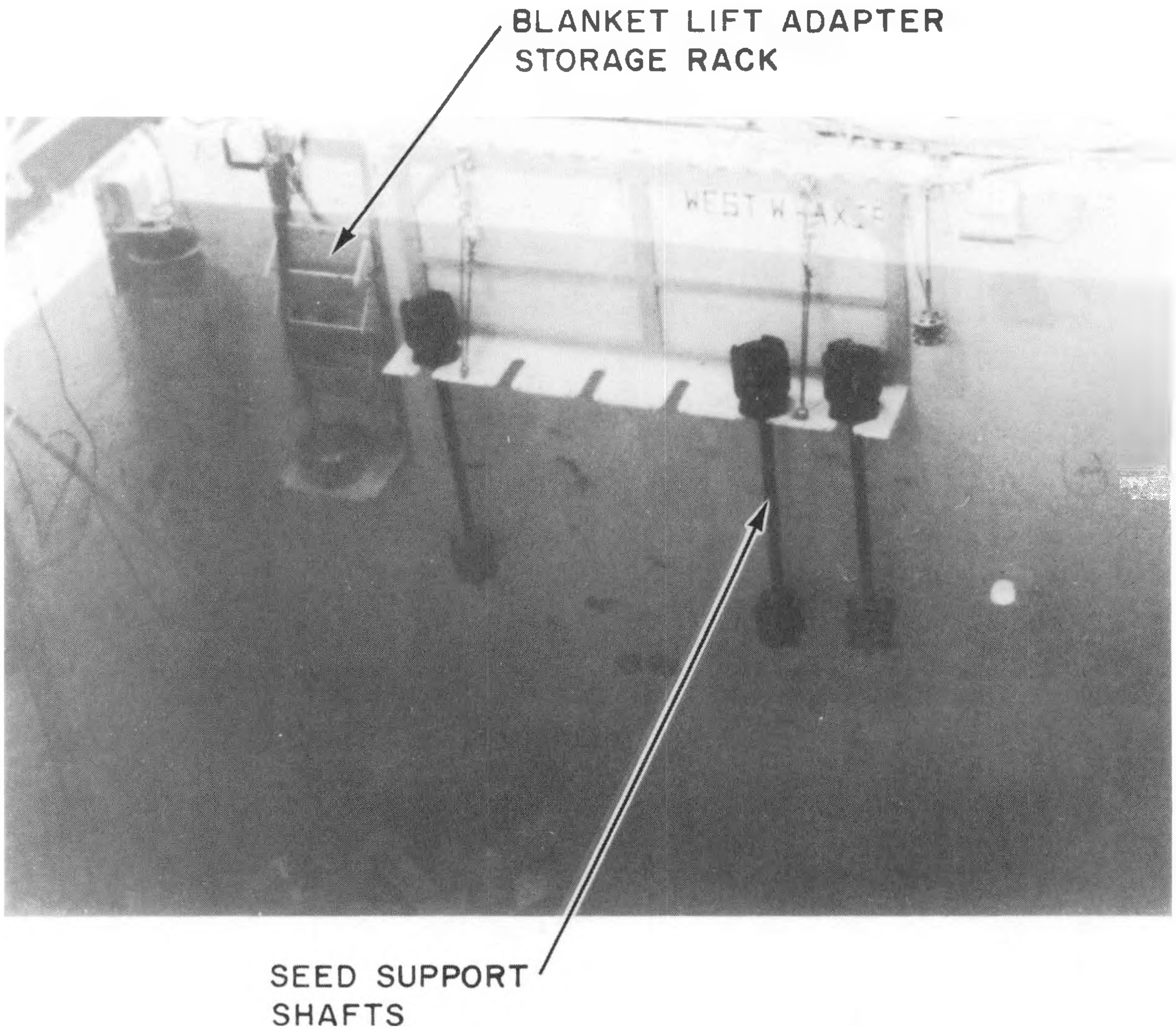



Figure 8. Seed Support Shafts on Storage Rack

this adapter was unbolted and removed, exposing the shipping plate with its accommodation for handling at ECF.

The shipping plate was secured to the module with nuts threaded onto the six studs previously installed. The nut installation tool (Figure 9) had two main features, a hex socket tip and a nut loading rod. The hex socket tip had an 11-inch deep hexagonal cross-section tube capable of holding seven nuts. Installation of a nut onto a stud was a two-step operation: (1) release a nut from the nut loading rod, and (2) thread it onto a stud. After engaging a stud with the pointed tip of the tool, the tool body was restrained and the nut loading rod was turned counterclockwise by inserting an Allen wrench into the socket at the top of the tool. This fed all the nuts down the rod. When the lowest nut reached the end of the threaded portion of the nut loading rod, it fell a fraction of an inch, guided by the socket tip, to rest on top of the stud threads. It could not engage the stud threads because it was not turning. As the next lowest nut made contact with the disengaged nut, the nut loading rod was raised from the thrust bearing. This was a visible indication that a nut had been released. The nut loading rod was then turned several turns clockwise to raise the nuts still engaged with the nut loading rod to ensure that only one nut would be released. The Allen wrench was then removed from the nut loading rod. The nut resting on top of the stud threads was also engaged with the hex socket tip, so the entire tool was turned clockwise to thread the nut onto the stud. Six of the nuts were installed on the six studs to hold the shipping plate/handling adapter on the module. The seventh nut was needed to verify that the sixth nut had been released. Once the nuts were installed, a measurement was taken to verify that the nuts were fully seated and did not exceed the 1-inch height requirement.

Preparation of the seed module was then complete and it could be removed from the disassembly stand. The module handling tool was grappled to the Shippingport adapter, the disassembly stand seed clamps were unclamped and retracted, and the intrusion bar was opened. The module was then transported to the fuel storage rack or to the M-130 shipping container.

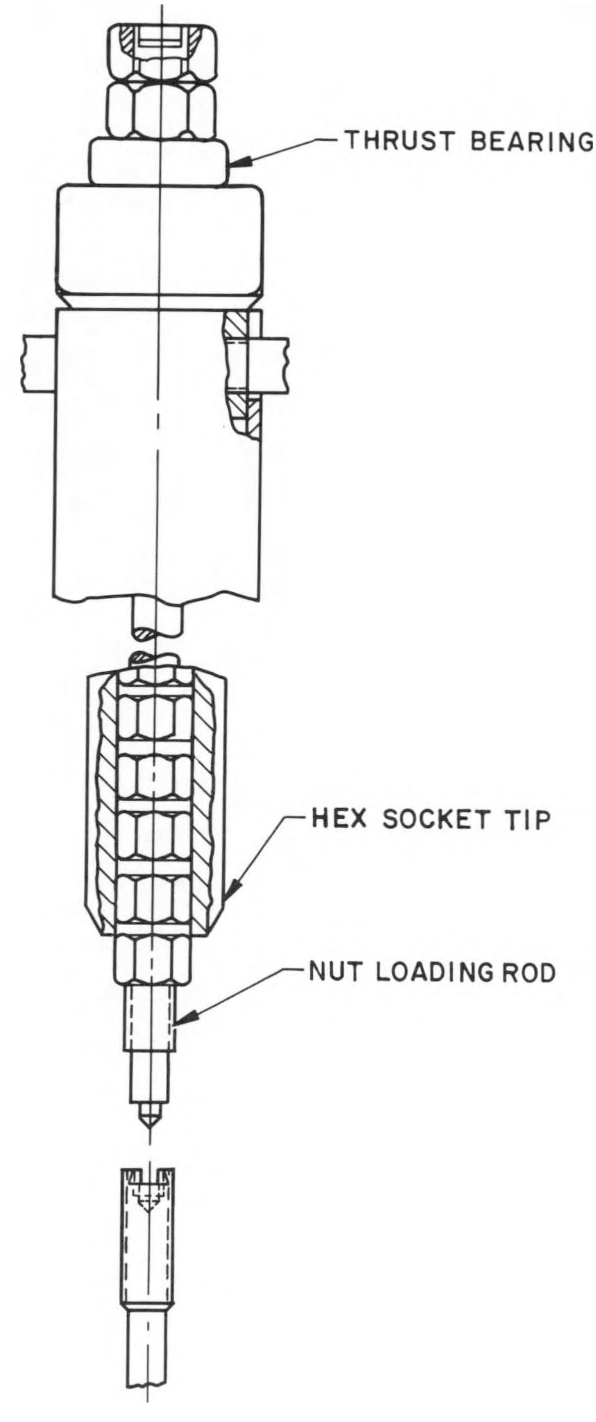



Figure 9. Seed Module Stud Nut Installation Tool

## 3.2 - BLANKET MODULE DISASSEMBLY

To reduce the length of the blanket modules (Figure 10) to fit in their M-130 shipping container, the support tube, seal block, stub tube, and guide tube extension were removed. After removal of the seal block, an adapter was installed onto the remaining portion of the module to allow handling with the same module handling equipment that was used to remove the module from the reactor.

The blanket assemblies provided a guide path for the movable seed assemblies. This path was formed by three components: the blanket support tube, the guide tube, and the guide tube extension. The blanket support tube also acted to suspend the blanket assemblies from the closure head by means of the module suspension system (Reference 1). The guide tube was an integral part of the blanket fuel module, comprising the internal structural member. It extended from the top of the module (where it connected to the support tube and seal block) to the bottom (where it connected to the guide tube extension and stub tube). The guide tube extension was a hexagonal tube provided to guide the seed module when it was positioned for reactor shutdown (i.e., with the fueled portion of the seed module below the fueled portion of the blanket module to provide minimum reactivity). The guide tube extension and stub tube were both connected to the guide tube by the same set of bolts.

The top surface of the seal block was about seven feet below the water surface. Tools used for the following operations were about 15 feet long to provide comfortable access to the operating components.

### 3.2.1 - Thermocouple Guide Tube Cutting

Thermocouple guide tubes on two of the blanket support tubes were located directly in front of top baseplate bolts as shown in Figure 11 (four locations total). Due to the length of the top baseplate bolt and the spacing between the bolt, the brackets, and the splash plate, a tool could not be designed to remove the four bolts blocked by the thermocouple tubing without first removing the tubing. To gain access to these bolts for untorquing and unthreading to enable removal of the support tubes, the section of tubing between mounting

