WAPD-TM--1608

DE88 005095

WAPD-TM-1608
Distribution Category UC-78

PRIMARY DISASSEMBLY OF LIGHT WATER BREEDER REACTOR MODULES FOR CORE EVALUATION

(LWBR Development Program)

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Contract DE-AC11-76PN00014

October 1987

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

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FOREWORD

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

Subsequent to development and successful operation of the Pressurized Water Reactor in the Atomic Energy Commission (now Department of Energy, DOE) owned reactor plant at the Shippingport Atomic Power Station, the Atomic Energy Commission in 1965 undertook a research and development program to design and build a Light Water Breeder 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 was 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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CE	Core Examination
COS	Cutoff Saw
ECF	Expended Core Facility
HDRF	Holddown and Rotation Fixture
LWBR	Light Water Breeder Reactor
MDA	Module Disassembly Apparatus
MTC	Module Transfer Cage
MVS	Module Visual Station
PIFAG	Production Irradiated Fuel Assay Gage
POB	Proof-of-Breeding
REX	Rod Examination Gage
RRS	Rod Removal System
SAPS	Shippingport Atomic Power Station
SC	Stabilization Clamps
UF	Utility Fixture
VDS	Vertical Disassembly Stand
VIG	Vertical Inspection Gage

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After successfully operating for 29,047 effective full power hours, the Light Water Breeder Reactor (LWBR) core was defueled prior to total decommissioning of the Shippingport Atomic Power Station. All nuclear fuel and much of the reactor internal hardware was removed from the reactor vessel. Non-fuel components were prepared for shipment to disposal sites, and the fuel assemblies were partially disassembled and shipped to the Expended Core Facility (ECF) in Idaho. At ECF, the fuel modules underwent further disassembly to provide fuel rods for nondestructive testing to establish the core's breeding efficiency and to provide core components for examinations to assess their performance characteristics.

This report presents a basic description of the processes and equipment used to disassemble LWBR fuel modules for subsequent proof-of-breeding (POB) and core examination operations. Included are discussions of module handling fixtures and equipment, the underwater milling machine and bandsaw assemblies, and the associated design and operation of this equipment for LWBR fuel module disassembly.

PRIMARY DISASSEMBLY OF LIGHT WATER BREEDER REACTOR MODULES FOR CORE EVALUATION

(LWBR Development Program)

SECTION 1 - INTRODUCTION AND BACKGROUND

This section contains an introduction and general description of the LWBR fuel assemblies, a summary of module disassembly operations prior to shipment to ECF, a brief description of the ECF facility, and the general requirements for LWBR module disassembly. Section 2 is a brief summary of the equipment used and the core examination program performed at ECF. Section 3 is a detailed description of the module disassembly process which includes general equipment descriptions and operational sequences used for the remote handling and disassembly of fuel modules. A summary and conclusion of module disassembly work is presented in Section 4. The appendices contain detailed discussions of major disassembly equipment components which warrant in-depth descriptions.

1.1 - LWBR FUEL ASSEMBLY DESCRIPTION AND PARTIAL DISASSEMBLY PRIOR TO SHIPMENT

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

1.1.1 - LWBR Fuel Module Description

LWBR fuel modules contained fuel rods, fuel rod support grids, module support structures, and instrumentation. The LWBR core had 39 fuel modules which consisted of 12 seed, 12 blanket, and 15 reflector modules. A module type was characterized by its cross-sectional geometry. The movable seed modules traveled vertically through hexagonal passageways in the blanket modules. Core reactivity was controlled by changing the axial position of the seed modules within the surrounding blanket modules. Reflector modules were located on the outer periphery of the core to reduce neutron leakage and to increase the thorium conversion (breeding).

Each module was designed to position and support Zircaloy-4 clad fuel rods in a precise, closely packed hexagonal array. Axial support for each rod was provided by a threaded end closure, which was either at the top or bottom end of the rod as it was positioned in the core. About half of the fuel rods were attached to a top baseplate, and the other half were attached to a bottom baseplate in each module. The nominal outside diameters of the fuel rods were:

a) seed: 0.306 inch

b) power flattening blanket: 0.527 inch

b) standard blanket: 0.571 inch

c) reflector: 0.832 inch.

The 10-foot long fuel rods were supported laterally in each module by a series of fuel rod support grids which consisted of hexagonal cells located on a triangular pitch. Each grid cell contained a spring that held the fuel rod firmly in place against two relatively fixed dimples. The grid spring force prevented flow-induced vibratory wear of the rods, yet accommodated axial rod growth without inducing enough thrust to cause excessive rod bowing. The LWBR grids (Reference 2) were fabricated at the Bettis Atomic Power Laboratory from AM-350 stainless steel sheets kept to a minimum thickness (0.0135 inch thick in seed grids, 0.014 inch in blanket grids, and 0.015 and 0.018 inch in reflector grids) to reduce neutron capture.

Support and axial positioning of the grids within the modules was obtained by bolting the grids to Zircaloy-4 support posts situated at the outer boundary of the grids as described below. The blanket grids were also attached to the blanket guide tube which formed the guide path for the movable seed.

1.1.2 - Movable Seed Assembly

There were 12 movable fuel (seed) assemblies in the LWBR core (i.e., one seed assembly in each blanket assembly). Each seed module was connected to a control drive mechanism and was raised or lowered to control core reactivity.

The movable seed assembly shown in Figure 1 contained a fuel region that was hexagonal in cross section and about 10 feet long. The fuel region was made up of 619 fuel rods supported laterally by nine grids spaced along the module length. Each fuel rod was axially fixed on one end by a threaded attachment to a 1 1/2-inch thick perforated Inconel 600 baseplate. Approximately half of the rods were connected to the top baseplate, and the other half were connected to the bottom baseplate. This design provided coolant flow through orifices in the baseplates and through the module, and distributed the thermal growth loads resulting from the fuel rods going from ambient to operating temperatures. The grids and baseplates were connected to six Zircaloy support posts which spanned the length of the fuel region and supported the fuel rods. The assembly was further strengthened and protected by the surrounding 0.080-inch thick hexagonal seed support shell. The shell was joined to the post frame by 120 screws that were locked in place by tack welding.

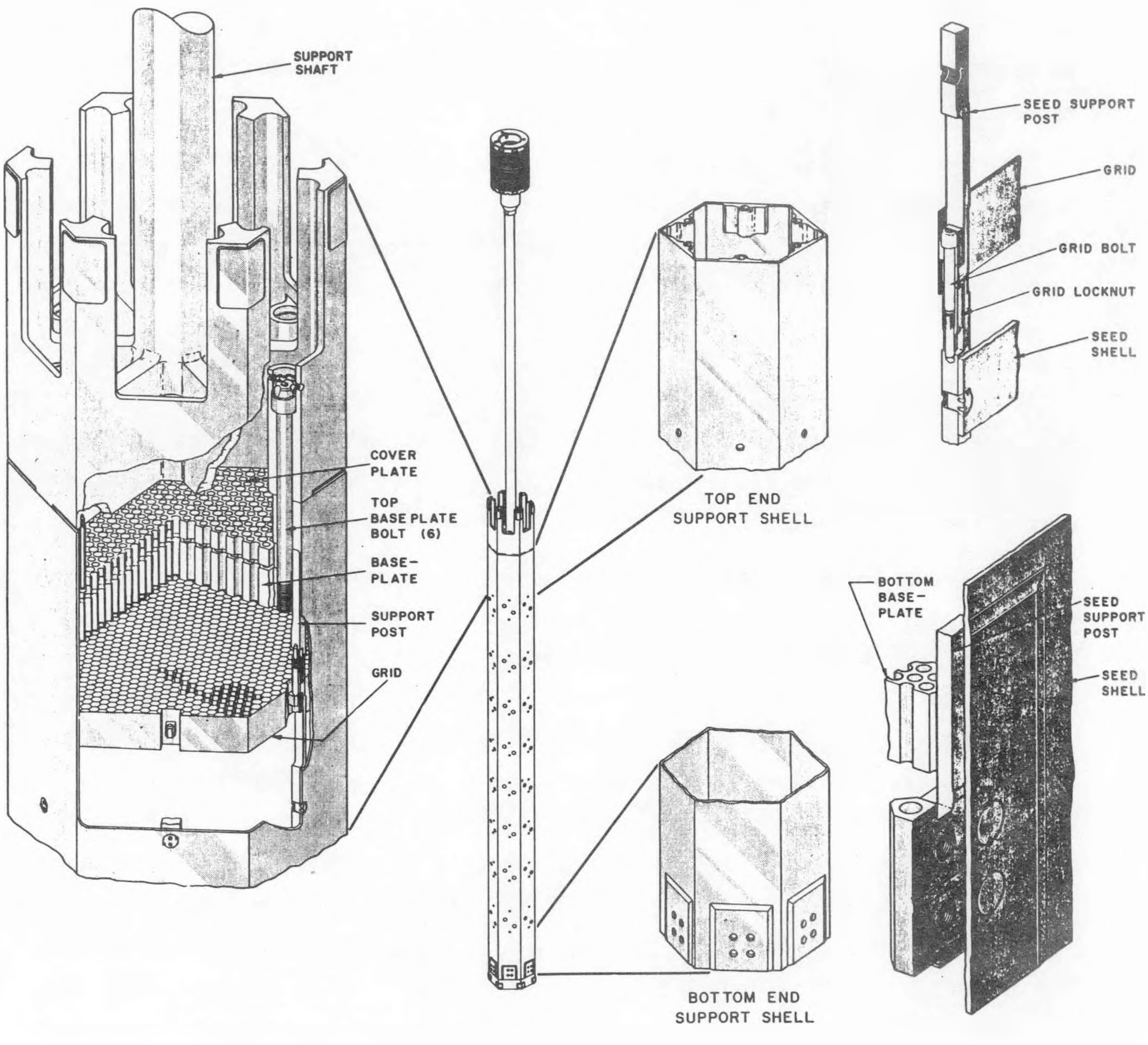

Figure 1 - LWBR Movable Fuel Seed Module Assembly

At both ends of the fuel region were 1/2-inch thick perforated cover plates which provided a capture mechanism for the fuel rods and the fasteners attaching the fuel rods to the baseplates.

To connect the module fuel region to the control drive mechanism, the support shaft was used. This consisted of a 2.65-inch diameter shaft, about 10 feet long, with a hexagonally shaped bottom end having the same cross section as the seed shell. The bottom end was attached to the module top baseplate using six bolts. The top end was connected to a balance piston which provided a downward force on the movable seed assemblies and balanced the upward hydraulic force produced by the cooling water flow.

1.1.3 - Blanket Assembly

There were 12 blanket module assemblies in the LWBR core. A standard Type I assembly is shown in Figure 2. The blanket assemblies provided structural support for the blanket fuel rods and also served as a guide path for the movable seed assemblies.

The fuel rod support system of the blanket modules was similar to that described above for the seed assembly. The basic differences between the three types of blanket modules were the cross sectional shape (which depended upon their position in the core) and the quantity and types of rods they contained. Type I modules contained 444 standard blanket fuel rods. Type II assemblies contained 261 standard blanket and 303 power flattening blanket rods. Type III assemblies contained 187 standard blanket and 446 power flattening blanket rods. The blanket assemblies and the movable seed assemblies formed the variable fuel geometry that controlled core reactivity. The fuel region was supported axially by baseplates, posts, and a guide tube, and was supported laterally by eight grids. The internal module guide tube consisted of a hexagonal Zircaloy tube structure approximately 0.190 inch thick and 10.18 inches across flats. The external module surface contained no covering and consisted of exposed fuel rods, posts, and grids. A triplate set of orifices at both ends of the fuel region distributed flow through the core.

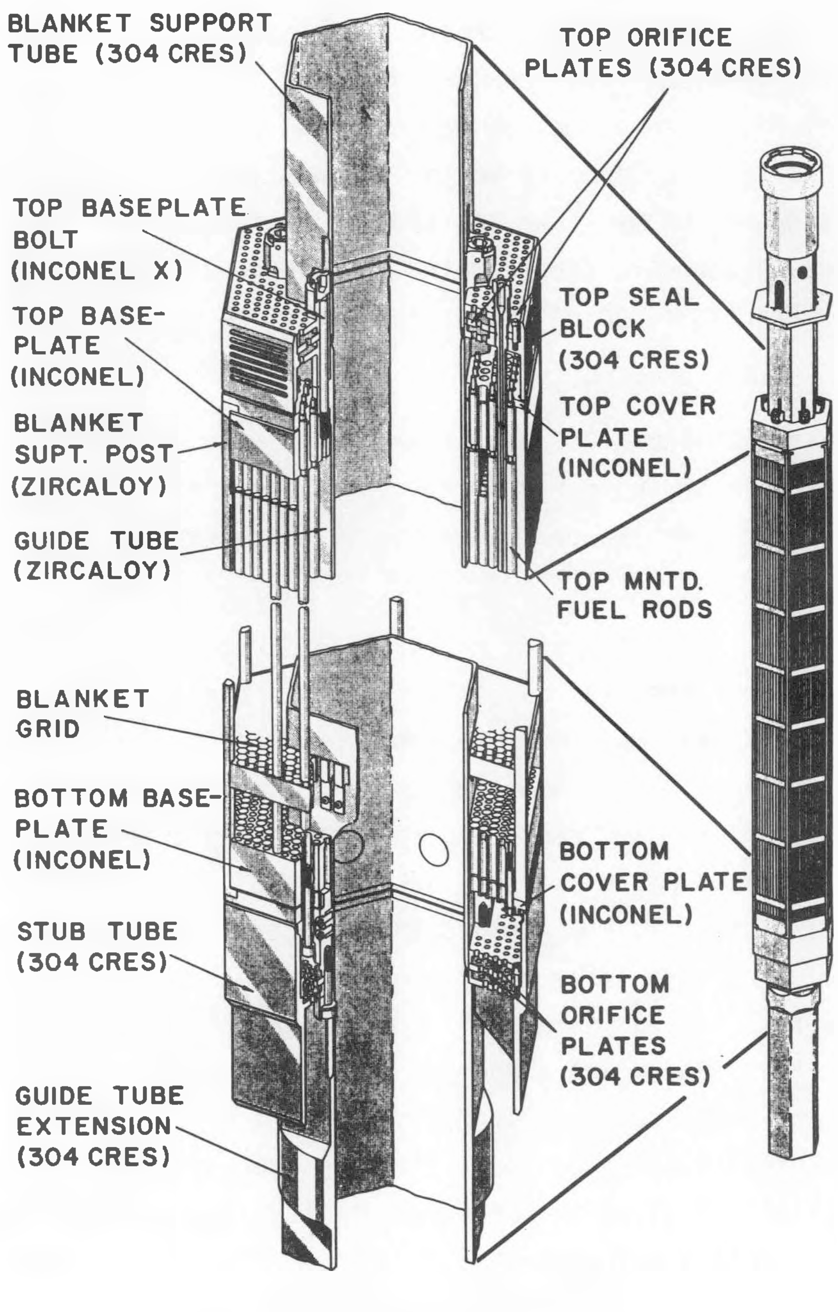

Figure 2 - LWBR Type I Blanket Fuel Module Assembly

The blanket modules provided the guide channel for the movable seed assemblies. This path was formed by three components which consisted of the blanket support tube, the guide tube, and the guide tube extension. The centrally located blanket guide tube was made of Zircaloy to minimize parasitic neutron capture in the fuel region. The support tube (top) and guide tube extension (bottom) were manufactured from Type 304 stainless steel for additional strength. The support tube suspended the blanket assemblies from the vessel closure head by way of the module suspension system. The blanket support tube also contained an internal ledge that supported the movable seed buffer cylinder/balance piston when the seed assembly was not connected to the control drive mechanism.

1.1.4 - Reflector Modules

The LWBR core contained 15 reflector modules which were located around the outside perimeter of the core. There were two types of reflector modules used which included nine Type IV and six Type V assemblies. The major difference between the two types was their cross sectional shape, as shown in Figures 3 and 4. The reflector region limited neutron losses from the core. The capture of neutrons by the thoria contained in the fuel rods produced new fissile fuel.

The basic reflector module structure was similar to the seed and blanket assemblies. The fuel rods (228 for Type IV, 166 for Type V) were supported by six grids attached to the post-baseplate frame, which was enclosed by a Zircaloy shell. The shell was attached to the module using 0.500-13 shoulder screws that were lock welded to the shell. Triplate orifices at the top and bottom ends of the modules controlled flow through the modules. The orifices were enclosed in stainless steel housings which also provided axial and lateral restraint for the module. The seal block located at the top of the module had an integral ledge that was clamped between the core holddown barrel and seal ring. In series with the seal block was the reflector support spring which maintained a preload between the reflector seal block and the clamping

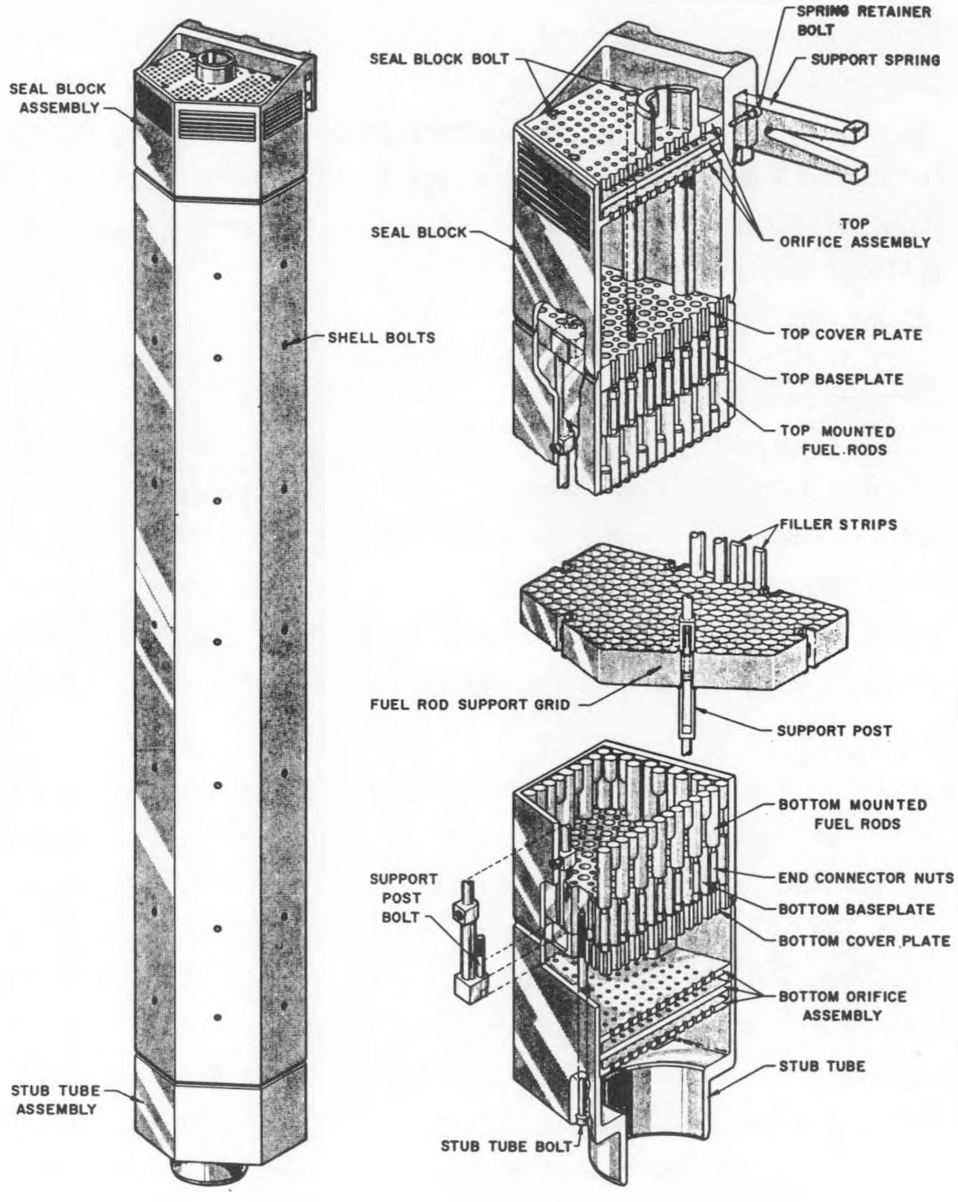

Figure 3 - LWBR Type IV Reflector Module Assembly

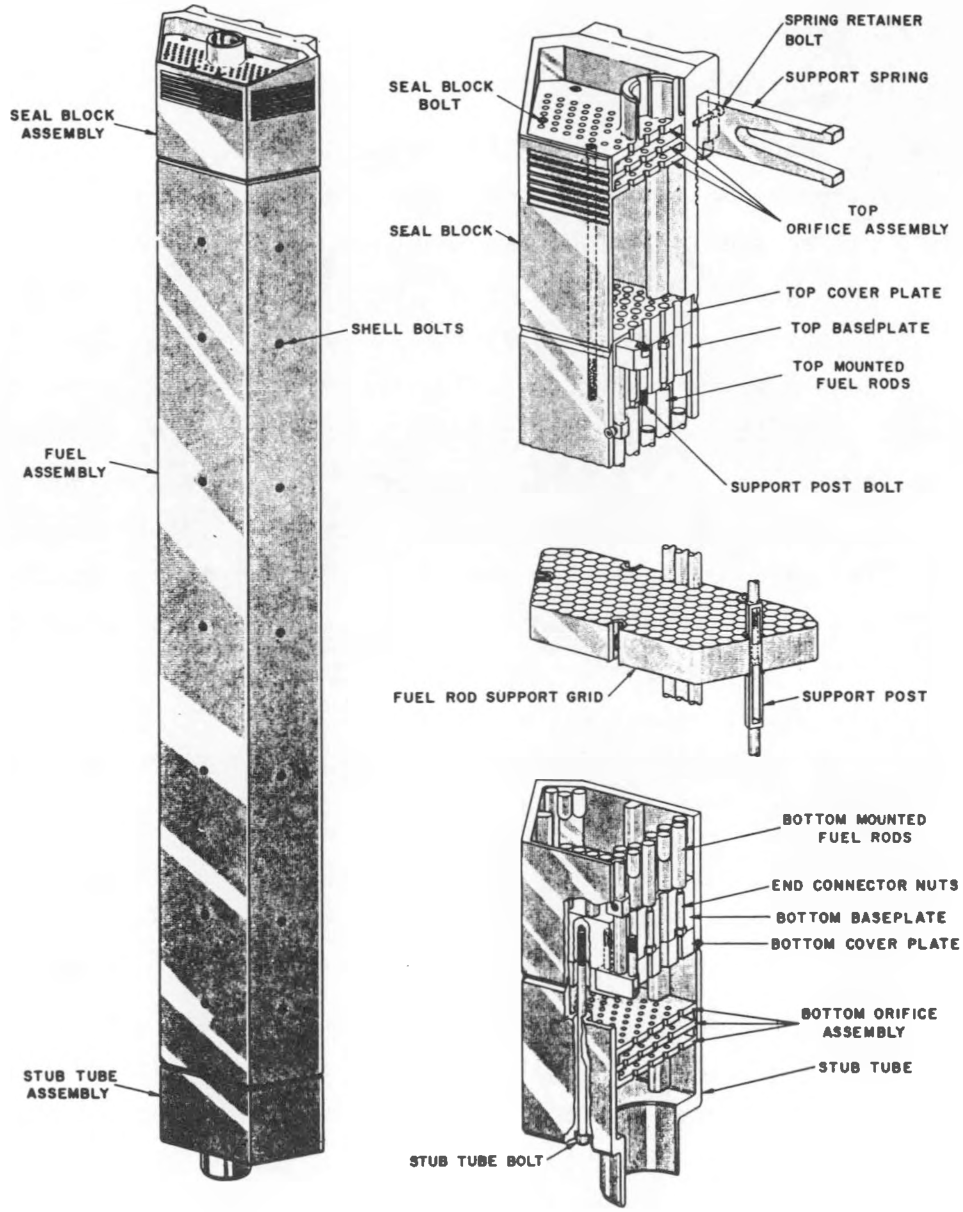

Figure 4 - LWBR Type V Reflector Module Assembly

components. The stub tube at the bottom of the module had an annular projection that fit into a hole in the core bottom plate, which provided lateral restraint for the bottom of the module.

1.1.5 - LWBR Module Disassembly Required for Transport to ECF

The LWBR fuel modules were partially disassembled at Shippingport to reduce each module to a length suitable for irradiated fuel shipping container rail shipment. Three specially modified shipping containers were used to accommodate the three geometrically different fuel module types. To shorten each movable fuel assembly (seed module) for installation into the shipping container, the seed support shaft (including the top stainless steel structural components used for operational hydraulic force balance) was removed. For this disassembly, the seed top baseplate bolts were removed, and lifting studs were installed in these tapped holes. The support shaft, balance piston, and buffer cylinder were all removed as a unit from the module. A shipping plate was attached to the installed lifting studs to regain module structural integrity for shipment. The shipping plate was designed to accommodate a lift adapter which was used for vertical lifting and was installed at ECF prior to removal from the shipping container. The as-received seed module assembly at ECF is shown in Figure 5.

To reduce each blanket module to a length suitable for shipment, the support tube and seal block assembly at the top of the module as well as the guide tube extension and stub tube assembly at the bottom of the module were removed. For top end disassembly, the instrumentation tubes were cut, and the blanket support tube was unbolted. At the bottom end, the six guide tube extension bolts were severed, and the stub tube and guide tube extension were removed. A shipping plate was installed at the top of the module to provide structural support and to accommodate the lift adapter. The ECF as-received blanket module assembly is shown in Figure 6.

Reflector modules were shortened to an acceptable shipping length by removal of the top seal block assembly. This disassembly operation was performed after the module was installed into the shipping container. As with the seed and blanket modules, a shipping plate was attached to the top of the

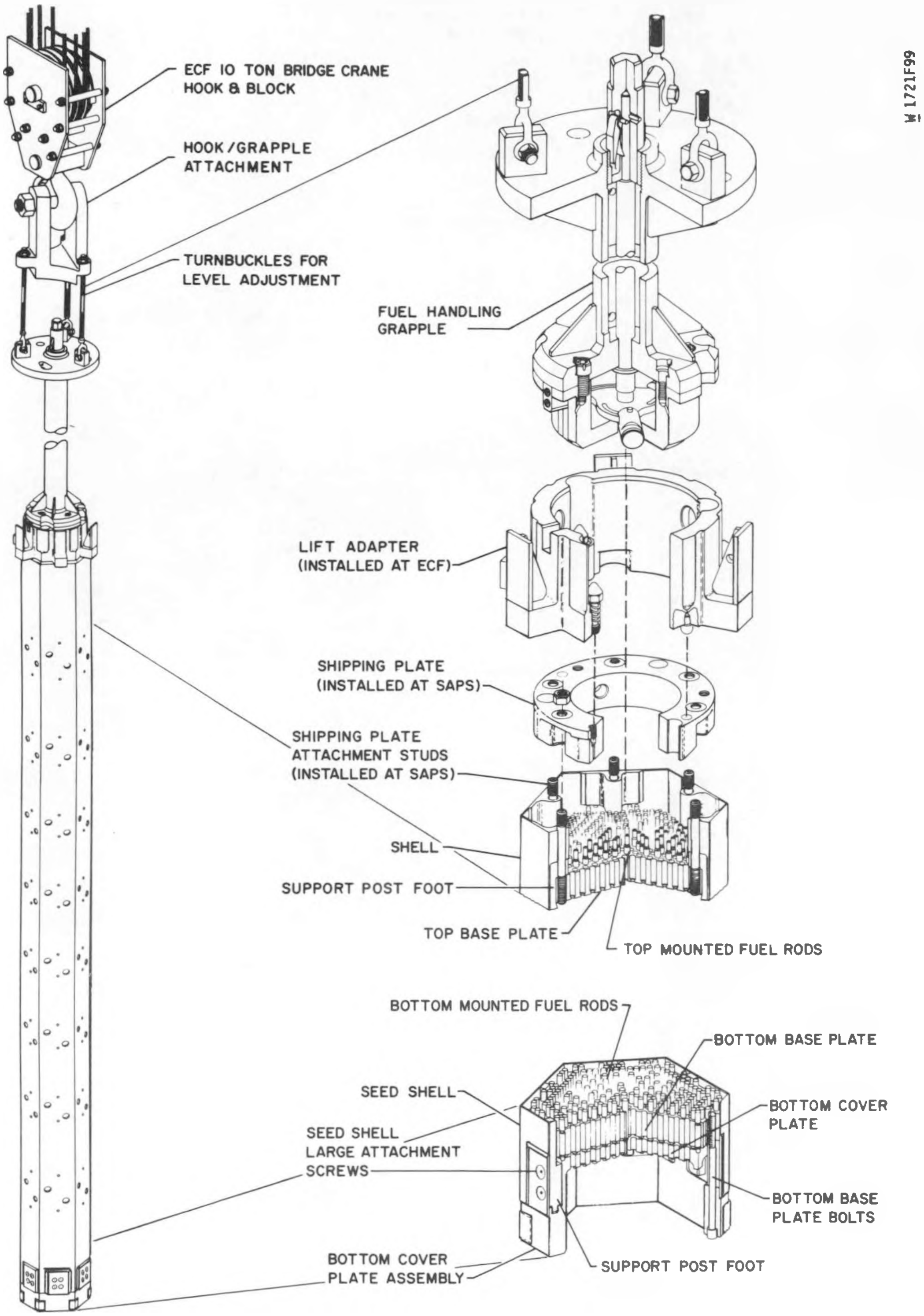

Figure 5 - LWBR Seed Module As-Received at ECF

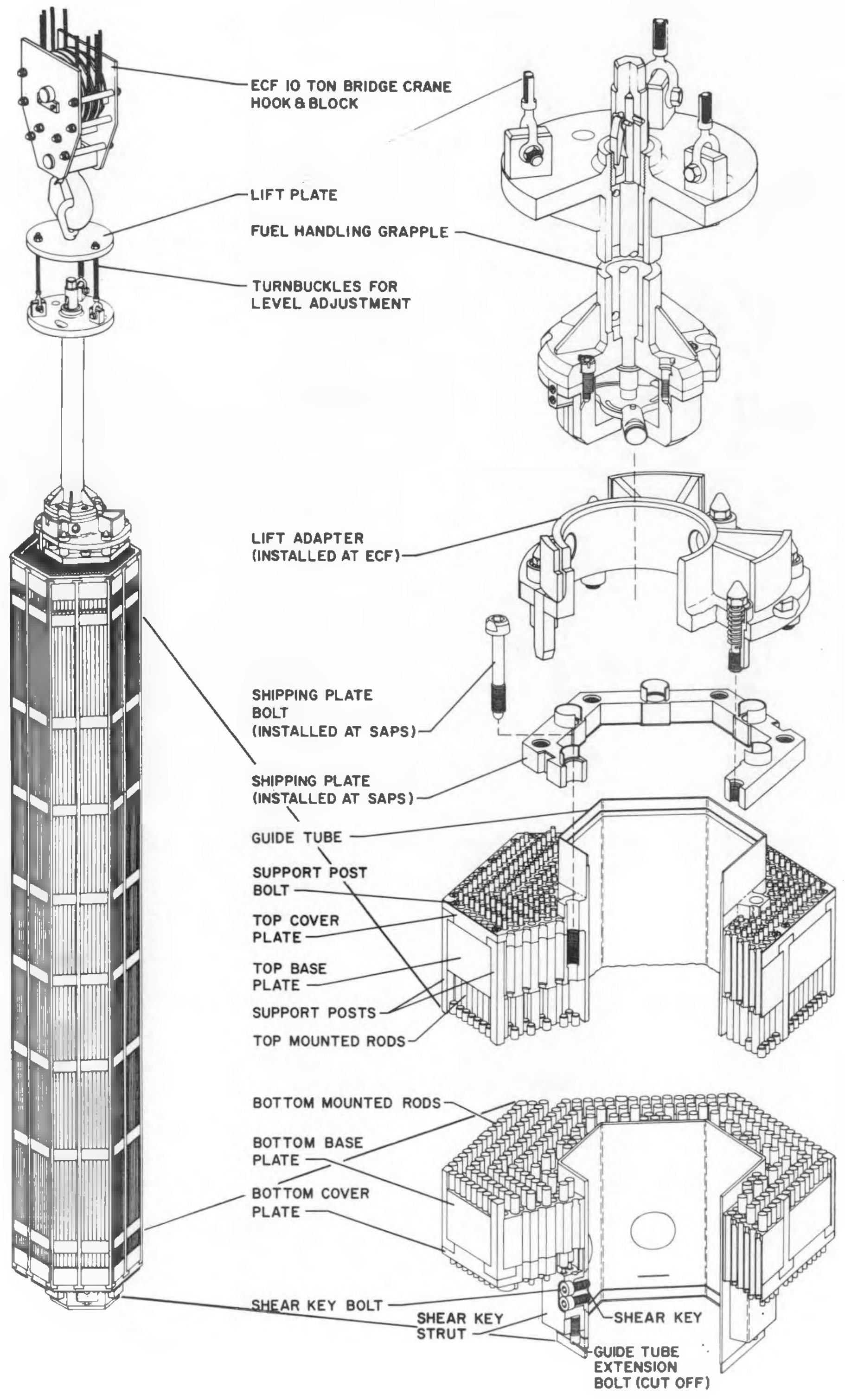

Figure 6 - LWBR Blanket Module As-Received at ECF

reflector module to provide structural support and accommodate the lift adapter. A typical ECF as-received reflector module assembly is shown in Figure 7.