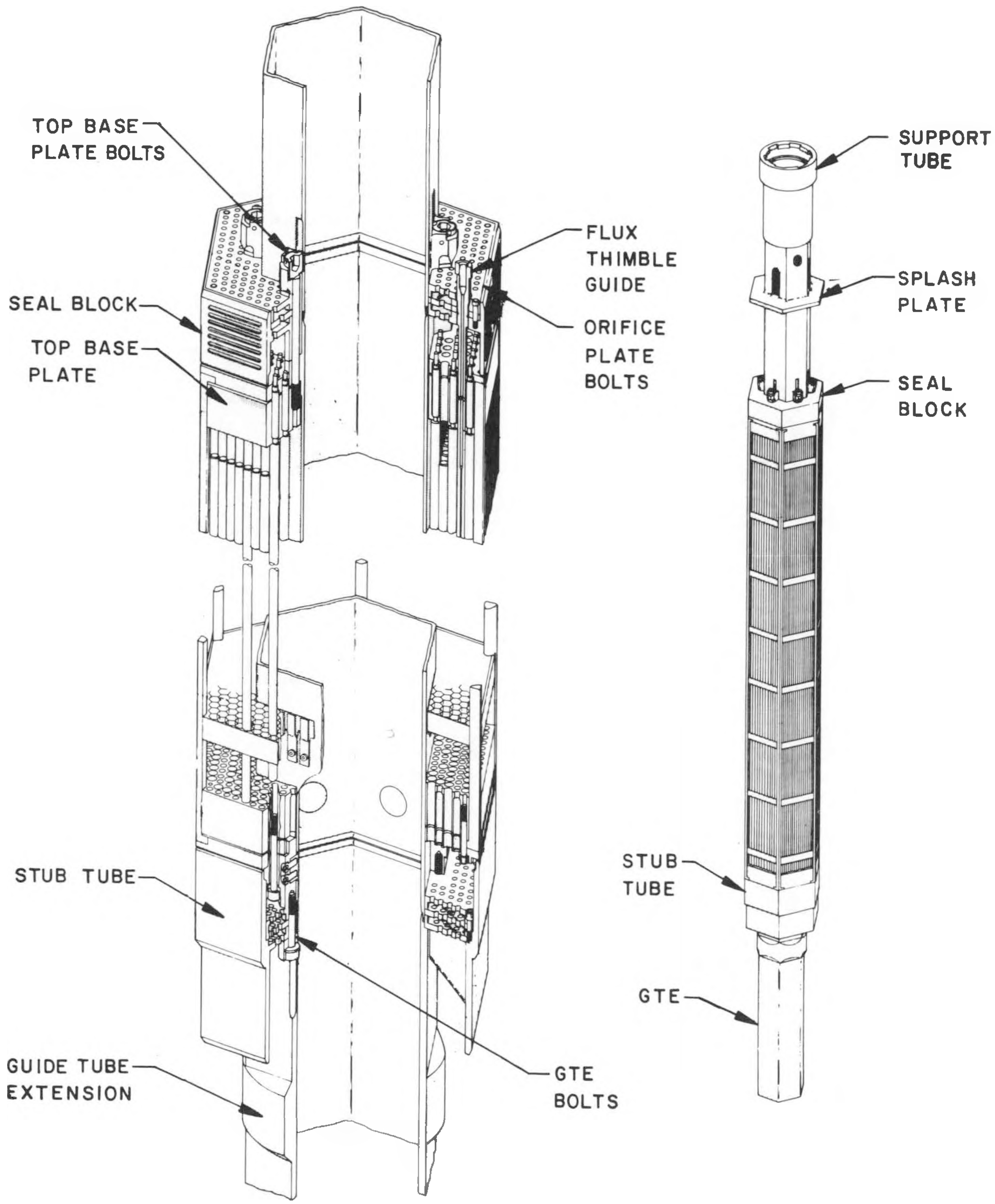



Figure 10. Blanket Fuel Assembly

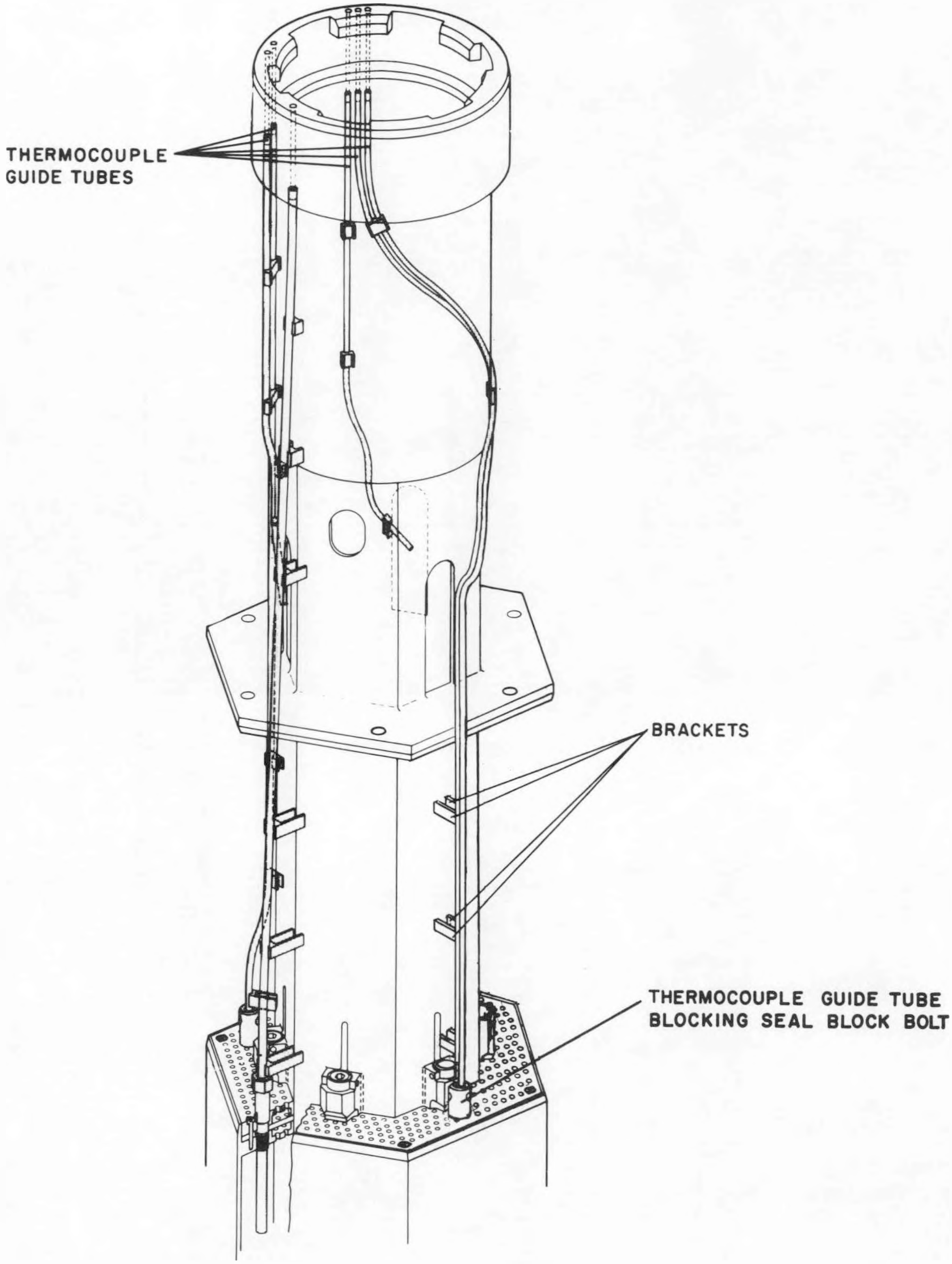



Figure 11. Top Baseplate Bolt Access Blocked by Thermocouple Guide Tube

brackets on the support tube was removed. Hydraulic shears were used to perform the thermocouple tube cutting. Figure 12 demonstrates the operation of the hydraulic shear and tubing retrieval tool on a training mock-up.

3.2.2 - Support Tube Removal

Captivation of the blanket top baseplate bolts was accomplished using the locking cup crimping method described for seed top baseplate bolt captivation (Section 3.1). Deforming the crimps of the blanket top baseplate bolt locking cups was performed during the untorquing/unthreading operations by providing up to 200 ft-lb torque to override the crimp. Because the blanket top baseplate bolts were larger than the seed top baseplate bolts, shearing of the bolt head was not a concern when overriding the crimp as it was with the seed bolts. A minimum of 350 ft-lb was need to yield the bolts.

The tool required to untorque and unthread the top baseplate bolts had to be offset around the splash plate. Also, the 200 ft-lb torque required to override the locking cup crimp and break loose the top baseplate bolts was too high to use a ratchet mechanism on the tool tip. Therefore, the tool was designed with interchangeable tips: one for untorquing and one (a ratchet mechanism) for unthreading. The untorquing tip was used until the running torque had decreased well below the 50 ft-lb torque capacity of the unthreading tip.

Unlike the seed module, the blanket module top baseplate was bolted in place to the support post so that the baseplate position could not change when the top baseplate bolts were unthreaded. Since the top baseplate could not move, all six bolts were untorqued and unthreaded in one cycle (as opposed to seed modules in which five bolts were removed and replaced with supporting studs before the sixth bolt was removed). Six of the 12 support tubes, along with other components, were placed in the PWR-2 lower core barrel (Reference 1, Appendix A-7) for disposal. The remaining six support tubes were placed in Vandenburgh liners for disposal. It was not necessary to remove the baseplate bolts prior to installing the support tube into the Vandenburgh liners. However, to accommodate disposal of the support tubes in the PWR-2 lower core barrel, three top baseplate bolts per support tube were removed prior to

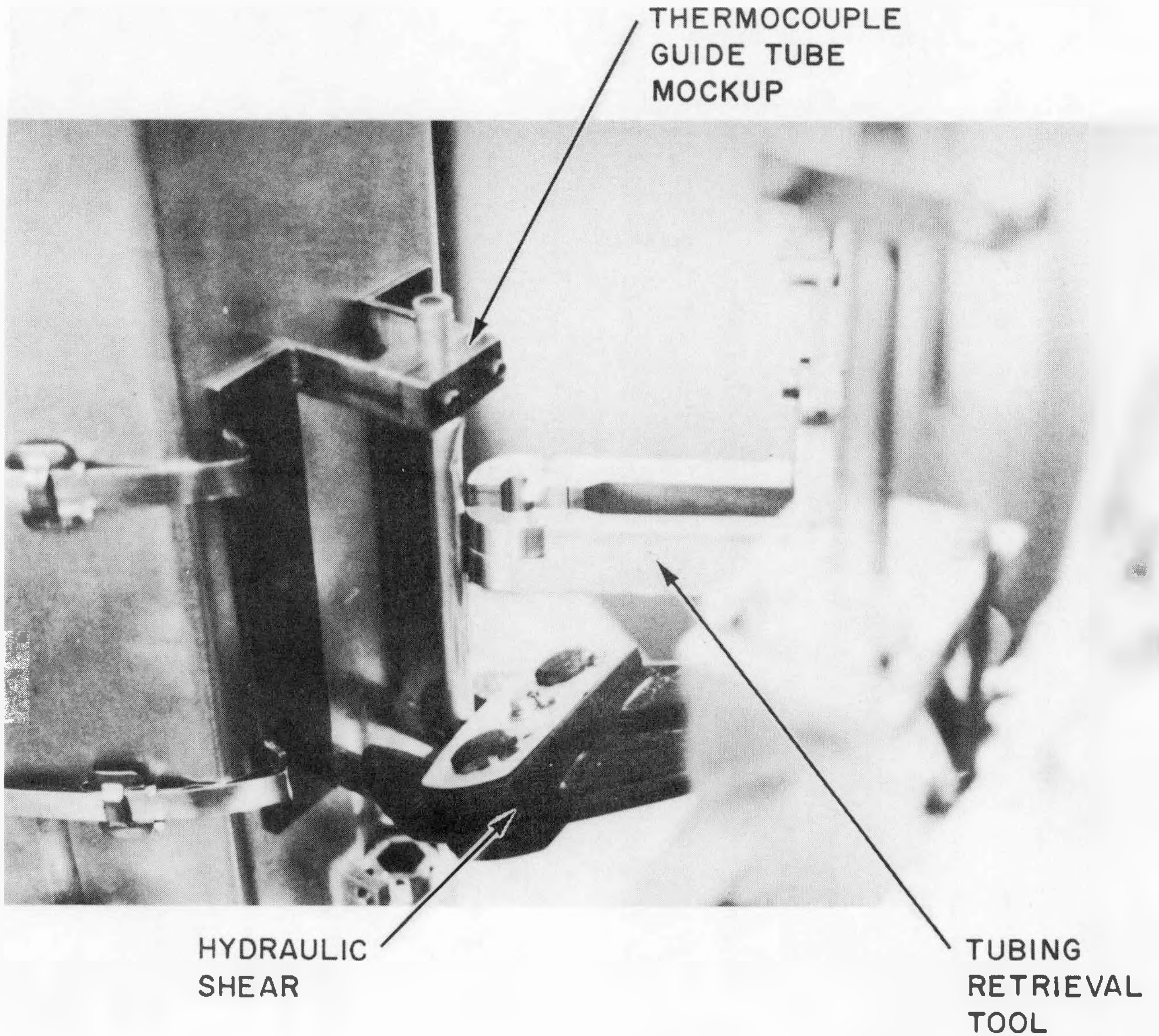



Figure 12. Cutting and Retrieving a Thermocouple Guide Tube Section (Training Mock-up)

support tube removal. These bolts were removed using a tool with the same offset design as was used for seed top baseplate bolt removal (Figure 7).

Once the top baseplate bolts were unthreaded, the seal block and the support tube were not secured to the remainder of the module. Possible interference between the external hex of the support tube and internal hex of the seal block could cause lifting or cocking of the seal block during support tube removal. To prevent lifting of the seal block during support tube removal, holddown clamps were installed (Figure 13). The support tube was removed and disposed of using the blanket handling tool or the support tube handling tool, depending on the disposal location. Spacers (shims of selected thicknesses) were located under the bolt lugs on the support tube. These spacers were part of the LWBR design to optimize core alignment. During removal of the support tube, the spacers sometimes adhered to the underside of the bolt lug. A spacer stuck to a bolt lug could fall off in transit to the support tube disposal location. To prevent loss of the spacer, a visual inspection was performed after the support tube was raised slightly to verify that a spacer did not adhere to a bolt lug. If the spacers were stuck, they were knocked off the bolt lugs onto the surface of the seal block using a probe pole. Once the support tube was removed, a hex-shaped bucket was installed in the seal block/guide tube hex, and the spacers were swept off the seal block into the bucket. In spite of great care in accounting for the spacers, two of them were lost during disassembly. One was pushed into the guide tube by the baseplate bolt as the support tube swung free; the second was lost during installation of the bucket into the guide tube. Both fell onto the debris plenum at the bottom of the disassembly stand and did not interfere with any subsequent operations.

### 3.2.3 - Flux Thimble Guide Removal

A flux thimble guide was threaded into the seal blocks of seven of the 12 blanket modules as shown in Figure 10. The flux thimble guides, which extended above and below the seal block, were removed before seal block removal. Direct access to a flux thimble guide allowed the design of a single tool to perform the untorquing, unthreading, and removal operations. The flux thimble

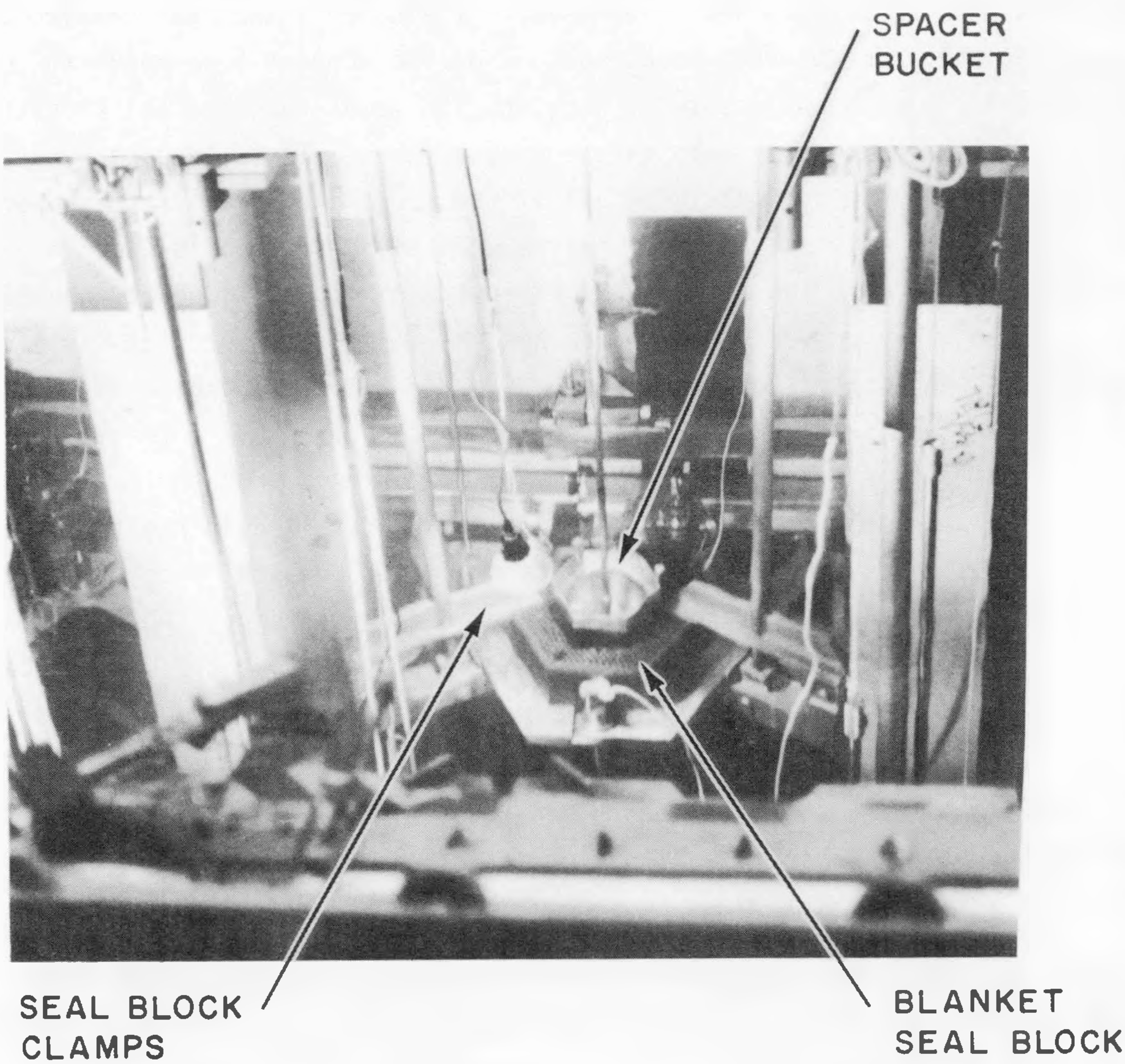



Figure 13. Blanket Seal Block Clamps

guide removal tool shown in Figure 14 consisted of three major components: the untorquing/unthreading shaft, the tool body, and the latch arm. The hex socket tip of the untorquing/unthreading shaft was engaged with the head of the flux thimble guide, and rotated until the flux thimble guide was unthreaded. Because the flux thimble guide was not a structural member, a torque of about 15 to 20 ft-lb was sufficient to break the guide free and to begin unthreading. After the flux thimble guide was unthreaded, the latch arm was swung underneath the head. The latch arm was then raised to secure the flux thimble guide to the removal tool, and the guide was transported to disposal.

3.2.4 - Seal Block Removal

In addition to the support tube, it was necessary to remove the seal block from a blanket module to reduce its length sufficiently to fit it into the blanket module M-130 shipping container. Removal of the top baseplate bolts to remove the support tube left the seal block and orifice plate loose on the module. To remove a seal block, three of the six orifice plate bolts, located 120 degrees apart, were removed to provide attachment points for a sling assembly while still leaving the orifice plate attached to the seal block. The orifice plate bolt removal tool resembled the flux thimble guide removal tool (Figure 14) except that the tip of the untorquing/unthreading shaft was a hex key. The hex key was inserted into the bolt head and the bolt was unthreaded; then a latch arm was swung under the bolt head, capturing the bolt to the tool. The bolt was withdrawn and transported to disposal. After the three orifice plate bolts were removed, a sling assembly was attached to the seal block at each of the three orifice plate bolt hole locations. A three-legged lifting device with turnbuckles on each leg was centered over the seal block, and one sling assembly was attached to each turnbuckle. A level, vertical lift was required for removal to prevent binding between the seal block and guide tube. The turnbuckles on the lifting device provided adjustment to obtain the desired levelness. After removal, the seal blocks were transported to the Vandenburgh CNS 3-55 liners (Figure 1A) for disposal.

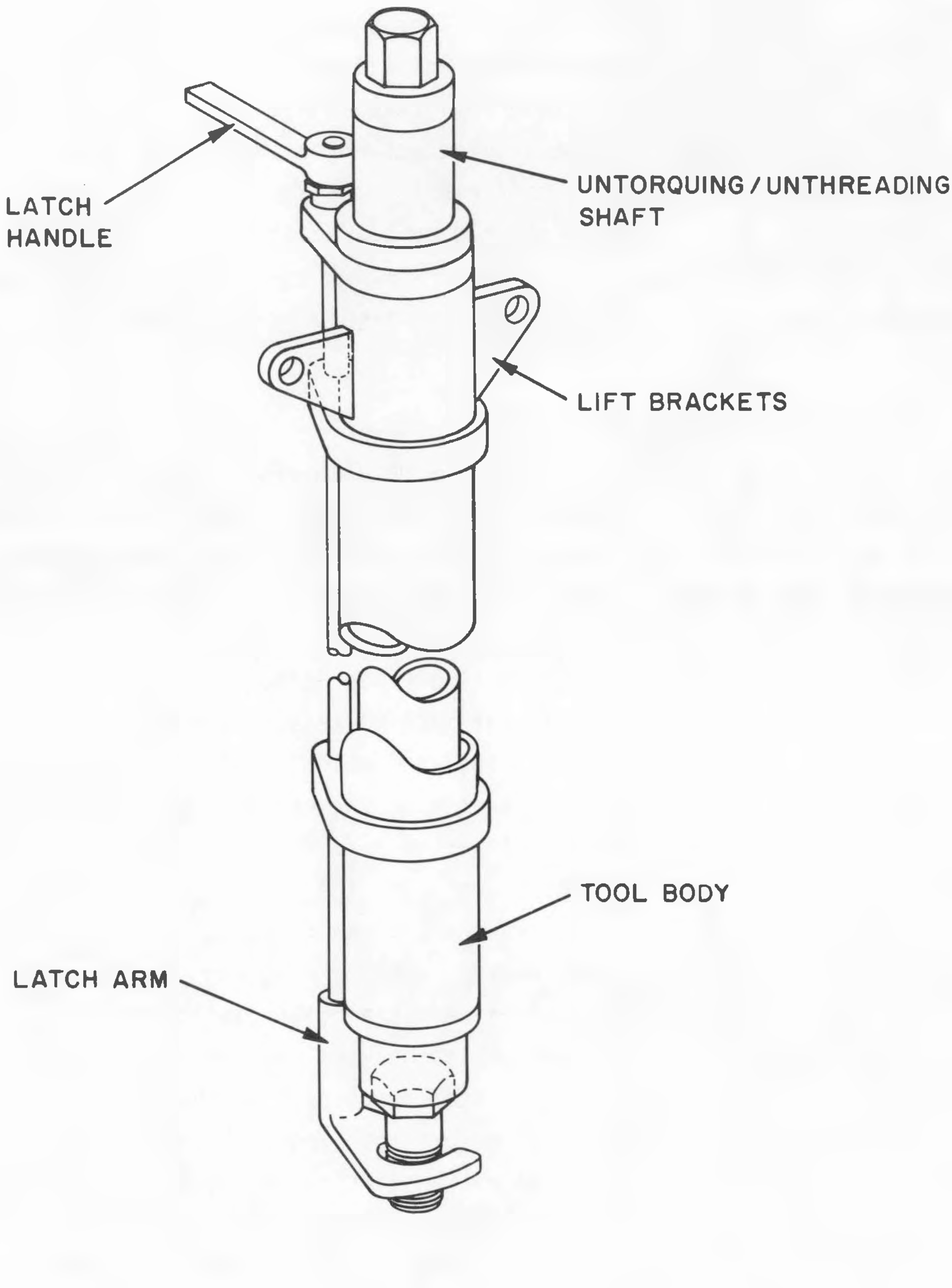



Figure 14. Flux Thimble Guide Removal Tool

A means of attaching the blanket handling tool to a blanket module after removal of the seal block was required. Therefore, a lifting adapter was installed over the hex on the guide tube using a short version of the blanket handling tool. Another tool was used to install and tighten the bolts that secured the lifting adapter to the module.

3.2.5 - Separation of the Guide Tube Extension/Stub Tube from the Fuel Module

Before removing the fuel portion of the module from the disassembly stand, the stub tube and guide tube extension (GTE) had to be separated from the module. The stub tube and GTE were attached to the module by the GTE bolts (Figure 10). Because access to the GTE bolts was blocked by the stub tube, a machine which cut through the guide tube wall from the inside, then through the bolt, had to be used. The cutting machine consisted of a diamond grinding wheel with an air motor drive which fitted inside the blanket module and seated on a leveling platform on the disassembly stand. A drive shaft connected to the grinding wheel assembly swung the wheel through an arc that permitted two GTE bolts 180 degrees apart to be cut, after which the machine was raised, turned, and reinserted two more times to cut all six GTE bolts. Appendix A2 provides a detailed physical and operational description of the GTE bolt cutting machine.

Once the lifting adapter was installed and the GTE bolts were cut, the module was prepared for removal from the disassembly stand. The blanket handling tool was grappled to the lifting adapter and the blanket clamp arms of the stand were opened. The separation device jacks in the disassembly stand remained clamped to the stub tube during removal of the module to aid in separating the GTE/stub tube combination from the fuel module. The disassembly stand intrusion bar was opened and the module was transported to the fuel storage rack or to the M-130 shipping container. After the module was installed in the M-130 container, the lifting adapter was removed and replaced with a shipping plate (Reference 2), which served to both lock the module in place and provide a lift point for handling at ECF.

### 3.2.6 - Stub Tube/Guide Tube Extension Removal

The final blanket module disassembly operations were to remove the GTE and stub tube from the disassembly stand and place the components into disposal containers. Each guide tube extension weighed 250 pounds and each stub tube weighed 100 pounds. To reduce radioactive waste volume, four guide tube extensions were placed in one disposal container and four stub tubes were placed in another disposal container along with several other components. Without disassembling the GTE from the stub tube, only one stub tube/guide tube extension assembly would have fitted into each container. However, the stub tube could not be separated from the GTE while these components were in the disassembly stand because the disassembly stand was not designed for this operation. Therefore, an auxilliary separation stand next to the fuel module disassembly stand was used to support the GTE while removing the stub tube.