Further information on LWBR fuel module design and disassembly at Shippingport can be found in References 1 and 3, respectively.

1.2 - ECF FACILITY DESCRIPTION

All LWBR module disassembly operations at ECF were performed in 35-feet deep water pits. The water pits were fabricated using 3-foot thick reinforced concrete walls that contained removable stainless steel gates. Personnel walkways were installed above the water pit walls to provide operational accessibility to the equipment.

The facility contained observation and control rooms located approximately 13 feet below the water surface. Leaded glass windows permitted horizontal underwater viewing of water pit operations. This area contained the underwater machinery operator control consoles and remotely operated manipulator controls.

Two general types of cranes were available for equipment lifting and handling operations. Primarily used were ten-ton bridge cranes that spanned the water pits. These cranes traversed the pits on rails mounted at the ground elevation. The bridge girders contained integral personnel walkways, and a work basket was suspended below one girder assembly. The crane hook remained underwater during most lifting operations to minimize contamination problems. Overhead building cranes were also used and consisted of a 125-ton capacity main hoist and a 25-ton capacity auxiliary hoist. The overhead cranes were primarily used to transfer equipment from the ground elevation into the water pits or when additional lift height above the standard bridge crane capacity was required. Additional information on ECF operations is provided in Reference 4.

1.3 - MODULE DISASSEMBLY OBJECTIVES AND SUMMARY

Module disassembly operations were conducted for two primary purposes. The first and most important reason was to facilitate fuel rod removal in support of proof-of-breeding operations. The second reason was to provide examination specimens of fuel module structures and components for evaluation of reactor performance.

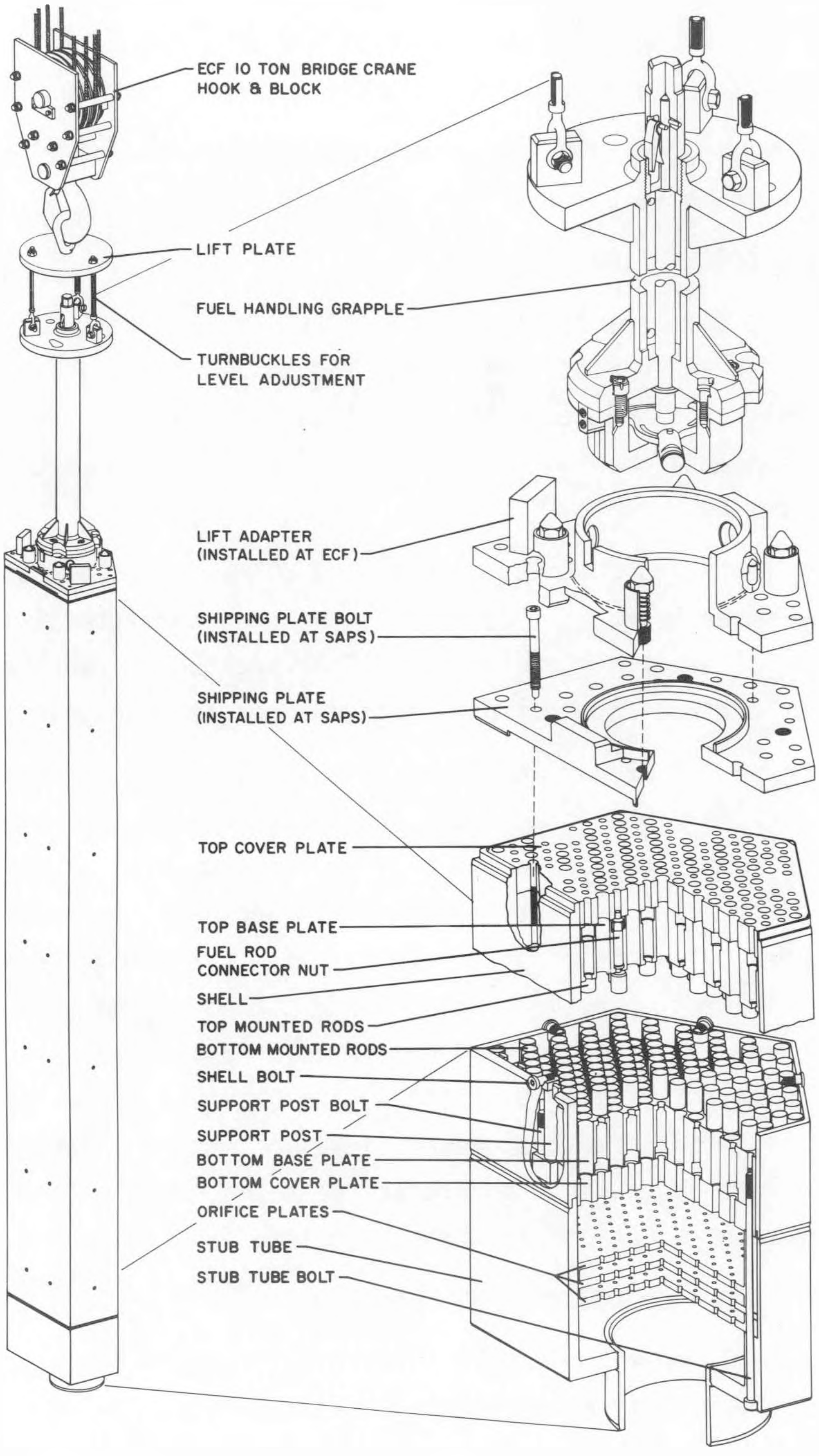

Figure 7 - LWBR Reflector Module As-Received at ECF

Proof-of-breeding operations required that intact fuel rods from 12 LWBR modules (four of each type) be removed from the fuel modules. As previously discussed, the fuel rods were laterally restrained in the modules by support grids at a minimum of six locations, and axially each rod was fastened to a top or bottom baseplate using a threaded connection containing a mechanically deformed lock retention device. The method chosen to remove the rods was to horizontally cut through the rod end stem/baseplate region to sever the threaded rod end connection and vertically remove individual rods. This work required specialized horizontal and vertical handling fixtures for each module type. All seed and blanket modules had the potential to form a nuclearly critical mass in a postulated worst case drop accident. To render this condition implausible, double-redundant lift rigging or the use of crush blocks was necessary for all fuel lifting operations.

Core examination operations requiring additional module disassembly were performed on one seed module and one Type IV reflector module. These examinations required removal of the module shell and shell attaching screws, and removal of support grid sections and grid-to-post connecting hardware. Module shells were removed prior to baseplate cutoff to expose the module internals prior to severing the fuel rod connections. The modules were visually examined and returned for top and bottom end baseplate cutoff and rod removal operations.

During rod pull, rods were removed (in addition to those rods required for proof-of-breeding) to provide access to a section of the grid that was identified for removal. Grid sections and grid-to-post attachment hardware were removed for visual and destructive examinations.

Handling and disassembly equipment was designed and fabricated to perform the module disassembly operations. Upon receipt at ECF, vertical lifting attachment features were needed on the partially disassembled modules. A double independently rigged lifting system was required which incorporated a fuel lifting grapple and redundant transfer cage to perform vertical module lifting and transfer to other LWBR stations.

A module handling utility fixture (UF) was required to provide support and secure the horizontal modules during cutoff and machining operations. An upender assembly was necessary to upend modules from the vertical orientation (required for transfer to other stations) to the horizontal position required for cutoff and machining operations. A second double-rigging method was also needed to transfer the horizontal UF from the upender to the machining apparatus.

A cutoff saw system (COS) with the capability to sever the fuel rod ends without applying significant loading to the potentially brittle irradiated fuel rods was required. For rotational positioning of the modules for the various cutoff and machining operations, a holddown and rollover fixture was needed.

After COS operations, the modules no longer had any structural lifting features or support to prevent the severed rods from sliding out through the grids. Stabilization clamp handling fixtures were designed to provide support and vertical lifting capability.

All operations were required to be performed with a minimum water cover to assure that radiation levels at the water surface would not exceed 0.2 mrem/hr. After completion of cutoff operations, the modules were transferred to the rod removal station (RRS) for rod pulling operations.

Core examination disassembly required underwater milling, drilling, and slitting operations. The module disassembly apparatus (MDA) was developed for this work. In addition to the major equipment mentioned above, numerous specialized support and handling components were required to remotely execute these operations. The detailed design and operation of this equipment is discussed in Section 3 of this report.

SECTION 2 - SUMMARY OF CORE EVALUATION AT ECF

The objectives of the core evaluation program were to verify fuel breeding and to verify the adequacy of the core component designs. Core evaluation included the following operations: (1) LWBR fuel module receipt, (2) LWBR module disassembly, (3) LWBR core examination, and (4) LWBR proof-of-breeding evaluation. This section is included to provide a general understanding of the other equipment and processes that were required to complete LWBR module processing. A brief summary of these operations is presented below.

2.1 - LWBR FUEL MODULE RECEIPT

Upon receipt of the LWBR fuel modules in the irradiated fuel shipping container at ECF, the container was transferred from the railcar to the water pit, and lift adapter plates were installed on each fuel module. These adapter plates provided a means to grapple and lift the fuel modules in the vertical orientation.

The fuel modules were then transferred individually to one of two water pits for storage in the module storage racks. Further information on LWBR fuel module receipt at ECF can be found in Reference 4.

2.2 - LWBR FUEL MODULE DISASSEMBLY

To achieve the evaluation goals of core examination and proof-of-breeding, the fuel modules had to be remotely disassembled to free core components and fuel rods. Actual module disassembly occurred on one of two machines, either the cutoff system (COS) or the module disassembly apparatus (MDA). The MDA and COS were actually one machine with two interchangeable machining heads. The MDA was a large underwater precision milling machine, and the COS was a large underwater horizontal bandsaw. The MDA was converted to the COS by replacing the milling head with the bandsaw attachment. The MDA/COS table had the capability of supporting any module type horizontally along with its associated disassembly fixturing. The MDA was used to machine module shell screws and slit module shells to permit external visual examination of the exposed fuel rods and to free module structural components, which included shells, grid sections, and grid fasteners for examinations.

The COS was used to cut off both ends of the module which severed the structural components to free all fuel rods. Twelve modules (four of each module type) were severed by the COS, and two modules (one seed and one reflector) were disassembled by the MDA.

2.3 - LWBR CORE EXAMINATION

With LWBR fuel receipt and module disassembly in progress, the core examination program was initiated. Visual examinations of the fuel modules by underwater television cameras were performed in the module visual station (MVS) and the vertical disassembly stand (VDS). The MVS was an underwater facility for supporting fuel modules in the as-received condition and for obtaining visual and dimensional characterizations of the module surfaces and shapes. Instrumentation packages mounted to a precision elevator platform, called the vertical inspection gage (VIG), were used to perform these inspections. The VDS was very similar to the MVS except that the VDS handled only cutoff modules from the COS. Video recordings made by the rod-to-rod gap examination gage (a system similar to the VIG) were used to perform fuel rod bow and gap measurements on peripheral and internal fuel rods. In total, 13 as-received fuel modules were examined in the MVS. One blanket module, one deshelled seed module, and one deshelled reflector module were examined in the VDS.

To perform individual fuel rod examinations, the fuel rods were extracted from the fuel modules. The COS preparation freed and exposed the fuel rod end stems for disassembly. The rod removal system (RRS), located directly above the VDS, was used to pull specified fuel rods from the cutoff modules. The RRS was a double arm jib crane with a grapple unit that utilized a collet device for engaging the fuel rod end stem. Approximately 1,100 fuel rods were removed from the twelve cutoff modules by the RRS. The fuel rods were removed for nondestructive examinations and proof-of-breeding evaluations and to allow module grid sectioning and core component removal by the MDA. Further details on the RRS can be found in Reference 5.

Nondestructive fuel rod examinations were performed using the rod examination system (REX). The REX components were attached to the back of the VIG carriage at the MVS. The following examinations were performed utilizing the REX: (1) detailed visual inspection, (2) free-hanging fuel rod bow measurements, (3) fuel rod length measurements, (4) fuel rod diameter measurements, (5) ultrasonic inspection for fuel rod cladding defects, (6) fuel rod radial profile measurements, and (7) eddy-current testing to measure cladding corrosion film thickness. Nineteen fuel rods were examined by the REX. Additional information on fuel rod examination systems can be obtained in Reference 6.

Destructive examinations of fuel rods were performed at a facility outside of the Naval Reactors ECF. These examinations included visual and dimensional inspections of fuel rod cladding, fuel pellets, fuel rod plenum springs, and fuel rod nuts; metallographic examinations of fuel rod cladding, fuel pellets, fuel cladding welding, fuel rod end stems, fuel rod plenum springs, and fuel rod nuts; fuel cladding tensile tests, hydrogen analysis, iodine and cesium analysis, and neutron fluence analysis; and fuel rod fission gas analysis, fuel depletion analysis, and neutron radiography. In addition to the fuel rods, the following core components were also destructively analyzed: (1) grid sections, (2) grid bolts, and (3) shell screws.

2.4 - LWBR PROOF-OF-BREEDING

The final aspect of the core evaluation program was proof-of-breeding. The nondestructive assay of fuel rods to determine end-of-life (EOL) fissile fuel content was performed using the production irradiated fuel assay gage (PIFAG) located in the ECF hot cells. A total of 524 fuel rods were assayed. The hot cells were located north of the water pits and connected to the water pits via a transfer canal and elevator. The PIFAG was used to perform nondestructive assay of a fuel rod by neutron irradiation of the fuel rod and subsequent counting of the delayed neutrons emitted. From this delayed neutron count, the amount of fissile fuel within the fuel rod was determined. Destructive analyses on seventeen fuel rods after they had been assayed by the PIFAG were performed at a facility outside of ECF. The results of these analyses were used to obtain correction and calibration factors related to the PIFAG measurements and to corroborate the results of the nondestructively determined rod fissile loadings. Additional information on the PIFAG and final proof-of-breeding results can be found in References 7 and 8.

SECTION 3 - LWBR MODULE DISASSEMBLY OPERATIONS AND EQUIPMENT

The mechanical disassembly of the LWBR modules for the most part was performed in the module disassembly apparatus (MDA) water pit. Permanently installed equipment within the pit included the MDA, which incorporated both milling and bandsaw heads and the module upender assembly. The sequence for module disassembly, as well as the equipment design, operation, and use is discussed in detail in the following section.