Because of space limitations in the disassembly stand, the guide tube extension/stub tube assembly was grappled from the inside hex surface of the GTE. This surface was smooth, with no penetrations or ledges to aid in grappling; hence, a friction lift was required. A section of the tool used to perform this operation is shown in Figure 15. The base of the tool was hexagonal, and fitted into the internal hex of the GTE. Two movable panels, 120 degrees apart, were fitted with sharp lift pins; a third pin was provided on a fixed panel 120 degrees from the movable pins. The movable pins were forced outward by operation of the drive shaft to make dents in the relatively lightweight components. The tool was designed with movable positioning blocks and replacable lift pins so that the same tool could be used for lifting both the GTE and the stub tubes. It was later judged that the sequence of lifting the assembly from the disassembly stand, placing it in the separation stand, then placing each component in shipping containers could best be performed by having two tools: one preset for use on GTE/stub tube assemblies and (after disassembly) guide tube extensions, and the other preset for stub tube lifts. Changeout of the positioning blocks and lift pins (two times for each disposal cycle) would have required unnecessary radiological exposure for personnel.

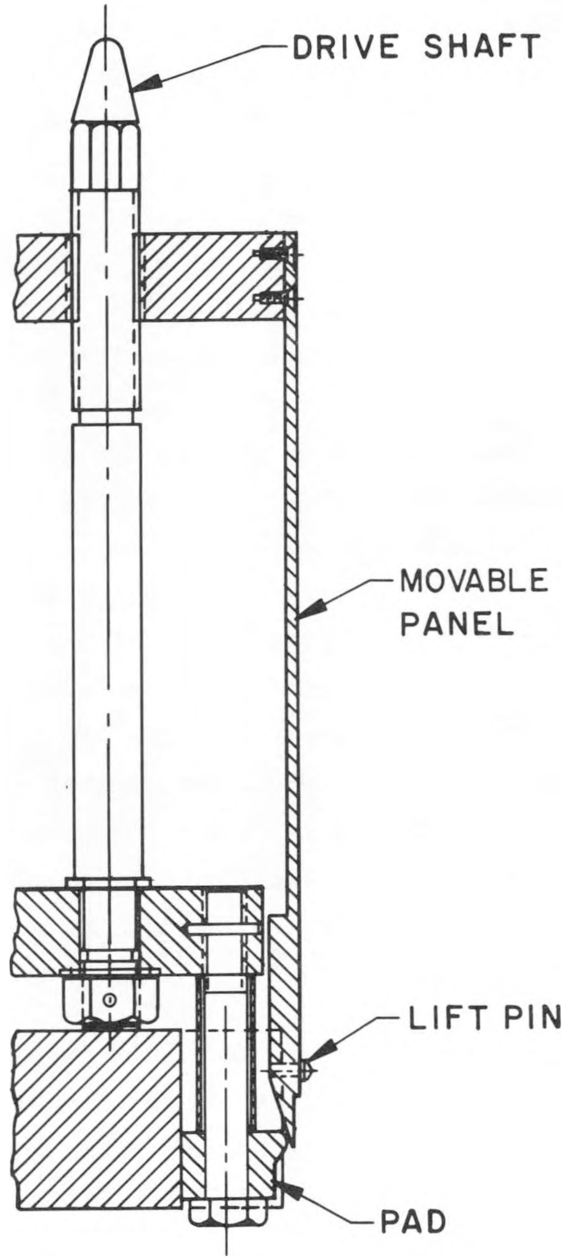



Figure 15. Blanket Guide Tube Extension/Stub Tube Lifting Tool Detail

A few operational difficulties occurred during disposal operations on the guide tube extensions due to limitations on the lifting tool capabilities. On three occasions within a 24-hour period, difficulty was encountered while attempting to place blanket module guide tube extensions into disposal containers using the GTE handling tool. Manipulation was required to seat extensions in the liners because of a slight sloping of the liner rack. During manipulation, the handling tool became disengaged from the extensions. Two of the three extensions were eventually seated in the containers, but one extension was left in a partially raised condition after repeated efforts to seat it failed. Three factors caused this problem: the lack of built-in grappling points to provide positive attachment of a lifting tool to the extension, the sloping deck on the disposal container rack, and tight clearances between the extensions and the segmented divider which supported the tubes in the containers. To continue with disassembly operations, an engineering evaluation of the handling tool resulted in increasing the torque on the drive shaft from 35 to 45 ft-lb, thus obtaining deeper penetration of the sharp conical lift pins. Work methods were discussed and a method was developed that ensured full penetration of the pins within the prescribed torque limits. Also, two of the three disposal container dividers had not been installed at the time of these events. They were modified to provide larger clearances to account for some of the misalignment caused by sloping racks. The remaining nine extensions were inserted into disposal containers with no major problems.

## 3.3 - REFLECTOR MODULE DISASSEMBLY

To reduce the length of the reflector module (Figure 16) to fit in the M-130 shipping container, the seal block had to be removed. The seal block removal operations were performed with the reflector module installed in the M-130 shipping container. The top of the seal block was 17 feet under the water surface.

### 3.3.1 - Flux Thimble Guide Removal

One reflector module contained a flux thimble guide which was similar to the blanket flux thimble guide. The reflector flux thimble guide, which extended above and below the seal block, had to be removed to permit seal

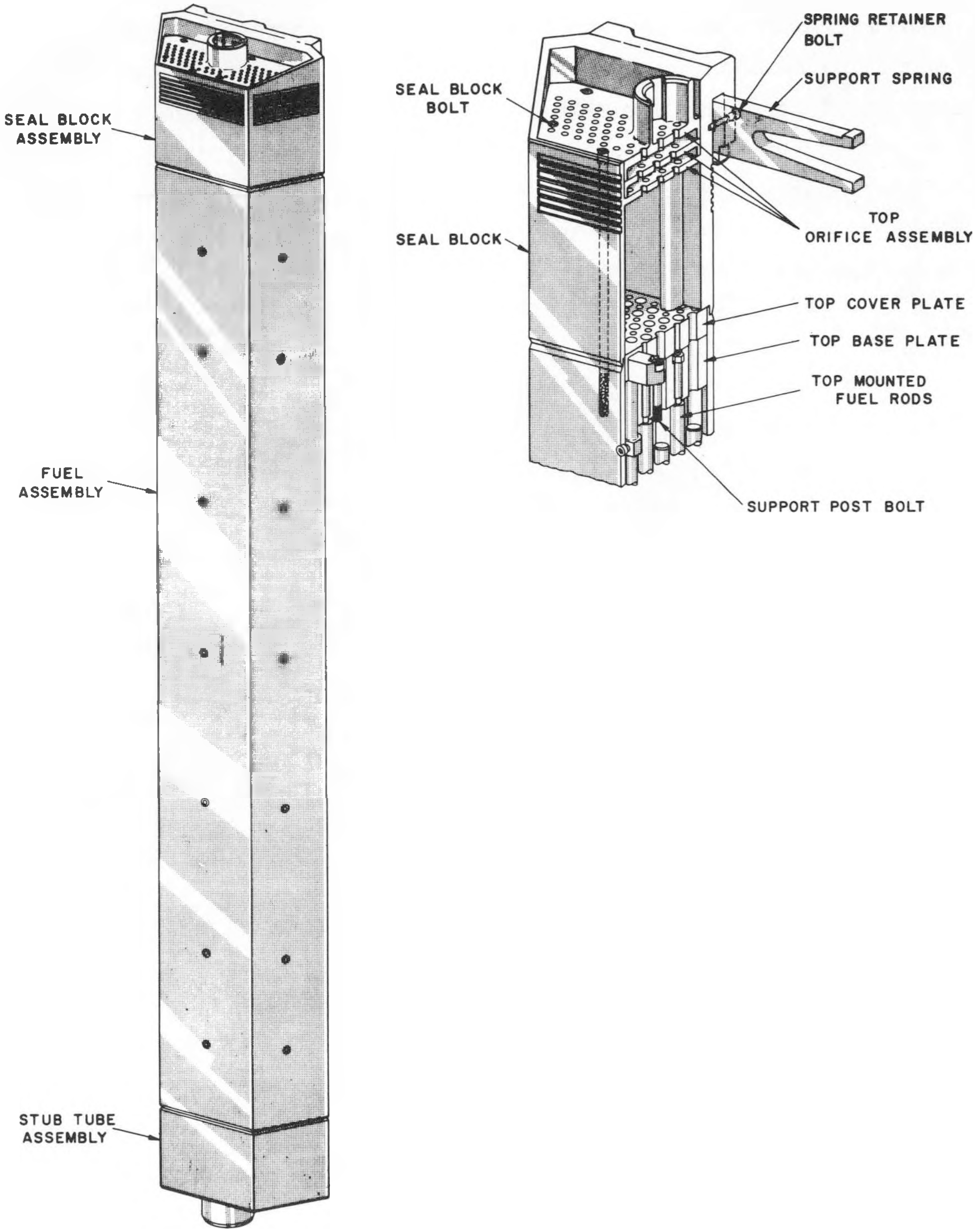



Figure 16. Reflector Fuel Assembly

block removal operations and post-removal scrapping. The flux thimble guide was removed by unthreading and lifting, using the two seed disassembly tools with adapters installed, which were used to unthread and remove the seed top baseplate (Section 3.1). The blanket flux thimble removal tool could not be used for removal of the guide installed in the reflector seal block because of the difference in working depth at the disassembly stand compared to that in the M-130 shipping container. The seed disassembly tools were of the proper length and were easily adapted for this one-time operation.

### 3.3.2 - Seal Block Removal

The size of the hex cavity in the reflector seal block bolts and the seed top baseplate bolts was identical. Two tools used for seed top baseplate disassembly were also used to unthread and remove the reflector seal block bolts. The bolts could not be removed along with the seal block assembly because they would have interfered with the seal block removal tool when the seal block was placed in the disposal area. Once the seal block bolts were removed, the seal block assembly was removed. A seal block removal tool, which clamped to the outside of the seal block (Figure 17), was used to remove the seal block assembly and transport it to a disposal area. The reflector handling tool could not be used for this operation because, after removing the seal block bolts, the top orifice assembly, which included the lifting lug (Figure 16), was not connected to the seal block. As was also true for the blanket GTE/stub tube assembly (Section 3.2.6), no specific lift points had been designed into the reflector seal block. The louvres in the labyrinth seal at the top of the seal block (Figure 16) were used to provide an attachment for the lifting tool guides. The seal block removal tool was designed to accommodate both shapes of reflector modules. Figure 17 shows the seal block removal performed on the training mock-up. After removal of the seal block, preparations were made for reflector module shipment to ECF as described in Reference 2.

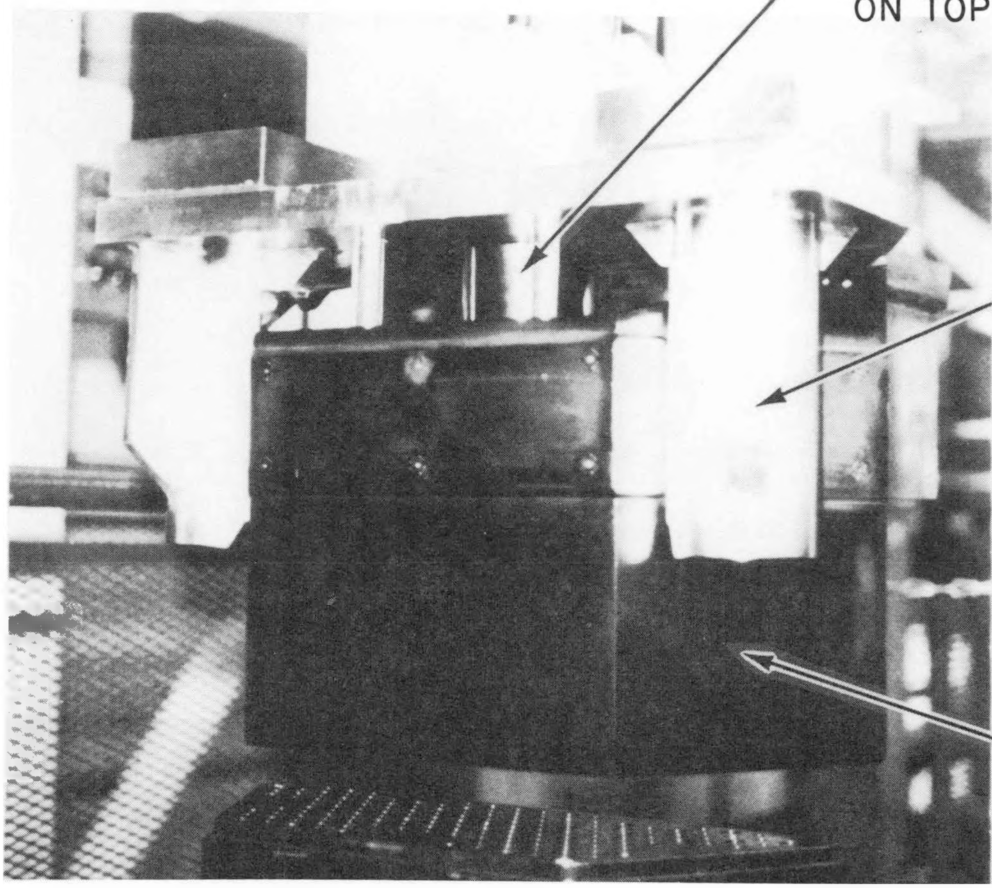



Figure 17. Reflector Seal Block Removal (Training Mock-up)

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## SECTION 4 - DISASSEMBLY SUPPORT

Partial disassembly of LWBR fuel modules so that they would fit into M-130 shipping containers was one phase of defueling operations which included removing fuel modules from the reactor, placing them into M-130 shipping containers, and shipping them to the Expended Core Facility (ECF). Details of operations other than module disassembly are presented in References 1 and 2.