3.1 - MODULE LIFT ADAPTER INSTALLATION

Prior to unloading modules from the fuel shipping container, lifting adapters were installed on each module (See Figures 5, 6, and 7). The lifting adapters contained captured bolts and were threaded into the module shipping plates. The purpose of the adapters was to provide a feature for vertical module lifting replacing previously disassembled components. The design used consisted of a right cylinder containing three equally spaced elongated holes.

3.2 - FUEL GRAPPLE DESIGN AND OPERATION

The fuel module grapple shown in Figure 8 was designed and used to perform all vertical module and fuel storage liner lifting. The grapple was designed to be inserted into a lift adapter nozzle and contained three radial cam operated lifting pins that engaged into the elongated lifting holes.

Fuel storage liners were right circular stainless steel containers approximately 26 inches in diameter and 158 inches long. All LWBR modules were individually installed into a liner for storage purposes at ECF.

A universal lifting nozzle design similar to the lifting adapters was incorporated into all equipment that was lifted with the fuel grapple, which included stabilization clamps and storage liners. The main function of the grapple was to provide positive assurance that the module was properly rigged prior to lifting. This was accomplished using a lockout device on the grapple actuating tool that prevented actuating tool removal until full lifting pin engagement was completed.

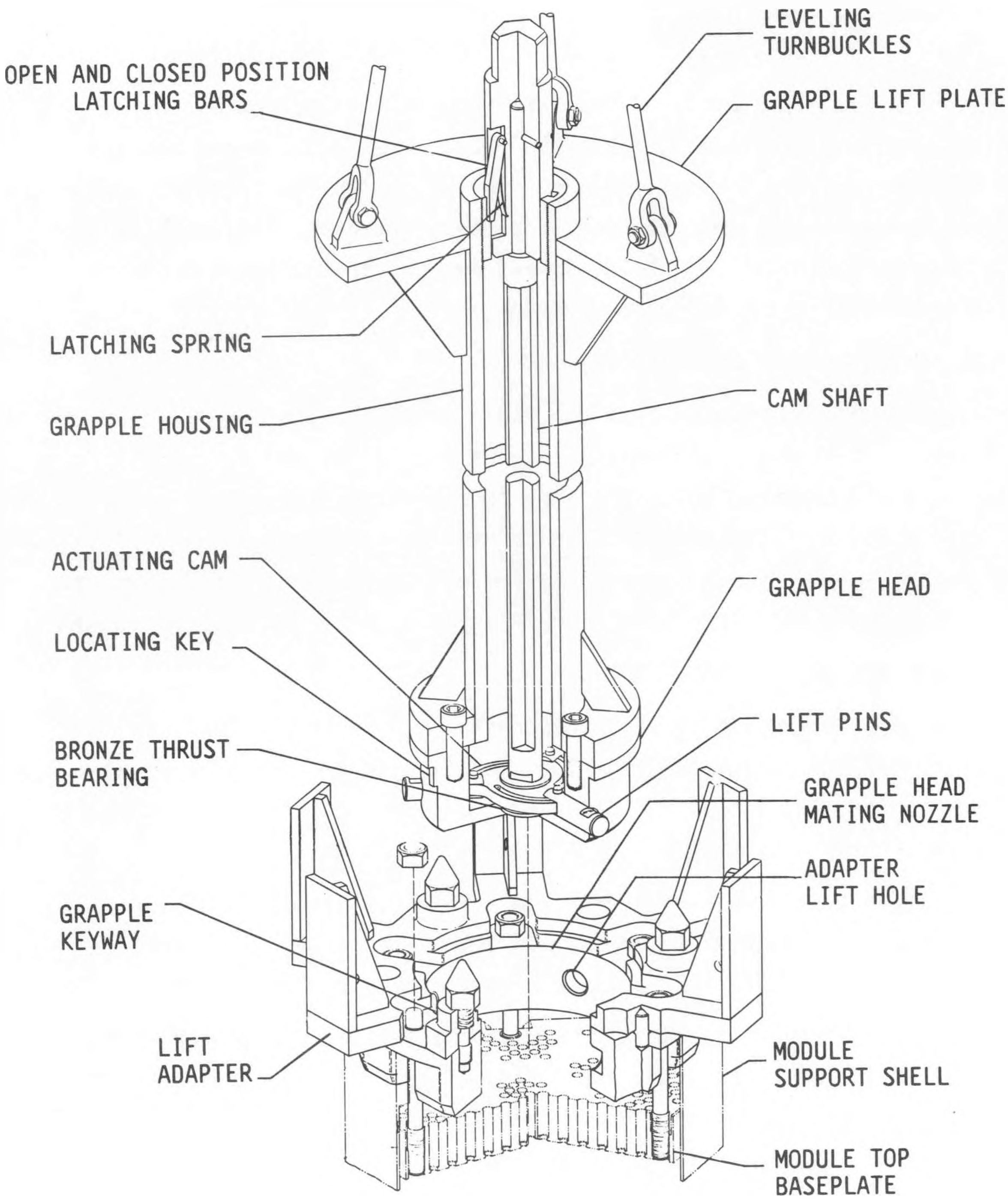

Figure 8 - LWBR Fuel Module Grapple
(Shown with Seed Module)

3.3 - TEN-TON WATER PIT BRIDGE CRANE

Module lifting and transfer operations, as well as other lifting operations within the water pits, were primarily performed using the 10-ton water pit doublespan gantry crane. The crane consisted of two horizontal bridge girder assemblies which contained integral personnel walkway platforms. A suspended work basket was added to the underside of the crane girder to facilitate operator accessibility around the crane hook near the water surface.

To control crane and hook position, an independent monitoring system was installed. The system consisted of stainless steel measuring tapes permanently attached adjacent to the X and Y axis crane rails and an absolute encoder readout of Z axis hook position. Monitoring of X and Y axis position was performed using closed circuit television cameras which viewed fixed pointers on the crane relative to the measuring tapes to indicate hook position. Hook elevation measurement was detected using an absolute encoder readout of drum rotation. Elevation measurement was digitally displayed in inches at the crane operator's console.

3.4 - MODULE TRANSFER CAGE

The module transfer cage (MTC) was designed to provide redundant vertical drop protection for all vertical fuel assembly lifting and transfer operations. An illustration of this assembly is shown in Figure 9. This system was required to meet the safety parameters necessary to provide double-rigged lifting and handling capability. The system consisted of a stainless steel frame that was suspended from the bridge crane trolley by four fixed length wire rope cables. The bottom of the cage contained hydraulically operated aluminum doors through which the fuel was raised or lowered. The bridge crane hook, in conjunction with the fuel grapple, was used to attach to and lift the fuel modules into the cage. The MTC was sized to accept as-received fuel modules, post cutoff (COS) modules, and the loaded storage rack liners.

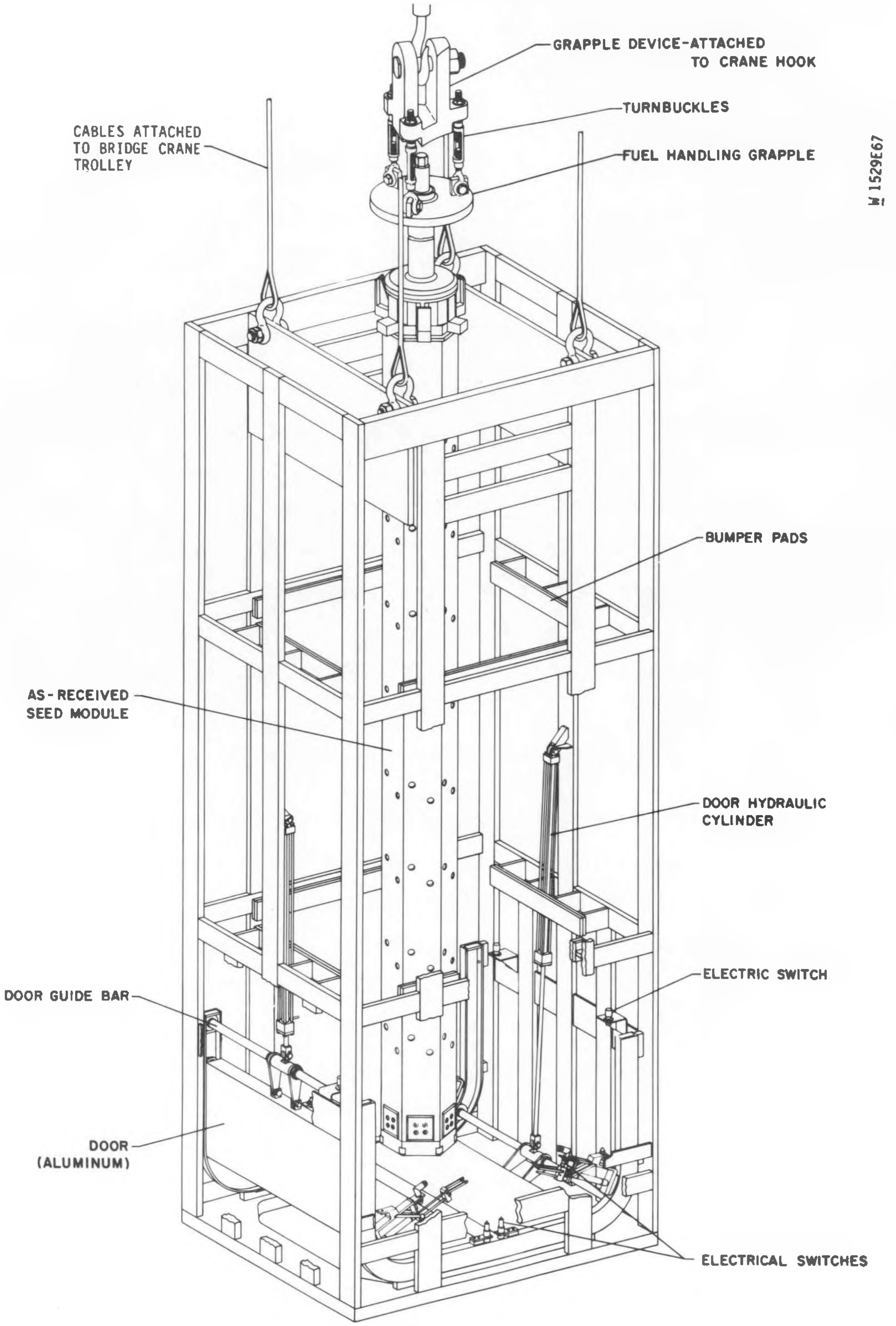

Figure 9 - LWBR Module Transfer Cage

To perform module transfer, the fuel was raised into the cage and the doors were closed. The fuel elevation above the doors was controlled using a limit switch to minimize the potential drop distance within the cage. At this time in the transfer process, if the fuel were dropped by the grapple (primary rigging), the cage would have prevented it from falling to the water pit floor. Design criteria of the cage limited impact loads to prevent fuel rod rupture during accident conditions. The cage also contained design features to retain the fuel assembly after a potential accident occurred.

During loading and unloading operations, double-rigged safety requirements were met by use of stainless steel crushblocks placed in module ports where transfer operations were performed. In the unlikely event that the fuel was dropped prior to securing the doors, funnels were located where necessary to guide the module back into the port. During this type of potential accident, the cage also provided lateral support of the fuel assembly.

Electrical interlocks between the MTC and the bridge crane limited bridge crane movement to micro-mode operation (3/8-inch jogs) when the transfer cage doors were opened. Locking of the doors was required to take the crane out of the micro-mode and allow operation at full speed.

3.5 - UTILITY FIXTURE

The purpose of the utility fixture (UF) assemblies was to provide support and handling of the modules during upending, horizontal lifting, COS/MDA operations, and installation of stabilization clamps on post-cutoff modules. An illustration of the utility fixture is shown in Figure 10. Two utility fixtures were built, one to accommodate the seed and three blanket module types, and one to accommodate the two reflector module types. The detailed UF design is discussed in Appendix A.3. The fixture was designed to provide an enclosure with the same internal shape as the external shape of the module it was intended to support. The internal configuration was changed for each module type by installation of inserts.

Removable end caps were provided on each end of the fixture so that the module ends could be exposed for cutoff. The end caps were attached using a barrel type clamp that was opened and closed with a single lead screw. The

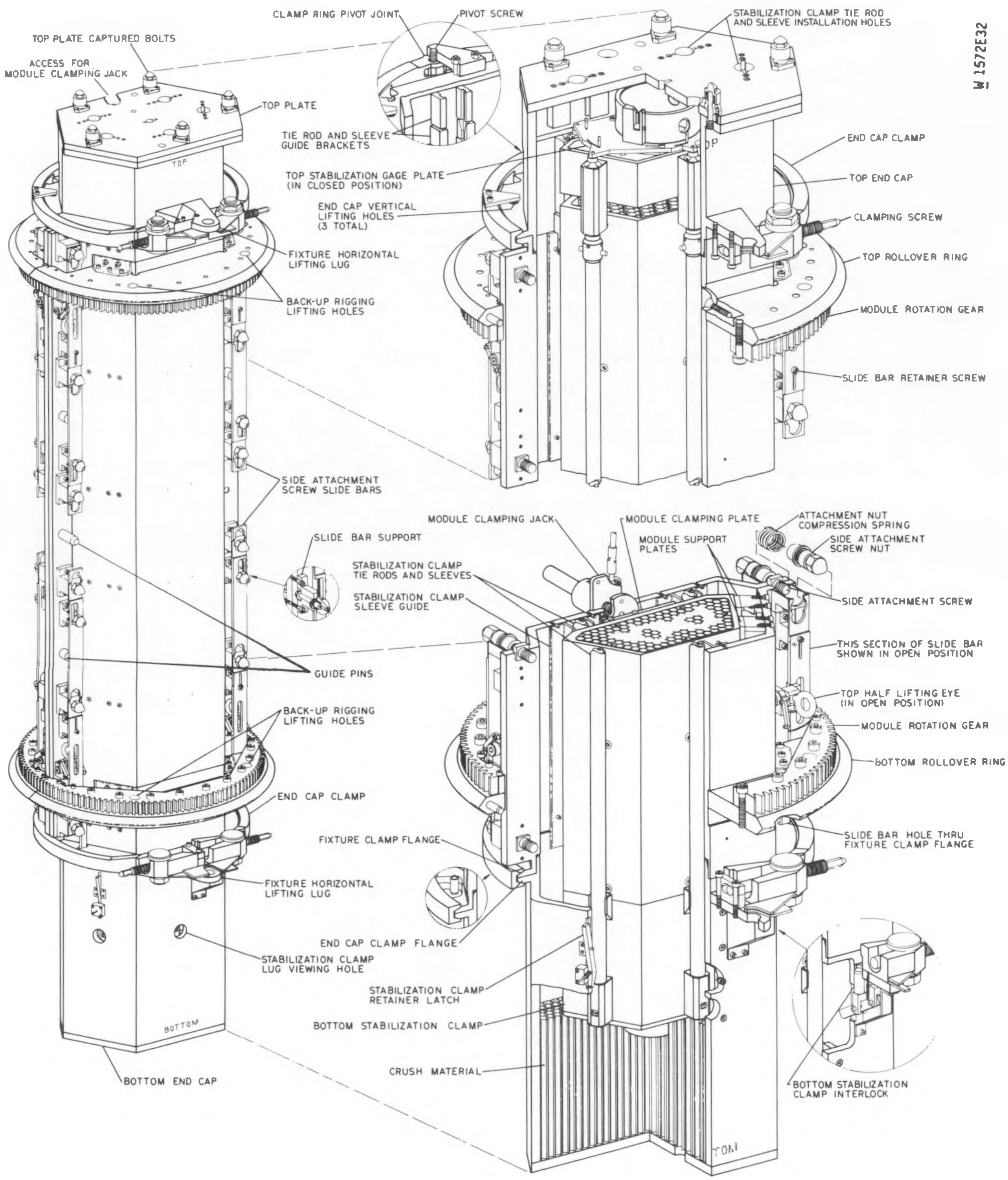

Figure 10 - LWBR Utility Fixture

top end cap contained a cover plate that was removable to permit vertical module installation when in the upender assembly. The fixture was also separable longitudinally to expose the exterior module surface for MDA machining operations. The two main body sections were held together using twelve 1 1/8-inch diameter captured studs and nuts. Separate top and bottom main body section removal provided access to all module features required for disassembly.