A discussion of the support activities required to accomplish the defueling program is presented in Reference 1. Defueling organization, support groups, radiation and contamination control, facility preparation, and reactivity control are discussed in the context of the entire program. Because each phase was distinct, certain support activities are better discussed within the context of each separate phase. Such activities are planning and training.

### 4.1 - PLANNING AND SCHEDULING FOR MODULE DISASSEMBLY

The plan for disassembly of the LWBR fuel module was first issued in 1982 as part of the Defueling and Shipping Operational Plan. Basically, the plan provided for seed and blanket fuel modules to be moved into the disassembly stand and disassembled in a systematic manner and in parallel with other fuel handling operations such as fuel module removal, M-130 container loading, or securing modules in the M-130 container. This provided for early disassembly of fuel modules and ensured that more than enough modules would be available for M-130 container loading. Since reflector modules were disassembled after installation into the M-130 container, no special scheduling considerations were required for reflector module disassembly. Disassembly of reflectors occurred immediately after loading into the shipping container and prior to securing the modules in the container for shipout.

As the LWBR defueling progressed, however, it became apparent that fuel handling operations and fuel module disassembly could not be performed simultaneously. Although crew size of the Operations personnel was adequate to support both efforts on a reduced efficiency basis, the facility requirements and the logistics of working both operations side-by-side made it almost impossible to perform. This fact reduced all fuel handling work to series effort and placed a burden on module disassembly to ensure that enough of the proper type of modules were disassembled by the time the next fuel shipping container was available for loading. In addition, disposal and storage of the components to be removed from the modules also played an important role in module disassembly scheduling. A number of highly radioactive components were disposed of in the PWR-2 lower core barrel located in the deep pit (Figure 1B), or stored on racks in the reactor pit; both operations required use of the Fuel Handling Building main crane. Since access to the lower core barrel and main crane was possible only while an M-130 container was not being removed from or installed in the deep pit*, careful planning was required to ensure that conditions were right for module disassembly to proceed without impacting planned fuel transfers.

Considering these factors, final planning called for seed and blanket module disassembly to be completed in time to support loading of a fuel shipping container or loading of the lower core barrel with components for disposal. The schedule through the first six fuel shipments provided only sufficient time, deep pit access, and main crane availability to disassemble the exact number of modules required for the six shipments. It was during the two-month period for preparation, loading, and shipout of the PWR-2 lower core barrel that the remaining fuel modules were disassembled. Disassembly operations were completed well ahead of the final four M-130 loadings.

As expected, disassembly of the first reflector, blanket, and seed modules was slow and identified minor problems which were resolved for subsequent module disassembly. Problems occurred primarily because of differences between conditions existing during training and in actual operation. Most problems during the first disassembly evolution involved corrections to written procedures. A few problems occurred because training was not conducted under water. Typical problems due to this expediency involved

*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.

difficulties observing operations with the underwater TV cameras or with electric cables for the underwater lights becoming tangled with tools. Each of the three evolutions required about twice as many shifts as initially planned. Disassembly time for the same modules later in the defueling improved significantly (Figure 18). Personnel productivity improved and, by the fourth module of each type, the initial time estimates were achieved or bettered. Reflector module disassembly is not graphed since that work was relatively short. Disassembly operations were accomplished in one shift per module almost from the first set of four modules. A total of seven shifts was spent on disassembly of the first four modules, however, because of a tangled wire rope on a disposal tray used to place the disassembled seal block into a disposal container.

Disassembly of reflector and seed modules were straight-line processes. Each began with the removal of top baseplate bolts and continued through to the end in a single direction. Blanket modules, however, had one option during disassembly that the other two module types did not have. The guide tube extension bolts could be cut as the first disassembly operation or could be deferred until last (after support tube and seal block removal and lift adapter installation). This flexibility was very useful in scheduling the disassembly of blanket modules. Guide tube extension bolt cutting was the longest of the disassembly operations, typically five shifts per module. The scheduling option was used to properly position the disassembly and removal of components in the sequence of events. If the deep pit was available for access to the PWR-2 lower core barrel, the cutting operation was initially skipped to remove and dispose of the blanket module support tube and seal block. However, if access to the lower core barrel was restricted by storage of an M-130 closure head, then guide tube extension bolt cutting was performed to fill the time until the M-130 work was completed.

Availability of disassembled fuel modules for loading into the M-130 container was not a problem during the LWBR defueling. Disassembly of fuel modules was adequate to support the need for loading the M-130 containers. No fuel shipping planning changes were required due to fuel module disassembly considerations.

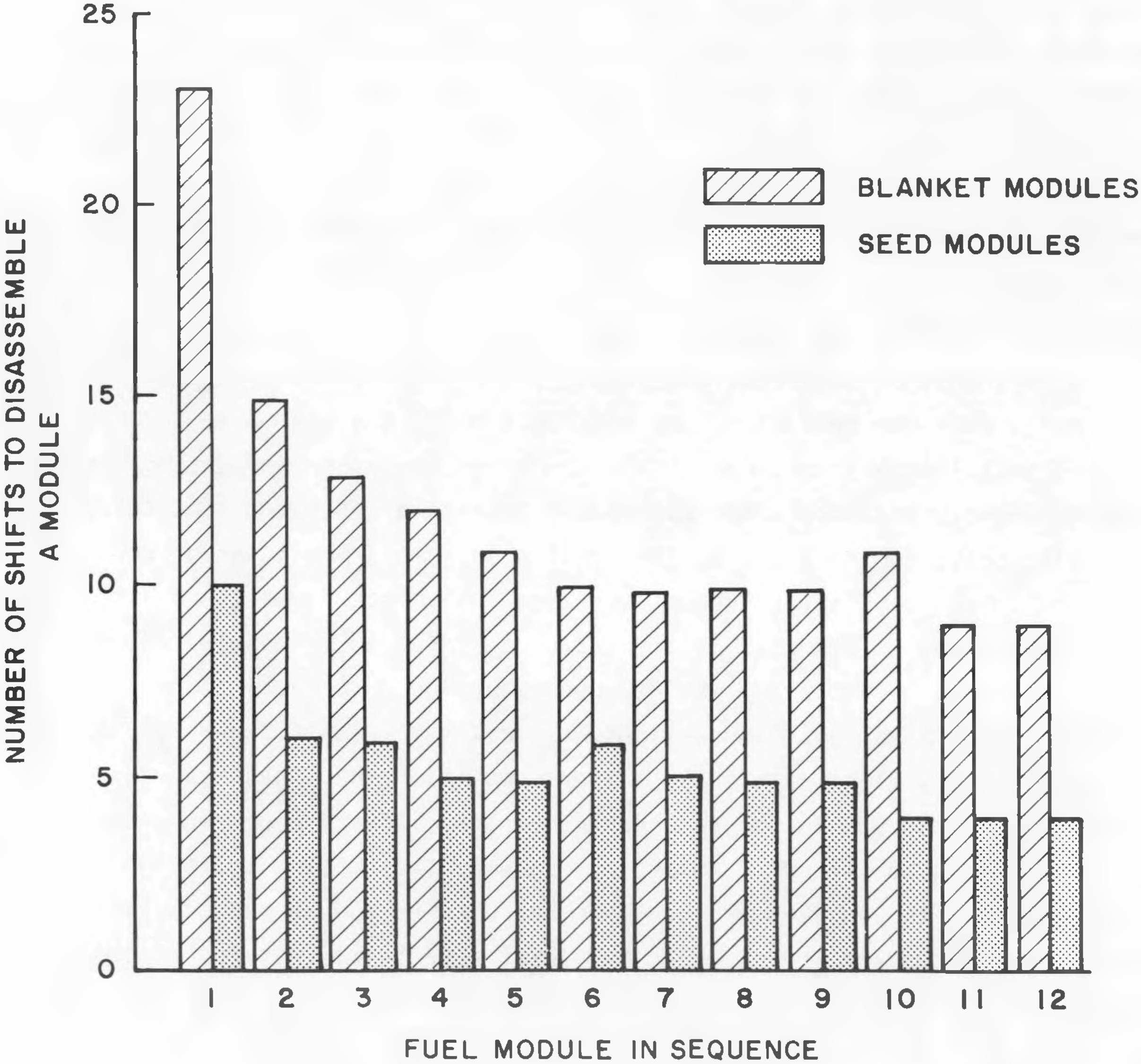


Figure 18. Time Intervals for Fuel Module Disassembly

## 4.2 - TRAINING PROGRAM AT BETTIS AND SHIPPINGPORT

The disassembly training program was designed to prepare and qualify supervisory and nonsupervisory personnel for performing the required operations. The overall responsibility for the content and conduct of the training program was assigned to LWBR Defueling and Shipping. This responsibility included providing all training of Bettis defueling personnel assigned to Shippingport and the training of Duquesne Light Company defueling personnel.

To qualify personnel for fuel module disassembly, the training program was structured with three goals in mind. One goal of the program was to give the trainees an understanding of what was to be accomplished. Another aim was to teach personnel the manner and techniques in which components, tools, and devices were to be handled and operated. Finally, the program was designed to enable trainees to understand the necessity for strict adherence to specific controls and procedures used in defueling. These goals were achieved through the use of numerous training methods, such as lectures, briefings, self study, use of visual aids and mock-ups, demonstrations of equipment and procedures, and participation in operations closely simulating actual disassembly operations.

Training was administered and tailored as much as was practical with consideration of each worker's previous refueling experience and the requirements of the trainee's job classification. Defueling technicians were required to participate in a minimum of two cycles of selected training operations involving the use of actual and simulated defueling equipment and procedures. Trainees were certified as qualified by demonstrating their ability to perform the assigned operations safely and effectively in a reasonable time and to cope with extraordinary and emergency conditions which might arise during defueling. Supervisory personnel such as Shift Defueling Engineers and Defueling Shift Supervisors were required to pass written and oral examinations in addition to directing practical training operations prior to assuming their respective responsibilities in the defueling.

During the two years prior to formal module disassembly training at Bettis in 1982, a thorough hardware and procedure development, checkout, and modification program was conducted. Nonfueled LWBR seed, blanket, and reflector test modules were used during tool and procedure checkout and subsequent training evolutions in a specifically prepared training area at Bettis.

Although disassembly tools had been functionally checked and accepted prior to formal training, some problems were discovered and resolved during training operations where the tools were used in a more realistic manner. One example illustrates the value of the training program to subsequent defueling efficiency. During removal of the seed module support shaft, lifting studs were inserted to replace the removed top baseplate bolts (Figure 2). As conceived prior to training, one tool was used to obtain a measurement of the stud height to ensure that the studs would not interfere with crush block material in the shipping container (Section 3.1.4). If a stud was too high or too low, the height of the stud could be adjusted with a second tool. Finally, after installing the lifting adapters with nuts threaded onto the studs, a measurement of the nut height was made to ensure that the nuts were seated. During training, it was found to be difficult to juggle the two tools used for stud height measurement and adjustment and to find space on the tool racks for the three separate tools used to install, measure, and adjust the lifting studs. A new tool was developed which combined the functions of the three separate tools, which made installation of the stud and measurement of its height a single operation. Potential defueling delays were avoided.

Module disassembly was practiced at Bettis, although some differences between training and actual defueling conditions existed. Work on the module disassembly stand (described in Appendix A1) was conducted in air rather than in water. This was an asset during training because the higher visibility during remote tool operations enabled personnel to familiarize themselves with tool and component behavior more readily. Working in air also allowed close examination of tools and components without the need for underwater video equipment. Although workers encountered a few minor problems at Shippingport during actual module disassembly, such as reduced visibility in the water environment and a few conditions that could not be adequately simulated, they were adequately prepared by their training at Bettis to perform the major disassembly operations safely and effectively.

The overhead lifting device at Bettis was lower than the main crane in the Shippingport Fuel Handling Building. As a result, some of the longer tools used in actual disassembly operations were duplicated in every way, except with a shorter length to accommodate the Bettis crane height. This did not significantly affect the effectiveness of training.

By familiarizing defueling personnel with equipment and procedures, coupled with the identification and correction of hardware and software deficiencies prior to the performance of the actual operation, the amount of radiation exposure to workers was minimized. Simulation of radiological conditions during training helped improve personnel proficiency in the control and handling of radioactive materials, thereby minimizing the time spent in radiation fields, the spread of radioactive contamination, and the generation of radioactive wastes.

Fuel handling training for Bettis personnel was conducted at Shippingport in the deep pit (Figure 1B) using actual fuel handling tools and facilities with training fixtures for blanket and reflector modules and a seed module mock-up. Training for module grappling, removal from the reactor vessel, installation and removal from the disassembly stand, and installation and removal from the fuel storage rack was conducted. Minor differences between simulated and actual conditions included such things as different grappling elevations, different weight indications, and an inability to simulate close module clearances in the reactor vessel. These differences did not significantly affect the training of personnel for handling of nuclear fuel.

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 towards the successful completion of the LWBR defueling at Shippingport in the required time and quality constraints.

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## SECTION 5 - SUMMARY AND CONCLUSIONS

Disassembly of LWBR fuel modules at Shippingport was required to permit them to fit into standard shipping containers for transfer to the Naval Reactors Expended Core Facility in Idaho. Disassembly of fuel modules was limited to removal of seed module support shafts; reflector module seal blocks; and blanket module support tubes, seal blocks, and extension tubes. Components removed from fuel modules were placed into containers for subsequent disposal.

A specially equipped disassembly stand was developed and used for removal of components from seed and blanket modules. Removal of seal blocks from reflector modules was accomplished after these modules were installed in the designated M-130 shipping container.

Removal of blanket module extension tubes required a unique air-powered grinding machine, which severed the attachment bolts by cutting through the guide tube walls from inside the module guide tube.

A comprehensive tool checkout and personnel training program prior to initiating disassembly operations produced significant benefits in terms of reduced radiation exposure to personnel and fewer operational problems. No significant problems occurred during disassembly. Radiation and personnel exposure levels were much lower than predicted.

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## SECTION 6 - 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, "Shipment of LWBR Fuel Assemblies from Shippingport (PA) Atomic Power Station to Expended Core Facility, Idaho," WAPD-TM-1553, October 1987.

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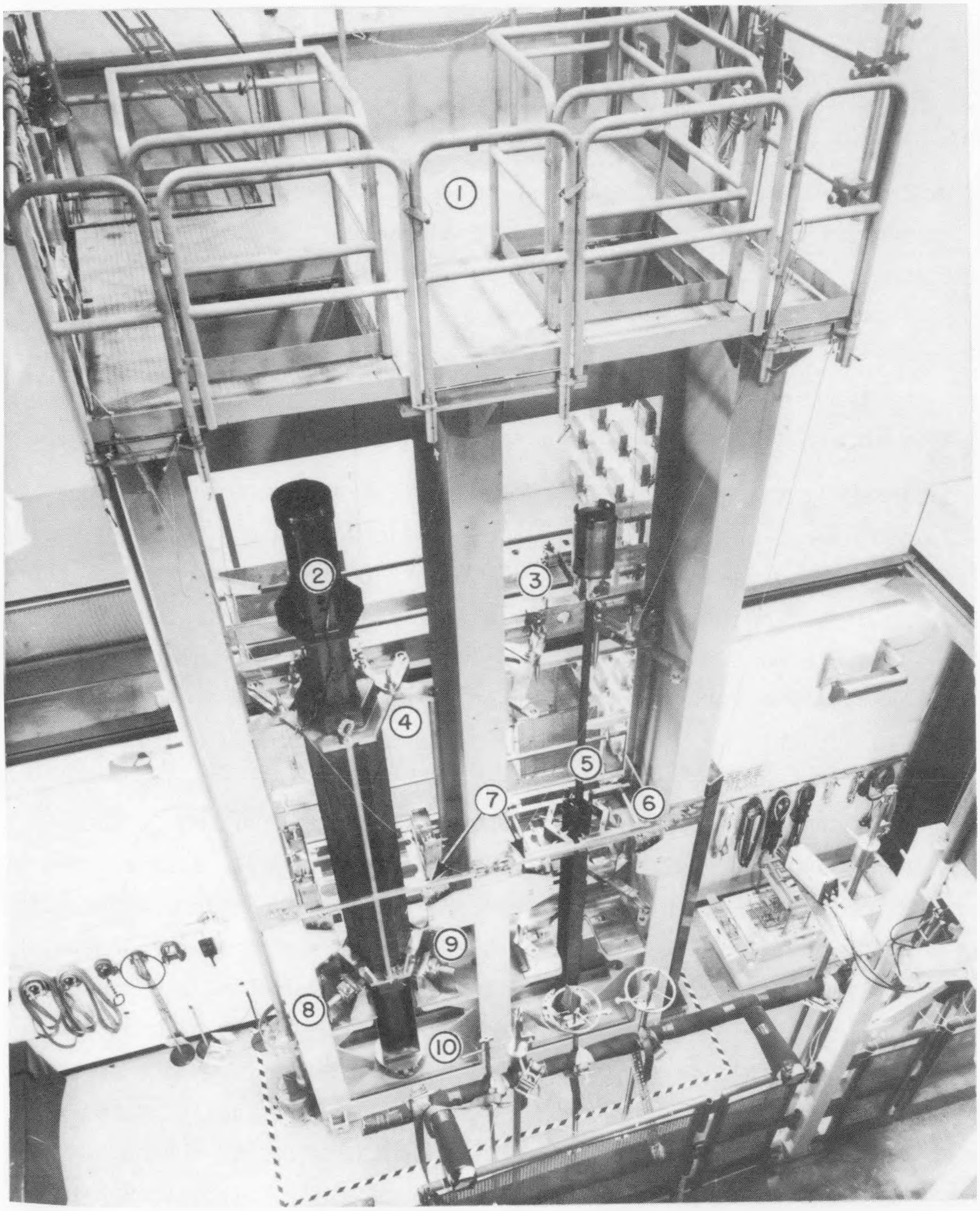
# APPENDIX A1 - SEED/BLANKET DISASSEMBLY STAND

## A1.1 - DESCRIPTION OF THE SEED/BLANKET DISASSEMBLY STAND

The LWBR seed/blanket disassembly stand was a large framework structure designed to support a seed or blanket module during disassembly operations to reduce the length of the modules to fit into an M-130 shipping container. It was located between the reactor pit and the fuel storage racks in the transfer canal (Figure 1A) to minimize fuel transport distances. To permit simultaneous work, the stand was designed with two identical work stations which could be adapted to accept either a seed or blanket module.

The disassembly stand (Figure A1-1) was fabricated from three 36-inch deep by 12-inch wide I-beams, 26 feet long, positioned to form two equal size bays, 6 feet wide by 3 feet deep. Lateral support plates were welded to the top and bottom of the back side of the beams to facilitate anchoring of the integrated structure to the canal wall. A gusseted horizontal plate was located approximately 5 feet from the bottom. This plate had a slotted hole in the front to support the separation device for blanket module disassembly. The separation device supported the blanket module and clamped onto the stub tube during separation of the fuel portion from the stub tube. The separation device also served as the guide tube extension bolt cutting chip collector and had a support which was vertically adjusted to support the guide tube extension. A bottom plate connected the beams at the bottom of the stand and positioned the assembly away from the canal wall. Leveling pads were attached to the bottom plate, and were remotely operated to level the disassembly stand at initial installation. The bottom plate also had a support block with a chamfered hex cutout which laterally and horizontally supported the seed module. A front plate was welded across the beams at the bottom of the stand, short enough to allow entrance of the module into the work bay.

Remotely operated and retractable mechanical clamping devices were provided to secure the modules in the stand. The blanket clamps were located at the upper and lower baseplate elevations. The seed clamps were located at the top baseplate elevation. If unsupported, the seed buffer cylinder would slide down the length of the support shaft, preventing the module handling tool from




1. PERSONNEL WORK PLATFORM
2. BLANKET MODULE (NONFUEL MOCK-UP)
3. BUFFER CYLINDER SUPPORT BRACKET
4. BLANKET CLAMP SWING ARM, UPPER
5. SEED MODULE (NONFUEL MOCK-UP)
6. SEED MODULE CLAMPS
7. INTRUSION BARS
8. GTE/STUB TUBE SEPARATION DEVICE
9. BLANKET CLAMP SWING ARM, LOWER
10. PLENUM FOR BOLT CUTTING DEBRIS

Figure A1-1. Seed/Blanket Disassembly Stand grappling the support shaft for removal. A retractable, remotely operated bracket was used to support the buffer cylinder. Due to possible growth in the seed modules, a shim had to be installed on the bracket under the buffer cylinder prior to ungrappling the module.

A work platform at the top of the stand provided access over each of the module positions for disassembly operations. This platform was equipped with hand rails and kick plates for personnel protection while working on the stand. A 3-foot by 3-foot opening over each bay provided access to the fuel modules being disassembled. A removable floor plate section, 36 inches wide, at the front of each of the bays was available; its usefulness was limited, hence it was seldom installed.

Anchor plates and concrete anchor bolts were used to attach the upper portion of the stand to the canal concrete wall above the water level. A square-beam support structure with integral stainless steel screw jacks was used to clamp the lower end of the stand between the walls of the transfer canal. The jacks were periodically checked for tightness.

Each bay of the disassembly stand had intrusion barriers to prevent accidental intrusion of a module into a bay already containing a module.

The seed/blanket disassembly stand frame, work platform, and square beam support structure were fabricated using structural low-carbon steel. The carbon steel parts were protected from corrosion by paint. The main frame was a unitized weldment, with the clamps and supports attached by bolting and located by dowel pins. All components of the stand which contacted the modules were constructed of (or were faced with) type 304 stainless steel. Bearing areas where relative movements occurred were a bronze-stainless steel combination or were chrome plated.

## A1.2 - OPERATIONS AT THE SEED/BLANKET DISASSEMBLY STAND

The appropriate clamps and brackets were positioned, the hand rails were removed, and either a blanket or seed module was received from the reactor vessel directly or from the fuel storage racks. The module was landed and clamped into position in the disassembly stand. The intrusion bar was closed, the handling tool was ungrappled from the module, and the crane moved away. The hand rails were replaced on the work platform and disassembly operations were started.

After the appropriate module structural components were removed and the module lifting adapter was installed, the hand rails were removed. The crane was moved into place over the bay containing the disassembled module, with the grappling tool in readiness. The module was grappled and unclamped from the stand, the intrusion barriers were opened, and the module was lifted out of the stand and transported to the M-130 container for loading and shipping or to storage in the module storage rack.

## A1.3 - PROBLEMS

A close coincidence was required between the center lines of modules installed in the disassembly stand and the clamping assemblies to preclude impacting fuel modules during the installation and clamping processes. Proper alignment of the clamps was required to ensure that the clamps would accommodate variations in module levelness due to module bowing and grappling tool tolerances. An optical alignment of the disassembly stand bays was performed at Shippingport in the radiologically clean fuel storage pit before installing the stand into the water in the transfer canal. The purpose of the operation was to develop a reference between alignment of the module clamps and work platform levelness. Optical targets were installed at each clamp level, the clamp alignments were adjusted, then vertical alignment was compared to platform levelness. After the stand was installed in the canal, it was leveled using the criterion developed from the earlier operation. Because of limits on adjustability, an exact alignment was not achieved, but the original objective of an alignment error of less than 0.010 inch per foot was attained.