The fixture was approximately 160 inches long and contained two 42-inch diameter rollover rings and rotation gears used for rotation and positioning on the MDA table. The rings were approximately 88 inches apart and were centered along the main body of the fixture.

Each module was supported on three sides within the fixture. One of the three sides contained a movable pressure plate assembly which was adjusted using a series of interconnected worm drive screw jacks. This design allowed the internal size of the fixture to be increased for module installation and removal, and eliminated lateral clearance prior to handling and cutoff machining operations. The pressure plate was tightened using one drive screw on the top end of the fixture. Torque limiters were used during tightening to prevent applying excessive forces to the modules.

The fixtures contained an intricate system of mechanical interlocks designed to preclude module lifting unless proper component assembly was completed. This interlock system included main body slide bar interlocks, which required that all attachment studs be tightened prior to allowing end cap installation, and end cap interlocks, which necessitated proper positioning and clamp tightening prior to obtaining accessibility to horizontal lifting points.

3.6 - MODULE UPENDER

The upender assembly was located in the southeast corner of the MDA water pit. Figure 11 illustrates this component. This assembly was installed at the bottom of the pit to allow sufficient height for vertical loading and transfer of the modules into the fixed elevation MTC. The upender was designed to upend modules contained in utility fixtures from the vertical to horizontal orientation and vice versa for MDA and COS operations.

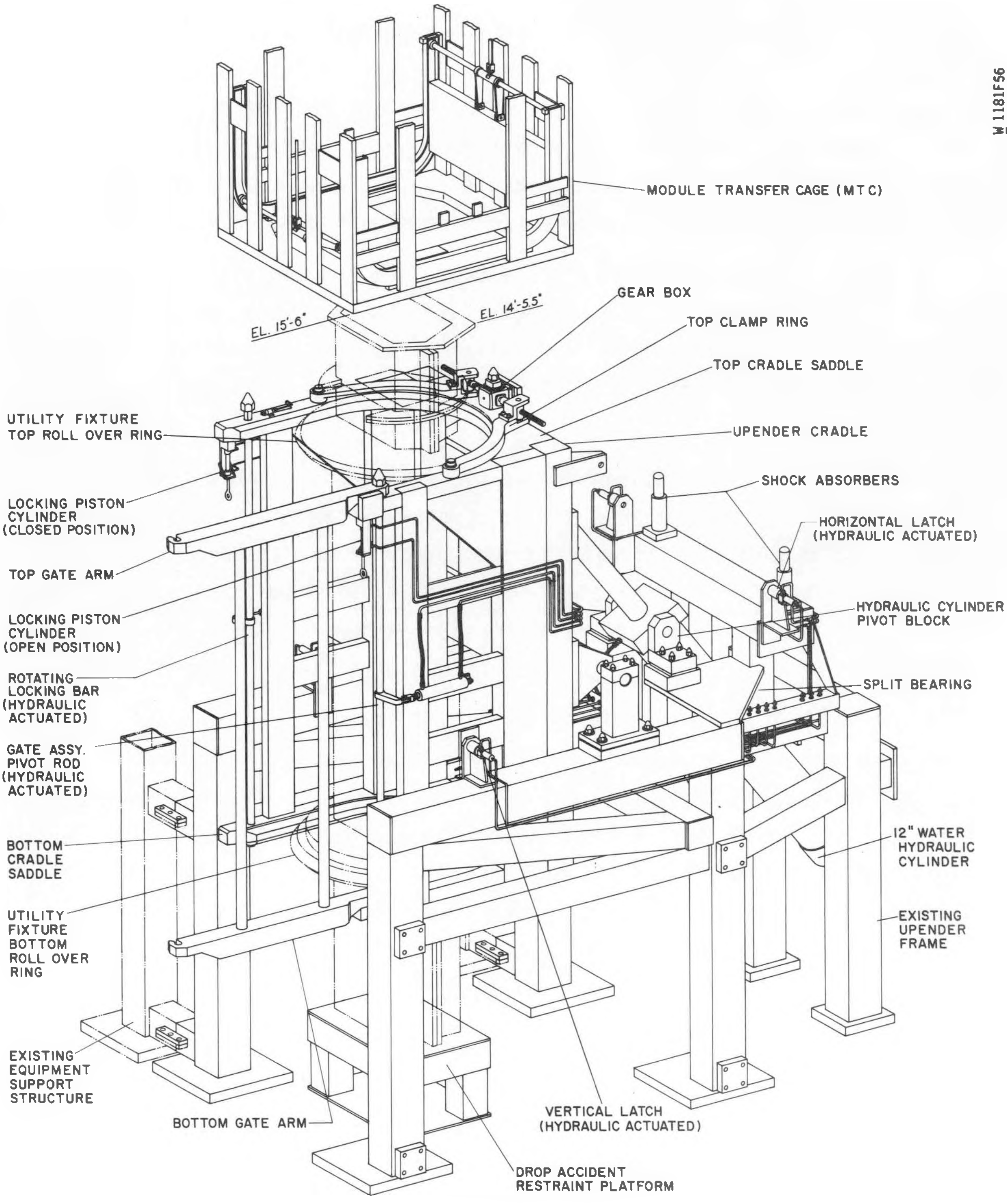

Figure 11 - LWBR Upender Assembly

The upender consisted of two main components, the frame and the cradle assemblies. The frame was constructed of 4-inch by 4-inch and 6-inch by 6-inch welded stainless steel tubing. This structure was integral with the MDA support structure and was used to provide lateral seismic bracing against the pit walls. The cradle was mounted to the frame through two trunions and was rotated by a 12-inch diameter hydraulic water cylinder. The cradle structure consisted of a welded rectangular stainless steel tube frame with 3-inch thick support plates on each end. The top of the cradle contained a remote hydraulically operated clamping arm gate assembly for loading and unloading the UF into the cradle.

The vertical UF was loaded into the upender, and the UF rollover rings were seated in the top and bottom end plates. The upender clamping arms were closed, and a remotely operated hydraulic lock pin was inserted through the clamping arms to secure the UF in the upender.

3.7 - MODULE TRANSFER INTO MDA WATER PIT

To begin module disassembly processing operations, the as-received modules were transferred from the storage rack liners to the MDA water pit. The equipment and operations discussed above were used to lift the vertical module out of the storage liner, transfer it through the water pits, and lower it into a prepared vertically oriented UF installed in the module upender. The UF was prestaged for module installation by having the proper end cap and main body inserts installed for the module type being received, and the top end cap cover plate removed. The crane monitoring system readings were used to establish when the crane was centered over the storage liner and UF ports. Initial coordinates for these positions were established using module mockups during a dry water pit checkout. Rotational orientation of the module was manually accomplished with a probe pole. Lead-in edges in the top of the UF and on the bottom of the module provided guidance for module lowering. The crane monitoring system vertical readings were used to confirm that the module was fully seated in the UF.

When the as-received module was properly loaded into the UF, the pressure plate jacks were tightened to secure the module, and the top end cap cover plate was installed. The module and UF were then slowly rotated to the horizontal position. When horizontal, the upender lock cylinder and clamping arms were remotely retracted to permit installation of the horizontal grapple.

3.8 - UTILITY FIXTURE GRAPPLE

The horizontal grapple was used to provide redundant double-rigged lifting of the horizontal UF between the upender and MDA stations. An illustration of the grapple is shown in Figure 12. The grapple was constructed of a spreader beam that contained two independent sets of lift rigging. The primary rigging was attached to the UF using one lift pin in each rollover ring. The load was carried through the spreader beam to the 10-ton bridge crane hook. The secondary lift rigging was attached to the UF through a lift lug on each end cap. The load was carried by link assemblies to two 5-ton chain hoists mounted to crane rails on the underside of the bridge crane girders. The lifting load was normally carried by the primary rigging, and 0 to 5 inches of slack was maintained in the secondary rigging. The amount of slack was controlled using limit switches to turn the chain hoists on and off as required. In the unlikely event of failure of the primary rigging, the assembly would drop through the 0 to 5 inch slack distance and the secondary rigging would pick up the load. Shock absorbers attached to each chain hoist were used to limit the impact loading.

In operation, the grapple was rigged to the bridge crane main hook and the two auxiliary chain hoists. The assembly was lowered into position on the horizontal UF, and the four lift pins were engaged by a single drive actuator. The drive assembly contained a lockout device similar to the vertical fuel grapple that required full lift pin engagement prior to allowing actuator tool removal. The horizontal module and UF were then transferred to the holddown and rotation fixture (HDRF).

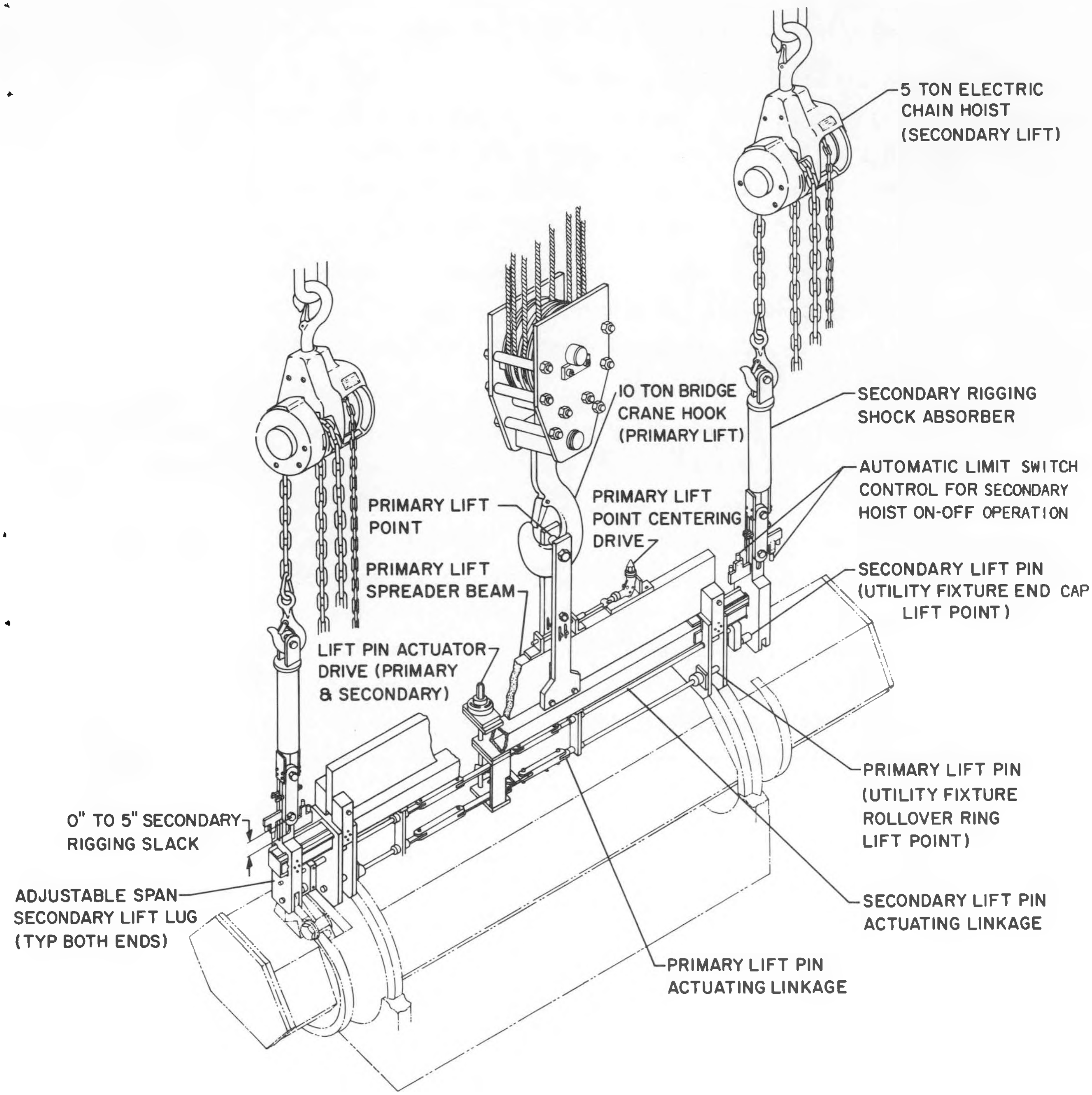

Figure 12 - LWBR Utility Fixture
Horizontal Grapple Assembly

3.9 - HOLDDOWN AND ROTATION FIXTURE DESCRIPTION AND OPERATION

The holddown and rotation fixture (HDRF) assembly was mounted on the underwater milling machine (MDA) table. An illustration of the HDRF is shown in Figure 13. This fixture was used to support the horizontal UF and rotate the module to access features for MDA and COS machining operations. A detailed discussion of the HDRF assembly is provided in Appendix A.4.

The system consisted of a 2-inch thick baseplate, 48 inches wide by 212 inches long, which contained two support saddles that mated with the UF rollover rings. Ball screw drive stage assemblies, mounted on linear rails, were installed at each end of the table.

The saddles contained eccentrically mounted cam rollers which were used to lift the UF off of solid support mounts and provide a low-friction surface for rotation. After removal of the horizontal grapple from the UF, a rotation drive gear assembly was installed on the support saddle above one UF rollover ring. With the UF supported on the rollers, a worm drive spur gear in the rotation drive gear assembly meshed with a mating gear on the UF rollover ring to produce module rotation. After the desired rotated position was obtained, the UF was lowered into the solid saddle supports using the cam rollers. A clamp assembly was installed above the second rollover ring to secure the UF in the HDRF during machining.

3.10 - UTILITY FIXTURE END CAP REMOVAL

The UF end caps were removed to provide access to the module baseplate region for cutoff operations. This was performed using the HDRF stage assemblies located on each end of the module. The stage assemblies consisted of a flat plate containing two vertical posts on the outboard ends. The posts contained a hole and keyway arrangement which was used to support various tooling. The plate was mounted on two 2-inch diameter ball bushing rails and the assembly was moved toward or away from the module with a 1 1/2-inch diameter ball drive screw.