The clamping device for seed modules consisted of two retractable brackets with three screw jacks on each bracket to provide clamping action on all six sides of each module. During disassembly stand installation and alignment operation prior to reactor fuel removal, the three jacks on one bracket were preset and locked using a nonfueled seed module mock-up as a guide. Prior to installation of a fueled module into the stand, the preset bracket was lowered into position. The module was installed and the second bracket was lowered, then the three jacks on this bracket were remotely operated to contact the module. The three jack pads on the preset jacks were supposed to contact the module, but due to fabrication tolerances and radiation induced changes in module dimensions, occasionally one of the pads did not contact the module, thus preventing equal clamping pressure on all six sides. To prevent module distortion and possible disassembly difficulties, a slight gap at one of the jack pads was accepted inasmuch as the locks applied during presetting operations could not be removed remotely.

The clamping force applied to modules by the screw-type jacks was limited by controlling actuator torque to prevent damage to modules or possibly inhibiting disassembly. However, the force applied to the module versus the torque applied to the jack or the angle of rotation of the jack drive was not consistent. Installation of a force transducer on the contact point of the jack would have provided a more accurate force measurement.

After the disassembly stand was installed in the transfer canel, a problem developed with both sets of blanket clamp arms that could not be repaired; the blanket clamp arms could not be completely opened or closed. In normal use, the blanket clamp swing arms (Figure A1-1, items 4 and 9) were positioned around a blanket module and a long locking pin was inserted from the top to the bottom arms, locking them around a module. As friction built up on the swing arm bearing surfaces, it became increasingly difficult to join and pin the arms. Disassembly of the last four blanket modules was restricted to the left-hand bay (Figure A1-1) and it was necessary to manually position one of the upper clamp arms using a hook and bar until the locking pin could be inserted. Although the clamp arms could not be fully opened, they could be opened far enough to provide clearance for a module moving into or out of the bay. The bearing surface of the stainless steel clamp arms was also made of stainless steel, but this was not considered a problem during design because the system would be operated only about 20 times over its lifetime. The stainless-to-stainless bearing surfaces, as well as the boron deposits on the bearing surfaces from the borated canal water, were determined to be the cause of restricted movement of the clamp arms. A better design would have used a bushing material or bearing on the pivoting surfaces.

## A1.4 - CONCLUSION

The disassembly stand was a useful aid to the defueling effort. It served its design function of supporting and constraining seed and blanket fuel modules during disassembly operations and provided an accessible storage location for disassembled modules prior to loading them into shipping containers. Problems with clamp arms for blanket modules did not inhibit the use of the stand.

# APPENDIX A2 - THE GUIDE TUBE EXTENSION BOLT CUTTING MACHINE

## A2.1 - DESCRIPTION OF THE GUIDE TUBE EXTENSION BOLT CUTTING MACHINE

The purpose of the LWBR guide tube extension (GTE) bolt cutting machine (Figure A2-1) was to sever the six GTE bolts in each of the 12 blanket modules, which were difficult to access by other means because of their "head down" orientation inside the skirt of the stub tube (Figure 10). Separation of the joint held together by the bolts was necessary for removal of the GTE, stub tube, and bottom orifice plates. These items, along with the support tube at the top of the blanket assembly, had to be removed to decrease the length of the blanket module to make it fit into the M-130 shipping container. The cutting machine also was adaptable for cutting the bolts holding the support tube and associated components to the top of the blanket if their removal by unthreading was not successful. This contingency feature was not needed during defueling.

The cutting machine consisted of three major subassemblies: an air-motor-powered grinding wheel mounted on a yoke assembly attached to a pivot shaft used to feed the wheel; a wedge assembly which rigidly clamped the cutting machine inside the blanket module; and a tube extension assembly which extended from the wedge assembly to the module disassembly stand decking and supported the various hydraulic and pneumatic lines, an electric motor for the feed system, and the components for elevation adjustment of the cutting wheel.

Supporting devices for cutting machine operation included an air compressor and an air exhaust system, a filtration system to remove grindings from the canal, and a control console to provide centralized control of cutting operations.

### A2.1.1 - Grinding Wheel Assembly

The cutting wheel was powered by a 1.9 hp air motor. The motor was capable of a free speed of 14,000 rpm in air, and approximately 6500 rpm under water with a cutting wheel attached. The motor consisted of a commercial rotary (sliding) vane rotor assembly in a stainless steel housing. The direction of rotation was not reversible.

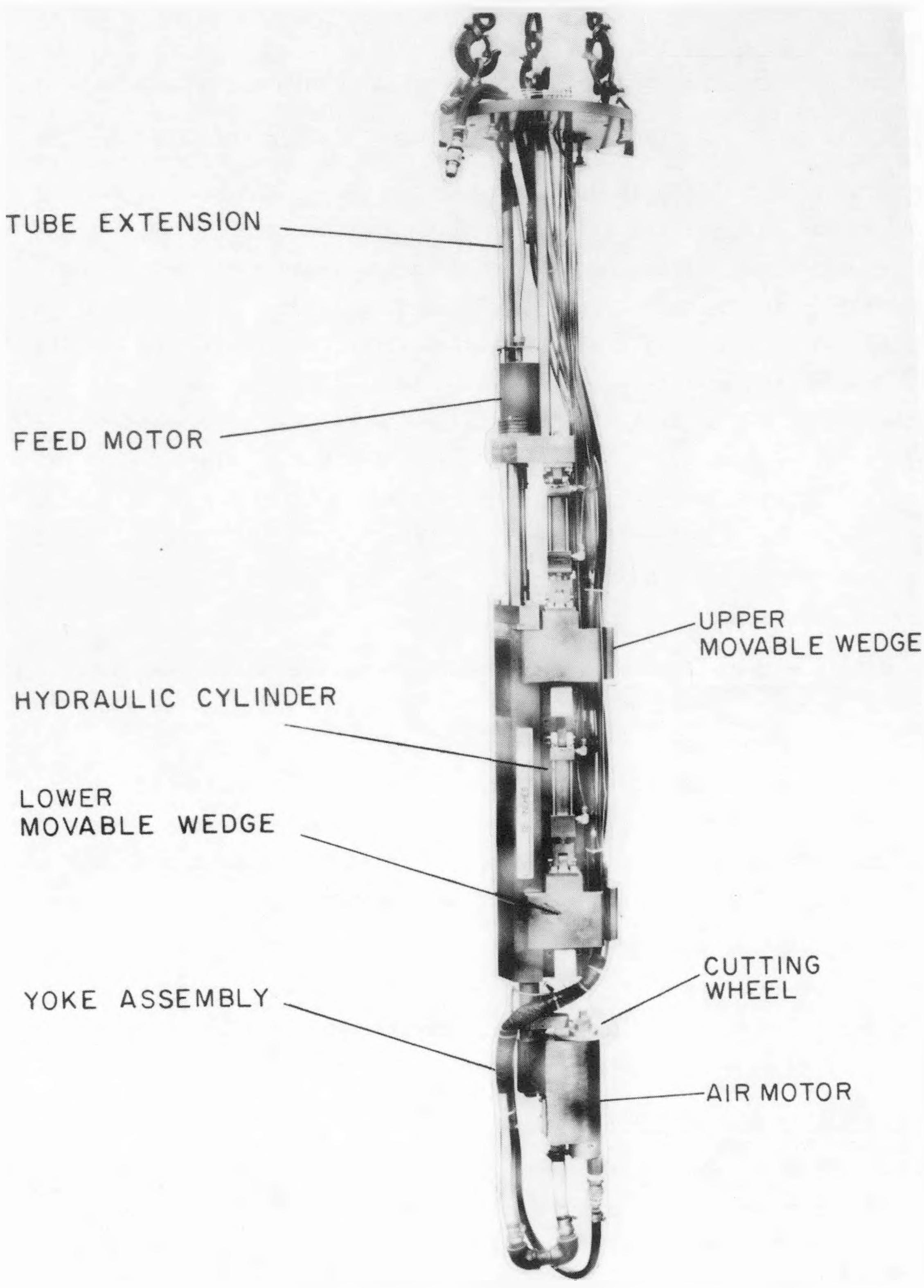



Figure A2-1. Guide Tube Extension Bolt Cutting Machine

The cutting wheel was held in place by a nut that was also used as a target for a proximeter which monitored the speed of the cutter shaft. The 5.00-inch diameter by 0.06-inch thick cutting wheel was composed of a metal wheel with 40-50 grit diamond impregnated material (Borazon) bonded to its circumference. The diamond material was thicker than the wheel, resulting in a relieved wheel design.

A design requirement for the air motor was that air would not escape from the motor to the canal water. If a sufficient quantity of air was released from the motor, the irradiated material debris caused by the cutting could be carried to the surface of the canal where it could become airborne. For this, a double lip seal capable of sealing against 150 psi on either side was used. The seal was a packaged unit with an O-ring seal to the bore of the housing. A semi-rigid wiper was formed to the cutter shaft diameter at installation. An 8 RMS surface finish and minimum hardness of Rockwell C-45 were required for a proper seal.

The connection of the yoke assembly to the wedge assembly was made by the pivot shaft. A No. 40 milling machine taper and a pin in the pivot shaft, which fitted into a groove in the yoke assembly, aligned the components. A bolt acted as a drawbar to hold the components together. This arrangement, including quick-disconnect fittings at the inlet and outlet of the air motor, allowed quick and simple removal of the yoke assembly from the cutting machine. This was required because the bearings and rotor assembly in the air motor were the items most likely to fail over the life of the machine. During the course of module disassembly operations, one air motor failure was experienced when a double lip seal failed. A spare yoke assembly was available and changeover was accomplished in less than one working shift.

The yoke assembly and cutting wheel were positioned by rotation of the pivot shaft. Figure A2-2 illustrates the feed path of the cutter. This geometry allowed cutting two GTE bolts from one setup inside the restricted space of the guide tube. Feeding the cutter on an arc resulted in material removal rates that were more constant than for a linear plunge.

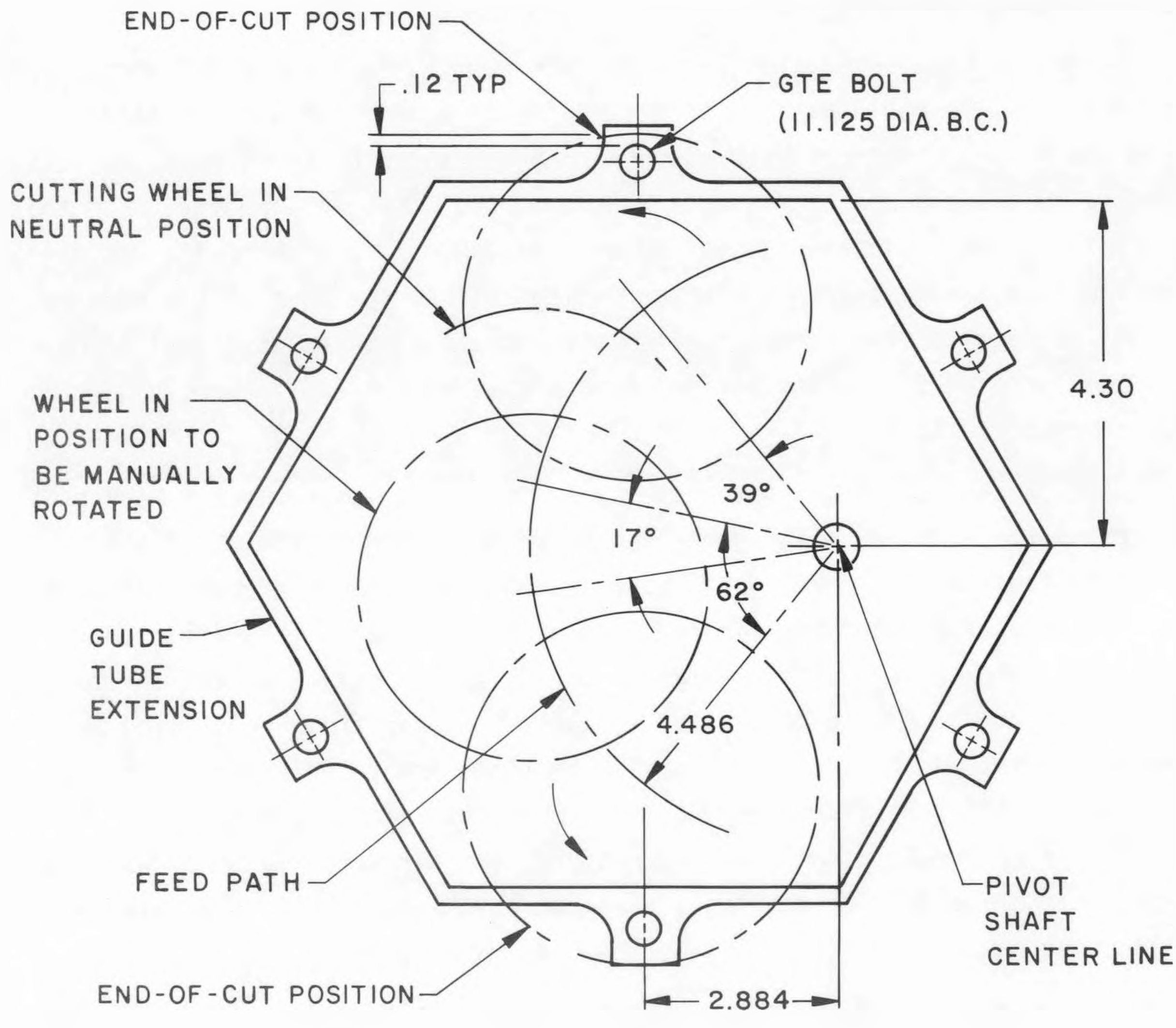



Figure A2-2. Feed Path of Guide Tube Extension Bolt Cutting Machine Cutting Wheel