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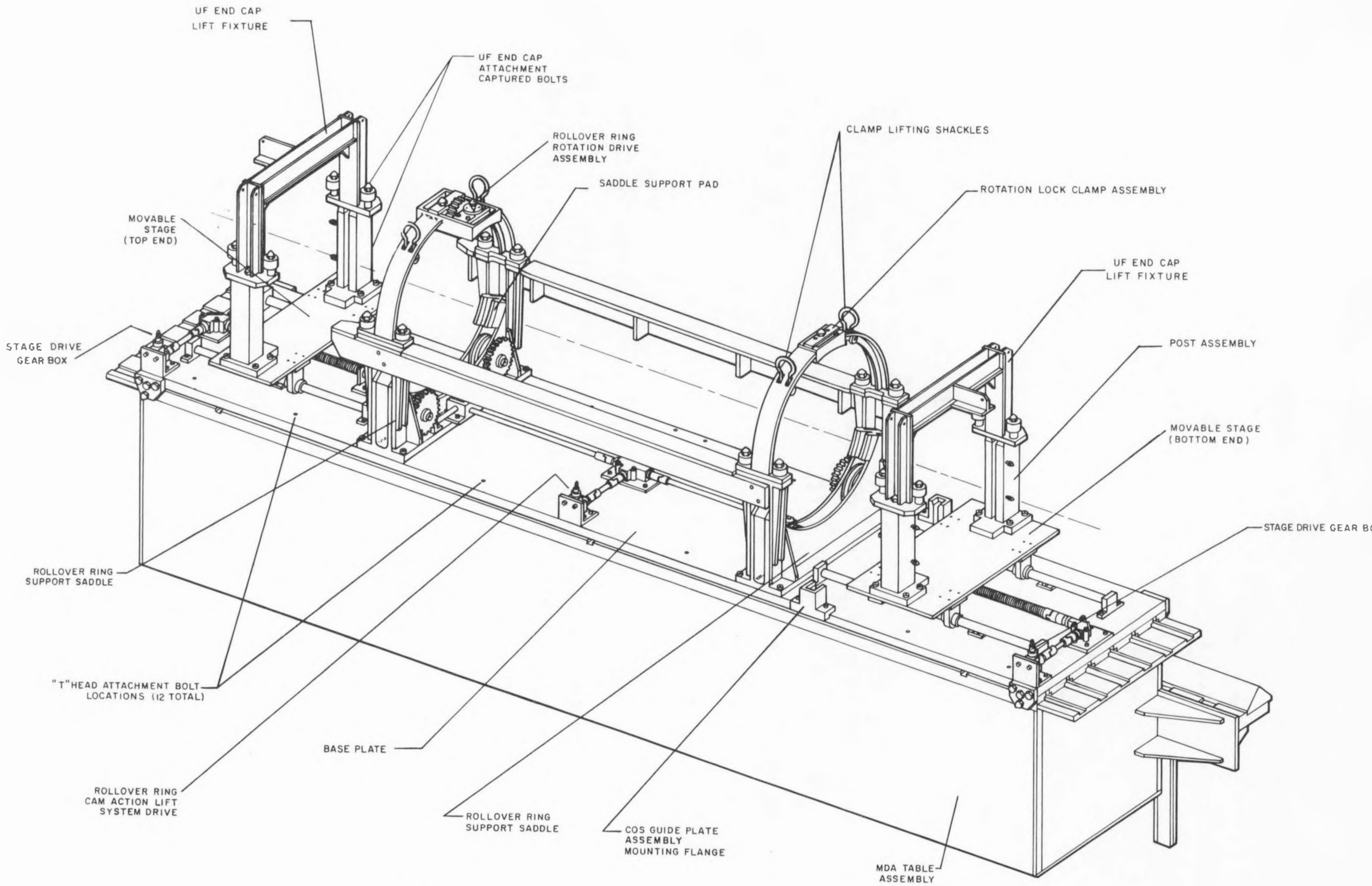


Figure 13 - LWBR Holddown and Rotation System

To remove the end caps, the UF was rotated to the position required for baseplate cutoff, which also oriented the end cap lifting attachment lugs with the end cap lift fixture. The lift fixture was installed into the stage posts and the stage was moved toward the UF to align the bracket with the end cap attachment lugs. Captured bolts contained in the lift brackets were installed into the end caps. The end cap barrel clamp was loosened, and the stage and end cap assembly were retracted from the module. The end cap assembly was lifted out of the stage posts and placed in a storage location until COS operations were completed.

3.11 - MODULE DISASSEMBLY APPARATUS AND CONVERSION FOR CUTOFF MACHINING

Module baseplate cutoff operations were performed using an underwater bandsaw head (COS) mounted on the module disassembly apparatus (MDA) system. Illustrations of the MDA containing the milling machine head and cutoff saw head are shown in Figures 14 and 15, respectively. The detailed MDA and COS development and design is discussed in Appendices A.1 and A.2, respectively.

The MDA was designed and developed for use as an underwater milling machine for fuel module disassembly operations. The assembly consisted of a table and base assembly, a carriage and knee assembly to provide longitudinal (X axis) and vertical (Z axis) motion, and a head assembly which contained a vertical milling spindle and provided horizontal (Y axis) motion. MDA translation and milling head positioning capability is shown in Figure 16. The table/base assembly consisted of a 48-inch wide by 212-inch long by 42-inch high stationary structure containing "T" slots for attachment of fixturing and support equipment. The carriage was a stainless steel weldment that provided support for vertical ways and translated on the base to provide longitudinal X axis motion. The knee assembly traveled vertically (Z axis direction) within the carriage and provided support for the head assembly. The knee contained two hydraulic counterbalance pistons which were used to reduce loading on the vertical drive assembly. The removable head and horizontal Y axis drive assembly were mounted on the knee. The head consisted of a drum

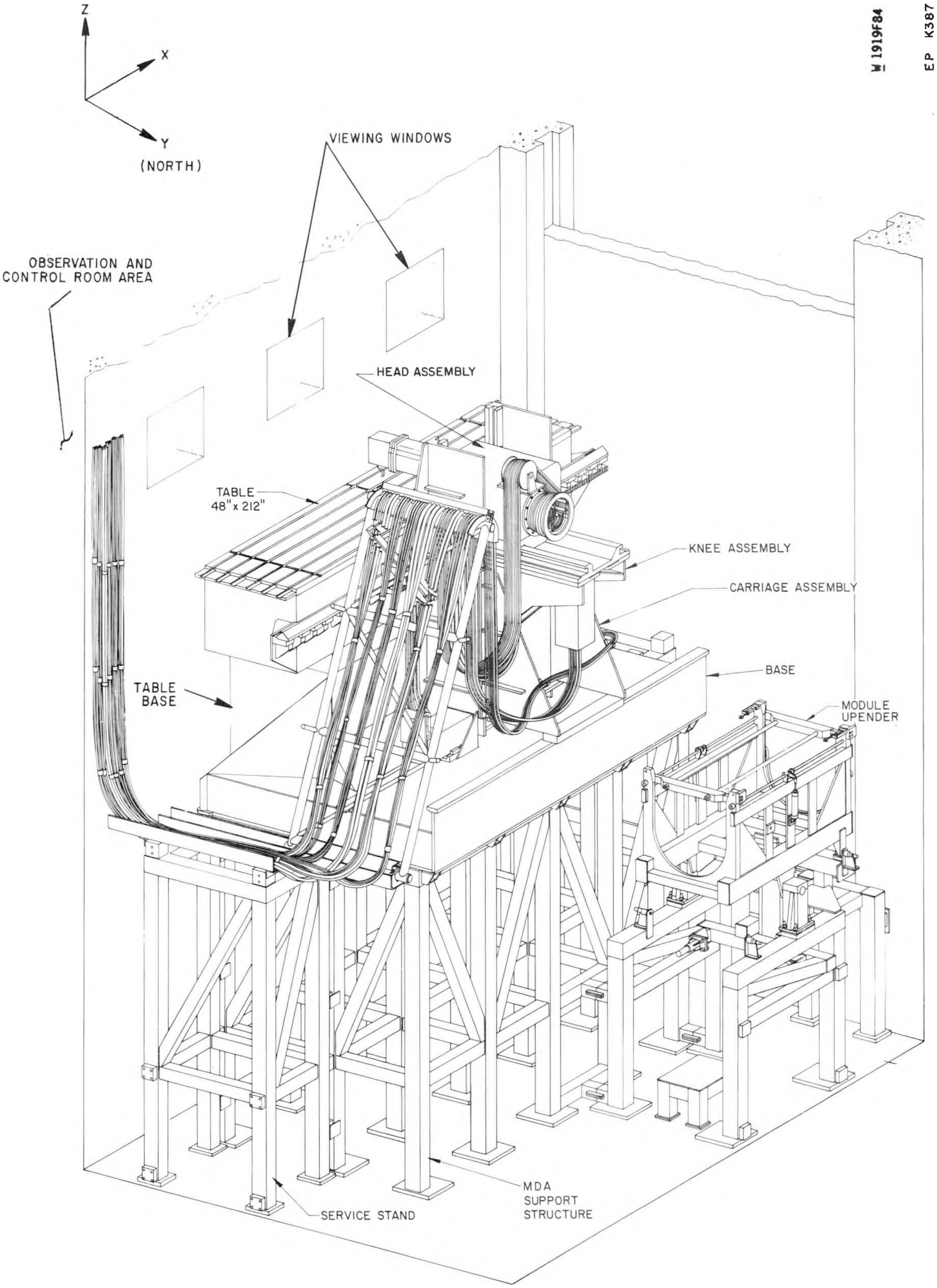


Figure 14 - LWBR Module Disassembly Apparatus (MDA)

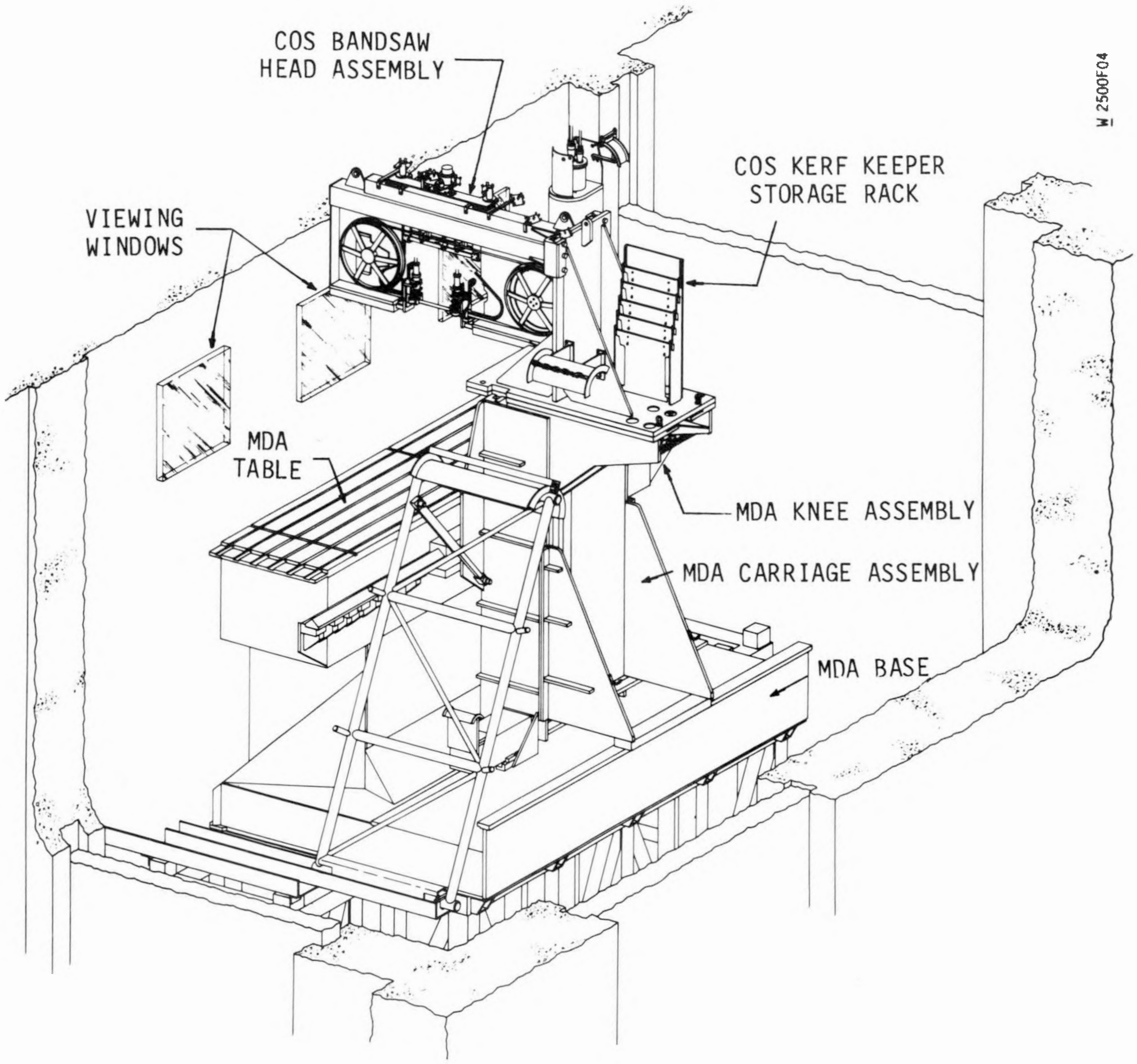


Figure 15 - LWBR MDA Containing the Cutoff Bandsaw Head (COS)

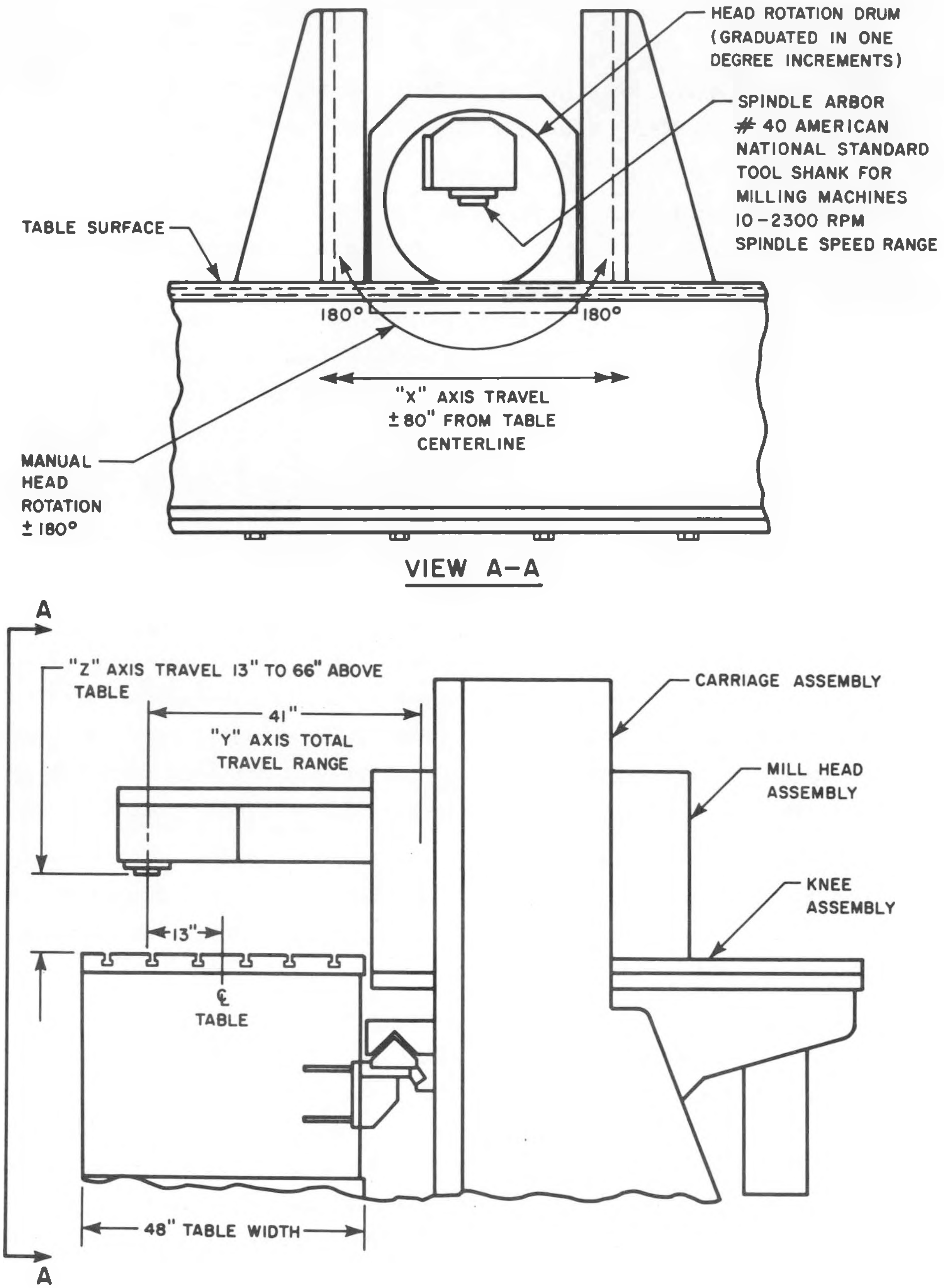


Figure 16 - Module Disassembly Apparatus Head Positions

that provided 360 degree rotational positioning about the Y axis and contained a right angle head vertical spindle with a #40 American National Standard (A.N.S.) milling machine taper.

Millhead tool changeout was performed by rotating the head 180 degrees to orient the spindle up. An automatically operated locking system engaged and disengaged the tool in the spindle. The head was rotated manually from above the machine using a worm drive gear. X, Y, and Z axis motions were all remotely operable using power driven feeds. The feeds provided travel of the millhead spindle through 160 inches in the X axis direction, from 13 to 66 inches above the table surface in the Z axis, and horizontal travel within 13 inches of the outboard edge of the 48-inch table width in the Y axis. Axis feed rates ranged from a minimum of 0.060 inch per minute to a maximum jog speed of 7 inches per minute in all directions. The millhead contained a high and low gear range which produced spindle speeds from 10 to 2300 RPM.

The MDA was supported on an equipment support structure. The structure was fabricated from welded stainless steel square tubing. An illustration of this structure is shown in Figure 14. The support structure was used to raise the height of the MDA table surface to the 23-foot water elevation. At this height, adequate water coverage (approximately eight feet) was provided above the modules to reduce the radiation exposure at the water surface to less than 0.2 mrem/hr.

All controls to operate the MDA were contained in control consoles which were located in the water pit observation and control room. From within this room, the operator viewed machining operations through leaded glass windows at approximately the table surface elevation.

Axis positioning was controlled using mechanically driven rack and pinion absolute digital encoders. Positional readouts of 0.001 inch were displayed at the operator console. An optical alignment system was also utilized to obtain feature location. This system consisted of an underwater camera mounted parallel to the millhead spindle at a known X and Y axis offset distance. Fiducial marks or component features were sighted with the camera using monitors in the control room. Camera offset values were subtracted from the sighted location to determine spindle coordinates of the desired location.

For baseplate cutoff operations, the MDA millhead (including the Y axis drive assembly) was removed from the knee and replaced with the COS bandsaw head. During changeout, all hoses and cables for millhead control remained installed and the assembly was placed on a stand at the bottom of the water pit. Changeover operations were performed using two cranes (one for each machine head) to manipulate the components around the crowded water pit.

3.12 - CUTOFF SAW DESIGN AND OPERATION

The cutoff saw (COS) was a horizontal bandsaw designed to traversely cut off the module ends in a plane near the center of the baseplate. The saw was used to sever the top and bottom ends of twelve modules (24 cuts), which included four modules of each type. Figure 17 contains an illustration of the COS.

The COS bandsaw was mounted on the MDA vertical carriage and knee assembly. The MDA provided the vertical travel required to sever the module ends, and the east and west translation required to position the bandsaw above the two module ends. North-south horizontal travel was not required, and this capability was not incorporated into the machine.

The COS bandsaw head was designed to be an underwater, self-contained assembly that could be remotely interchanged with the MDA milling head. The integral COS systems and auxiliary equipment included: 1) an alignment system used for saw cutting plane positioning, 2) a blade drive system to power the blade, 3) COS control console which controlled the bandsaw blade drive system, interfaced with the MDA axes drives to control the cutting force, and displayed numerous operating parameters, 4) a blade replacement fixture for blade changeout and installation, and 5) a debris suction system to recover severed fuel rod components and cleanup the station after cutting.

3.12.1 - Alignment System

The COS alignment system utilized a similar design as the millhead spindle alignment system. For baseplate cut alignment, a vertically mounted underwater camera was installed on the sawhead at a known offset distance from the blade. Module features were sighted with the camera and viewed on a closed circuit television in the water pit control room. The offset value was subtracted from the

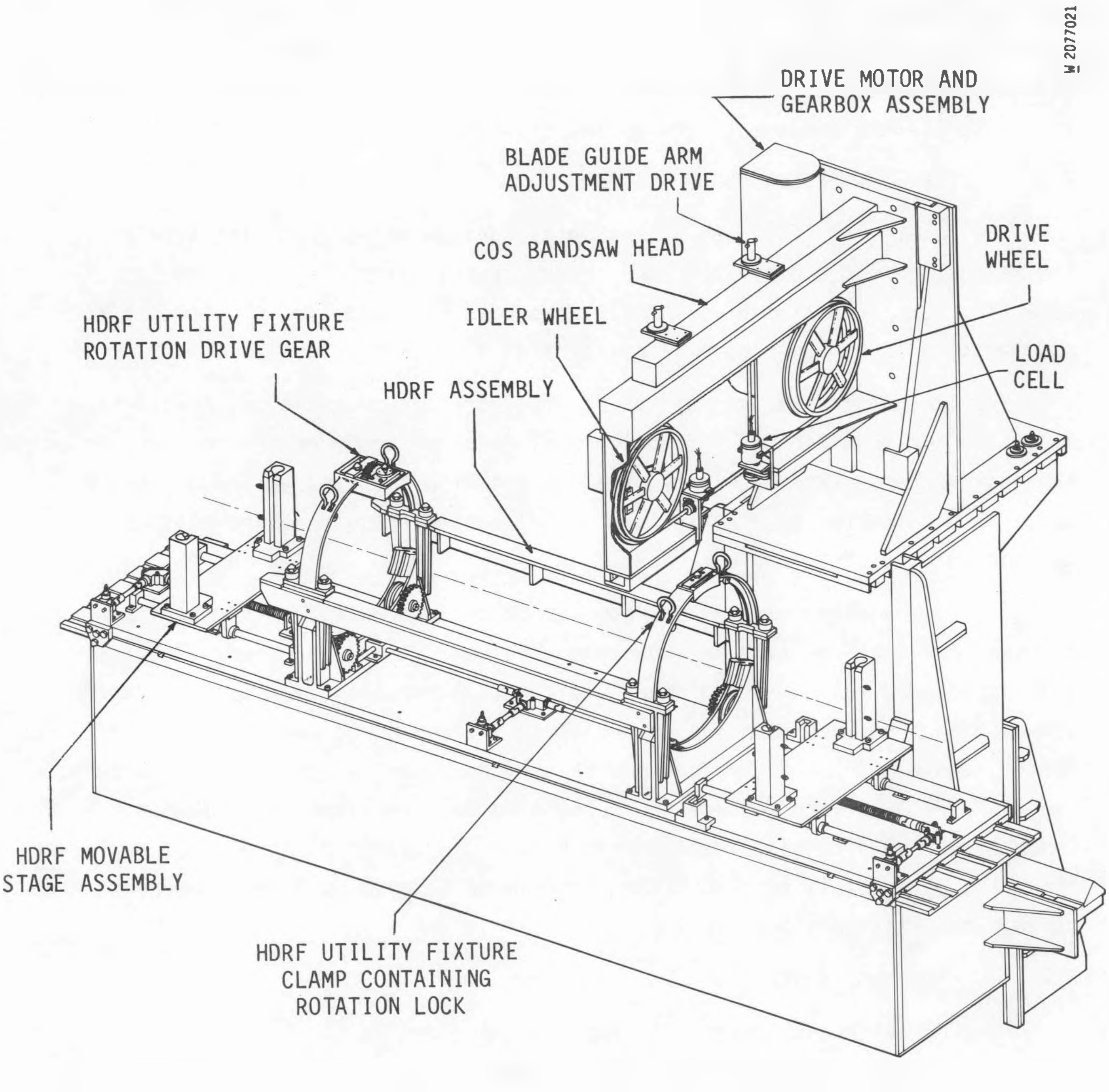


Figure 17 - LWBR Cutoff Saw (COS)
(Shown with Holddown and Rotation
Fixture Installed on Table)

sighted target to determine the coordinates required to position the blade above the desired location. To confirm saw position prior to cutting, saw blade contact with the module was initiated at the intended cut location and a gage bar was used to confirm saw position with respect to a known module feature.

3.12.2 - Blade Drive System

The blade drive system consisted of a drive wheel and motor assembly, an idler wheel, a blade tensioner, and blade guide rollers. The saw was powered using a 5.5 horsepower variable speed DC motor. The motor was mounted to a 70:1 cone drive right angle gear reducer. The gearbox output shaft provided direct drive to the 26-inch diameter blade drive wheel. The motor and gearbox housing were contained in a watertight stainless steel enclosure. The enclosure was pressurized to prevent water seepage into these components. A photograph of the gearbox assembly is shown in Figure 18.

At the other end of the drive system, the idler wheel was mounted to the COS frame on a slider assembly (Figure 19). Blade tension was obtained using a double-acting hydraulic cylinder which translated the idler wheel away from the drive wheel. Guide rollers were used to twist the blade from the horizontal to the vertical orientation where the blade passed through the module. The guide rollers contained two unique design features which enabled remote adjustment of the span between the rollers and also provided guide roller rotation which removed the blade twist, simplifying replacement blade installation.

3.12.3 - Control Systems

The COS contained numerous control systems to monitor blade tension, blade speed, temperature detection, housing air pressure, and various other machine parameters. The blade load cell sensor system was a unique design that enabled precisely controlled cutting of the fuel rod connections within the allowable limited width cut zone. The load cells, mounted at two locations above the blade, were used to detect blade cutting force (see Figure 20). Blade force information was used to control blade cutting load which minimized potential runout toward the fuel rods and prolonged blade life. The load cells directly monitored the force applied to the blade during cutting operations. Actual cutting force was controlled through a computer feedback system which adjusted the MDA vertical feed (Z axis) to produce the desired blade force.

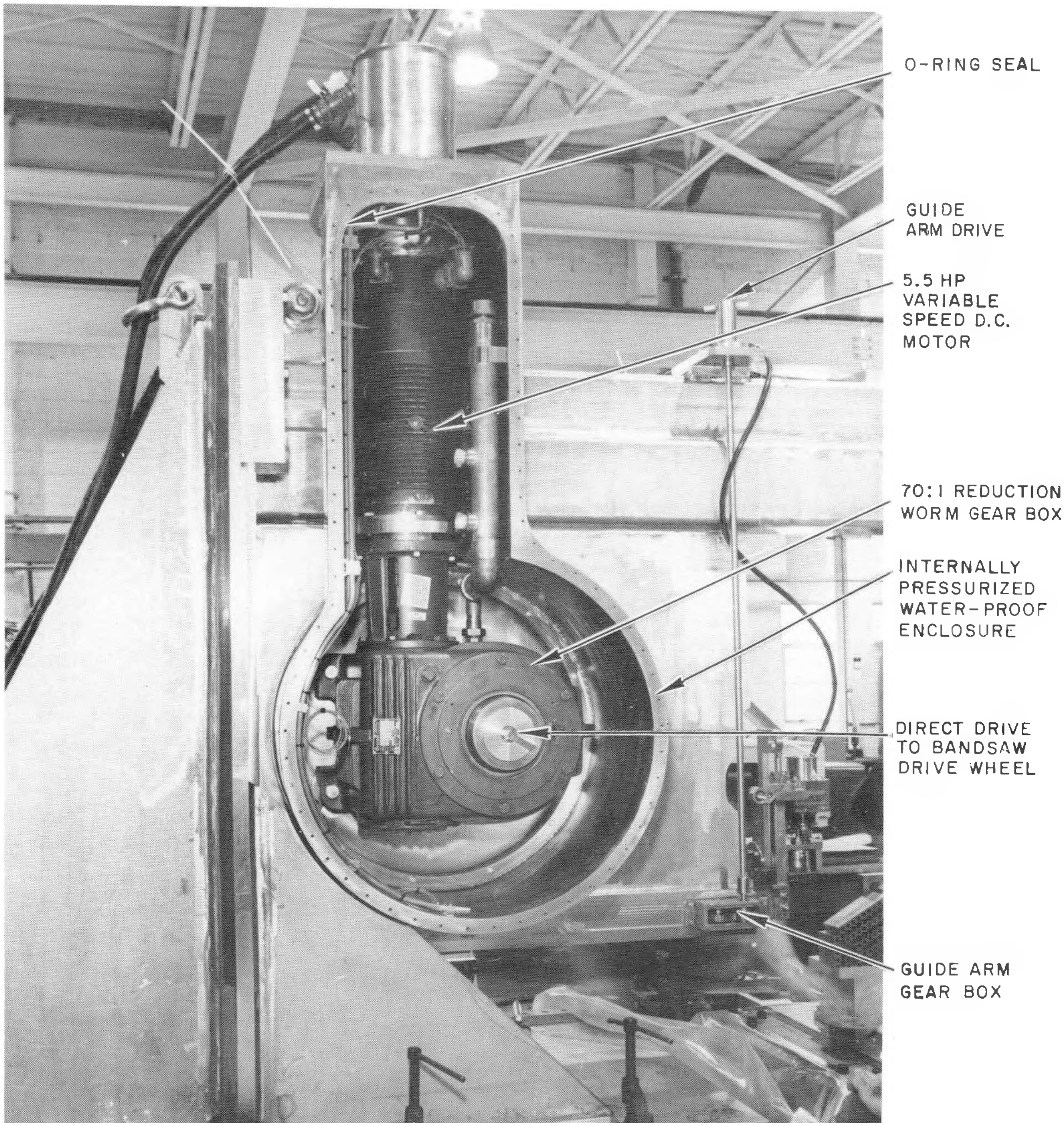


Figure 18 - MDA-COS Gearbox Assembly With Housing Back Cover Removed

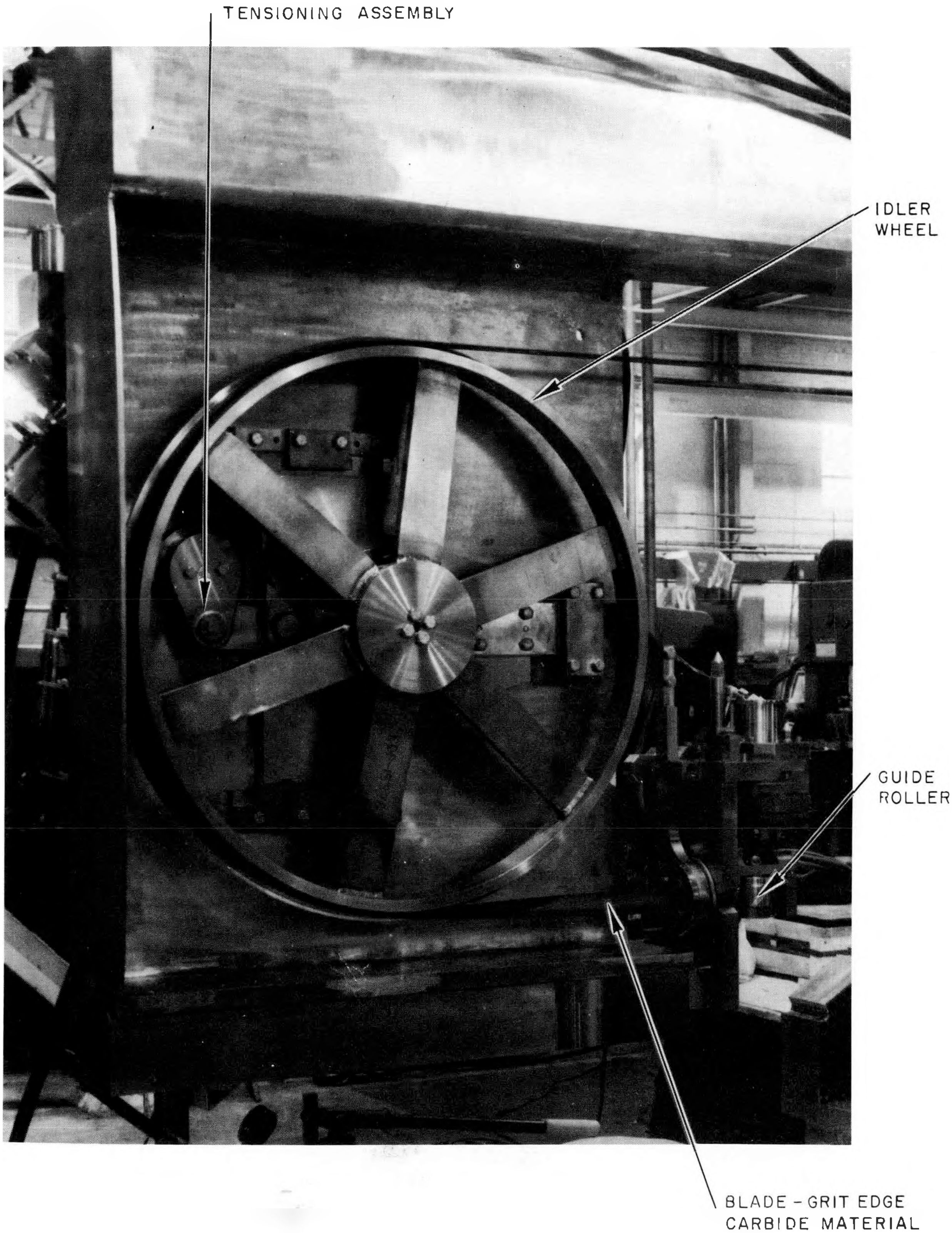


Figure 19 - MDA-COS Bandsaw Idler Wheel Assembly
(Blade Side)