The pivot shaft was rotated by a d-c stepping motor mounted above the canal water level on the tube extension subassembly. A stepping motor was used because of its ability to supply a fixed, repeatable movement. An extension shaft connected the motor to the pivot shaft. The stepping motor was a 200 step/revolution model with a 2708:1 speed reducer connected to its output shaft. The motor control was capable of operating the motor from 0 to 1000 steps/second in the base speed range. A high range of 100 to 3000 steps/second was also available. Theoretically, the available rotational speed range of the pivot shaft was 0 to 2 degrees/second. However, the mass of the components to be moved inhibited the operation of the motor at the lower end of the speed rate spectrum. Experimental data indicated that the minimum operational speed of the motor in this feed system was 1.6 step/second, which corresponded to 0.06 degrees/minute rotation of the pivot shaft, or 0.005 inch/minute feed rate of the cutting wheel. In use, it was never necessary to utilize the lower end of the feed rate spectrum. Feed rates used for GTE bolt cutting ranged between 0.010 and 0.020 inch/minute.

The feed rate was controlled to maintain the speed at which the cutting wheel turned within the range of 3800 to 4600 rpm (5000 to 6000 surface feet per minute for the 5-inch wheel). If the speed exceeded this range, the feed rate could be increased by adjustment of a potentiometer on the motor control unit to create a heavier drag on the wheel, thus slowing it down. Likewise, the feed rate was decreased if the wheel speed was too slow. A continuous display of the cutting wheel speed was provided to the operator by a tachometer connected to a proximeter, which was mounted adjacent to the shaft above the cutting wheel.

A2.1.2 - Wedge Assembly

The pivot shaft axis was located in the guide tube by the geometry of the wedge assembly. The pivot shaft was located on the axis that divides the guide tube from corner to corner in order to cut two GTE bolts from one setup (Figure A2-2). The cutting machine was rigidly held in place by four 20-degree wedges on the clamping body. Each wedge was operated by a stainless steel hydraulic cylinder using water as the hydraulic fluid. The four wedges were paired off, with one set directly above the other. The two wedges on a side (top and bottom) were mechanically connected by two tie rod assemblies. The tie rod assemblies allowed either the top or bottom cylinder to retract both wedges should the other cylinder be out of service. Sufficient relative motion between the wedges was provided to allow for bow in the blanket module. This was done to ensure that the wedges could be retracted even if a hydraulic cylinder was out of service. The hydraulic circuit could operate each cylinder individually or in any combination.

When the wedges were retracted, the cutting machine fitted through the blanket lifting adapter and guide tube with considerable clearance. When clamped against the guide tube, the wedges were displaced 1.00 inch outboard of the retracted position. The hydraulic cylinder had the capability of displacing the wedge 1.25 inches outboard of the retracted position.

By pressurizing the hydraulic cylinders in a planned alternating sequence, the wedges caused the cutting machine to center itself in the guide tube. The sequencing action forced the back side of the clamping body, opposite the wedges, into the hex of the guide tube. A high clamping force was not necessary since the forces and vibration generated by the cutting operation were very low.

A2.1.3 - <u>Tube Extension Assembly</u>

The cutting machine was suspended from the module disassembly stand by the tube extension assembly. The tube extension was a structure which was bolted to the top of the wedge assembly and extended up to a leveling platform resting on the disassembly stand deck. Nylon rings were located between the lifting plate and leveling platform. The rings minimized the resistance to sliding between the two components, permitting the cutting machine to freely position itself when the wedges were activated. The elevation of the cutting wheel was adjustable at the leveling platform elevation. This provision accounted for two contingencies. First, the cutting elevation was not precisely the same for each blanket module because of differences in radiation induced growth and assembly tolerances. A measurement on each module provided information to calculate a cutting height. After establishing an ideal cutting height, the cutting wheel had to be positioned within ±0.120 inch. Second, if a cutting wheel broke during a cut, changeout of the wheel required removing the machine from the module. Precise relocation of the previous cut could not be guaranteed so the elevation was changed for continuation of operations.

The cutting machine was suspended from the module disassembly stand by the leveling platform. The horseshoe shaped platform was installed inside the 3-foot by 3-foot access opening in the disassembly stand deck, with the open side of the horseshoe facing the canal. This arrangement permitted the cutting machine to be installed without lifting the yoke assembly and contaminated components from the water.

A2.1.4 - Air Supply and Exhaust System

Proper operation of the air motor required adequate air flow (60 cfm), a pressure drop across the rotor approaching 90 psig, and clean, dry, lubricated air. An air supply system was designed and procured to power the air motor. It included a 30 hp electric powered compressor capable of delivering dry air in excess of 100 cfm at 120 psig.

An in-line mist-type lubricator supplied oil for lubricating the air motor. The outlet air line was critical because backpressure at the outlet of the air motor would reduce the pressure drop across the motor. Normally, commercial air motors exhaust directly to the atmosphere. Because of radiological requirements for a closed air system, the exhaust side of the air motor was connected to a hose which ducted exhaust air away from the cutting area and through a 200 cfm high-efficiency particulate air filter. Pressure drops of up to 15 psig were experienced on this system, thus necessitating higher operating pressure from the air supply.

A2.1.5 - Removal of Cutting Debris

The cutting operation (grinding) generated approximately 18 grams of irradiated material per cut. The materials removed by cutting were Inconel X-750 (GTE bolt), type 304 stainless steel (bottom orifice plate), and

Zircaloy-4 (guide tube). All were highly irradiated and, therefore, could complicate handling of the cutting machine if it became contaminated by the debris. Because the Zircaloy is pyrophoric when in a powdered form, special arrangements were provided to keep it from being exposed to air. The cutting debris was in the form of small particles of grinding dust. Due to the small particle size and to the agitation provided by the high-speed cutting wheel, the debris could have become suspended in the water for several hours before settling if there were no provision for getting rid of it. The spread of the cutting debris was controlled by maintaining a flow of water downward through the guide tube. This was accomplished by connecting a pump to the bottom of the GTE. The water and material were withdrawn by the pump and passed through filters, and the water was returned to the canal.

Changes in the pivot shaft length during the cutting operation (due to heat generated by the blanket module) could have produced side loads on the cutting wheel. However, the flow of water produced by the grinding collection system also served to keep the cutting machine temperature close to the canal temperature, thus limiting the thermal expansion and protecting the cutting wheel from breakage or binding. This grinding collection system provided adequate protection throughout the cutting process.

A2.1.6 - Control Console

A control console was located near the disassembly stand, where the cutting machine was used, to provide centralized control of cutting operations. Included in the cabinet were: a hydraulic hand pump and a valving system for expanding and retracting the wedges; a motor controller with panel-mounted switches and speed selector (a 10-turn potentiometer) for adjusting feed rate and direction of feed of the grinding wheel assembly; solenoid-controlled air valves; a tachometer and circuitry which integrated pulses from the proximeter into a d-c signal proportional to the grinding wheel speed; a clock and elapsed time indicator; and a position indicator which displayed the number of revolutions of the stepper motor.

A trained and qualified operator manned the console during cutting operations. He had direct control over the feed motor, controlling both direction and rate of feed.

Three safety systems were built into the console, each of which would shut down the entire cutting system. A pressure switch in the air supply line was used to sense a broken or kinked hose. A high/low pressure sensor on the grinding collection system could shut the system down if filters became clogged or if the pump stopped working. The third sensor was a water level sensor in the air exhaust line from the 200-cfm high-efficiency particulate air filter, which detected excess condensate in the filter plenum.

## A2.2 - CUTTING MACHINE OPERATIONS

Operation of the bolt cutting machine began with installation of the leveling platform onto the disassembly stand. After the leveling platform was leveled, a measurement was taken from the top of a reference level on the module to the top of the machine seating surface on the leveling platform. The cutting machine was then installed into the guide tube. Once it was seated, the distance from the cutting wheel to the seating surface of the machine was measured. Based on the two measurements, the elevation of the cutting wheel was adjusted to position it at the proper location; then the machine was clamped inside the blanket module guide tube by four wedges. A specially trained operator then performed the bolt cutting operations -- two bolts located 180-degrees apart were cut, one at a time. The time required for each cut was approximately 50 minutes. Following cutting, the wedges were unclamped and the machine raised out of the guide tube, rotated 60 degrees, and reinstalled into the guide tube. These operations were repeated until all six bolts were cut.

## A2.3 - ALTERNATIVES TO GRINDING

Several methods for removal of the GTE bolts were considered. These methods included the use of a remotely operated wrench, end milling, drilling, sawing, grinding, electric discharge machining, and plasma arc cutting.

Although use of a remotely operated wrench was consistent with all other bolt removal operations during module disassembly, this method was not used because of the complexity of the tooling required to remove the bolts and the need for a contingency removal plan (cutting) to sever the bolts should galling prevent removal.

Plasma arc cutting has a tendency to fuse material together at the joints. This was a major concern for cutting the GTE bolts since several components would be fused together during cutting, preventing separation of the blanket module from the stub tube after bolt cutting.

An electrical discharge machining cutting test was performed to determine the feasibility of using this process in the borated canal. A small quantity of potassium tetraborate was added to the water in the test setup. The test concentration of potassium tetraborate was much less than the 4400 ppm concentration in the canal. The electric discharge machine cutting process was greatly retarded in the test setup; therefore, use of this process was not considered feasible.

Tests of end milling and drilling methods were performed. High forces were required to cut the bolts, and the cutting tip became dull after each cut. Replacing the cutting tool five times per module was considered excessive from both a time and radiation exposure standpoint.

In comparison to all of the cutting methods considered, use of a slitting saw was the second-best method. The time required to make a cut during testing was much faster than the grinding method. However, just prior to completing the cut, the saw blade teeth would catch the edge of the bolt and shatter the blade.

The selection of grinding was based on the following test results:

1. Grinding was the most reliable method for cutting the bolts. Grinding had a 100-percent success rate in all of the tests. The other cutting methods yielded a 50- to 70-percent success rate.

2. Grinding was relatively insensitive to the properties of the material being cut. The test program showed that a diamond-impregnated bronze grinding wheel will cut material ranging from soft unirradiated Zircaloy to hardened tool steel. Feed rates, cutting speeds, and tool wear are strongly material-dependent for the other cutting methods. Cold working of the material due to inaccurate feeds and speeds does not affect grinding.

3. Grinding required a less complicated machine than the other methods. Less rigidity is required for grinding because the cutting forces are lower due to the relatively slow cutting rates.

4. A grinding operation was much easier to control. Grinding required only that the cutting speed was controlled between approximately 3500 and 7000 rpm. The other mechanical cutters required a closer control of both cutting speed and feed rate.

5. Grinding was insensitive to gaps between the blanket inner guide tube, orifice plate, and bolt. Grinding was also insensitive to the expected loss of preload in the guide tube bolt. In comparison, slitting saws were broken due to the cutter teeth catching on the uncut ligament of the bolt when the bolt rotated as a result of the cutting forces.

## A2.4 - PROBLEMS

During cutting of bolts on the first seven modules, only two cutting wheels were used. When the fuel portion of the seventh module was removed, the stub tube remained with the fuel portion. It was determined that the cutting wheel had broken (after the bolt was cut through), and that broken pieces of the wheel remained in the cut, preventing separation of the stub tube from the fueled portion of the module. To minimize the chance of repeating this event, it was decided to replace the cutting wheel after cutting six GTE bolts in each module. For the remaining modules, no blades were broken.

## A2.5 - CONCLUSION

The overall performance of the cutting machine was very good. The only major problem that occurred was the one broken cutting wheel. The machine required some routine maintenance, which resulted in minimal downtime.

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