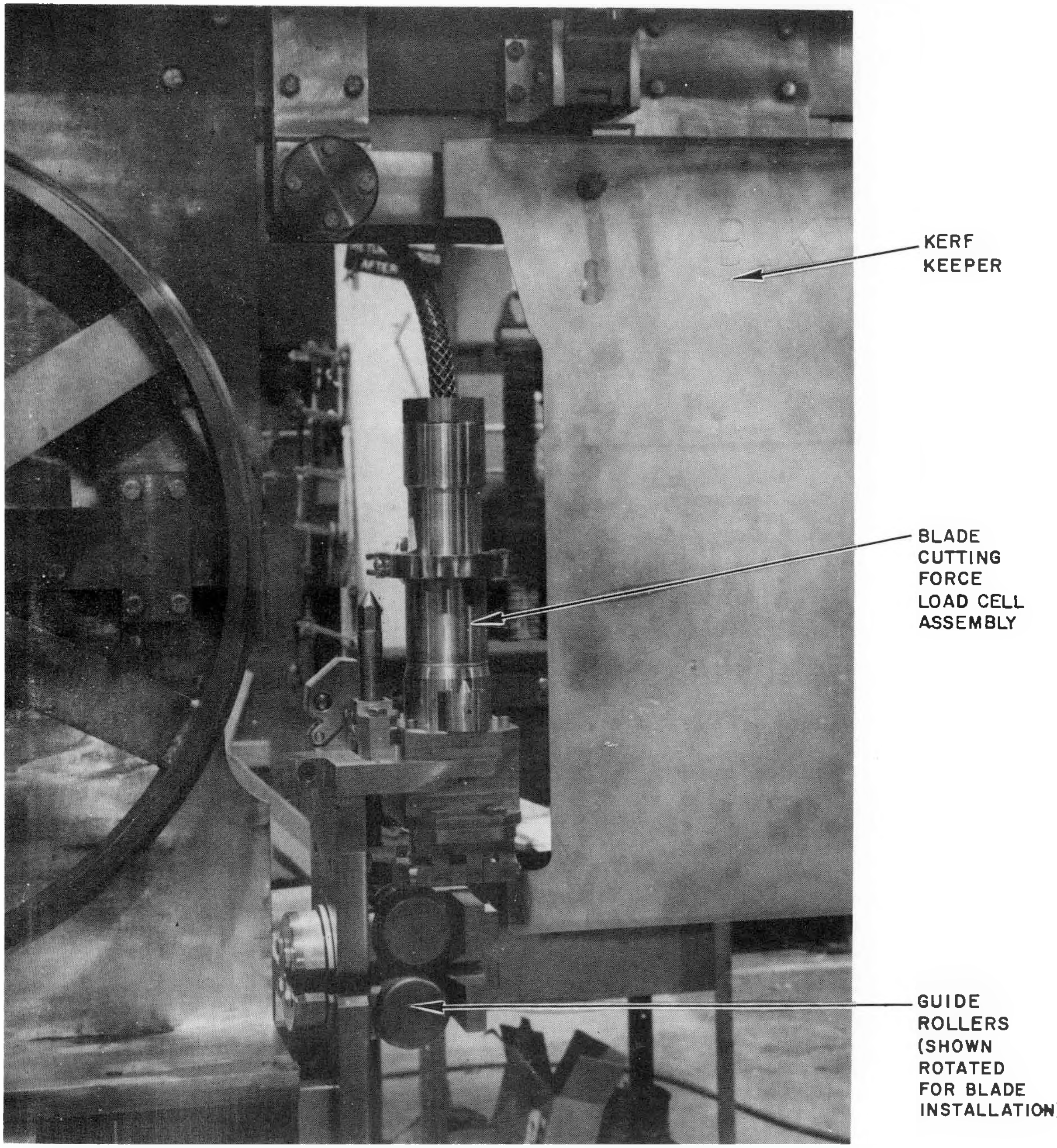


Figure 20 - MDA-COS Bandsaw Load Cell Assembly and Blade Guide Rollers

All COS systems were controlled using two consoles located in the water pit observation room. A Modicon microprocessor was used to provide automatic control of required sensors and detectors throughout the saw, including vertical feed control.

A kerf keeper system (shown in Figure 21) was installed above the bandsaw blade to maintain an open kerf. This system was required to enable cutting blades to be withdrawn and reinserted during blade changeout. During baseplate cutting, severed fuel rod nuts and stems moved into the saw kerf due to machining vibrations. When the new blade was energized to clear the kerf, the round severed pieces rotated, preventing blade advancement.

The kerf keeper system consisted of a flat plate of approximately the thickness of the blade backing material which was fed into the cut behind the blade. This prevented loose fuel rod nut pieces from entering the cut and blocking the blade path. To prevent buckling of the kerf keeper plate during insertion into the saw kerf, a limit switch was located at the top of the plate. This switch stopped bandsaw feed when the force to insert the kerf keeper plate became too high.

3.12.4 - Blade Replacement Fixture

The remote bandsaw blade installation fixture was designed to install a conventional bandsaw blade on the COS while underwater. An illustration of this fixture is shown in Figure 22. The fixture design consisted of a lightweight aluminum frame which contained magnetic blade supports to retain the blade in the necessary shape to fit over the bandsaw wheels and guide rollers.

For blade installation, the idler wheel was retracted toward the drive wheel using the tensioner mechanism, and the guide rollers were rotated to the horizontal orientation to eliminate the blade twist. The blade installation fixture was lowered onto the saw frame support saddles which were designed to pivot the fixture about the top end of the saw frame. The fixture was then rotated into the saw to engage the blade around the bandsaw wheels and into the guide rollers. With the blade held aligned over the wheels, the tensioner

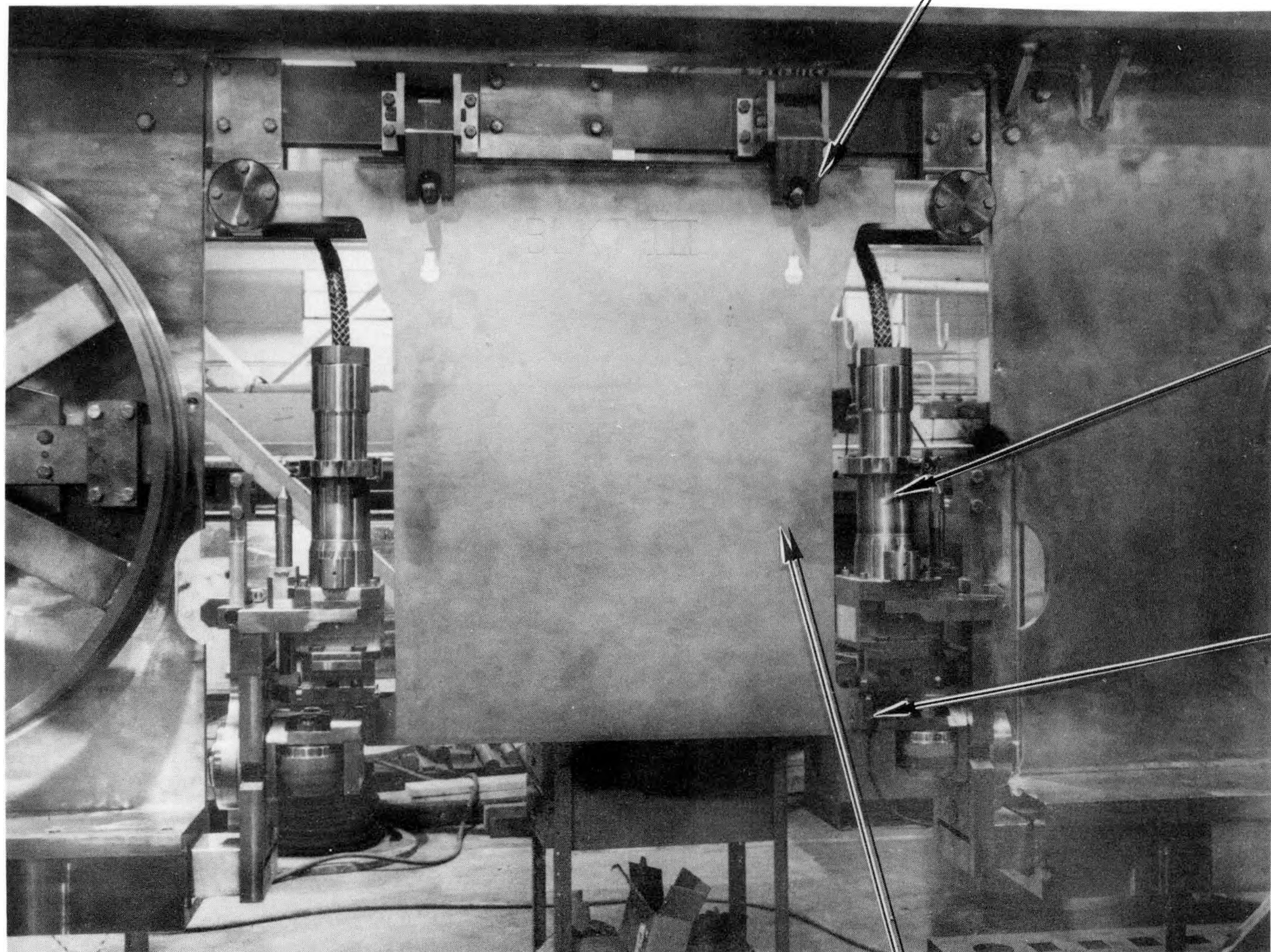


Figure 21 - MDA-COS With Blanket III Kerf Keeper Plate Installed

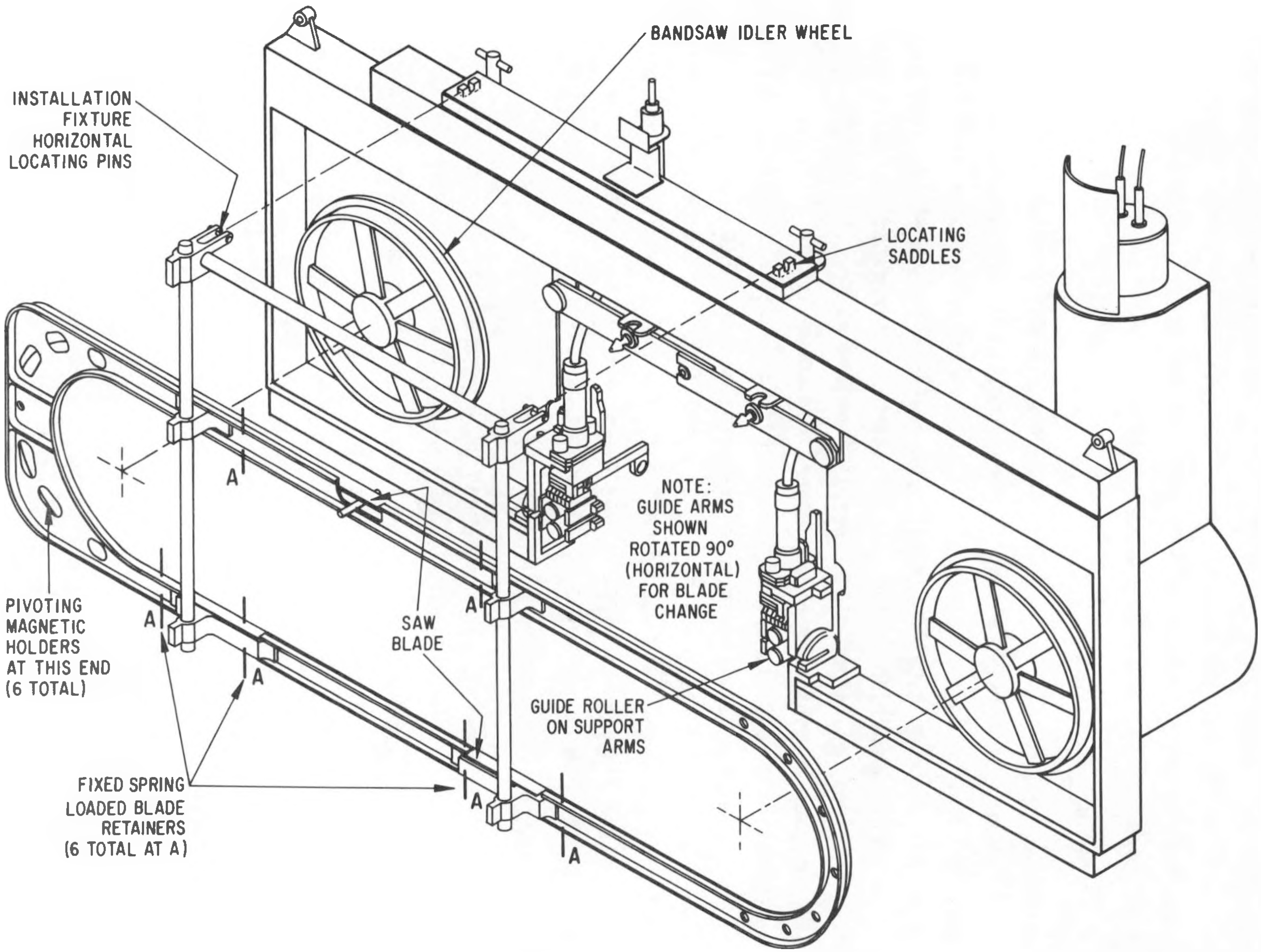


Figure 22 - LWBR COS Bandsaw Blade Installation Fixture

was energized. This snapped the blade off of the installation fixture magnets and retained it on the bandsaw wheels. After tensioning, the installation fixture was removed and the guide rollers were rotated to twist the blade into the vertical orientation, completing the new blade installation.

3.12.5 - Debris Suction System

A vacuum suction system was used to clean the cut faces of the fuel modules and remnants. Chips were also removed from the UF and HDRF with a vacuum suction hose. A special banjo-shaped suction collector pickup nozzle was designed for the module cut surfaces. The nozzle entrance was a circular opening in a vertical portion of the suction chamber. A reduced flow area in the chamber provided separation of the debris from the water. The lower portion of the chamber contained a compartment for accumulation of these pieces which retained rod nuts and stems required for core examination. A trap door on the bottom permitted remote discharge of the parts into a stationary remnant component container. For operation, the device was suspended from a probe pole and was connected to the ECF plant water suction inlet supply. The circular opening of the chamber was placed in contact with the surface to be cleaned and moved up and down manually in a sweeping motion.

3.13 - MODULE BASEPLATE CUTOFF OPERATIONS

As previously discussed, the module and UF were transferred onto the MDA table and rotated to the position for end cap removal using the HDRF assembly. The UF end cap was removed and stored, and the module was prepared for baseplate cutoff operations. An illustration of the setup used for module baseplate cutoff is shown in Figure 23. The rotational position selected for module cutoff was chosen to orient the baseplate hole pattern so that the cutting blade would not experience long sections of solid material in the triangular pitch baseplate hole pattern. Figure 24 contains the rotated cut orientation used for each module type.

Remnant clamps were designed and used to support the cutoff remnant during machining. An installed remnant clamp is shown in Figure 23. Remnant support was necessary to prevent saw blade binding and excessive fuel rod

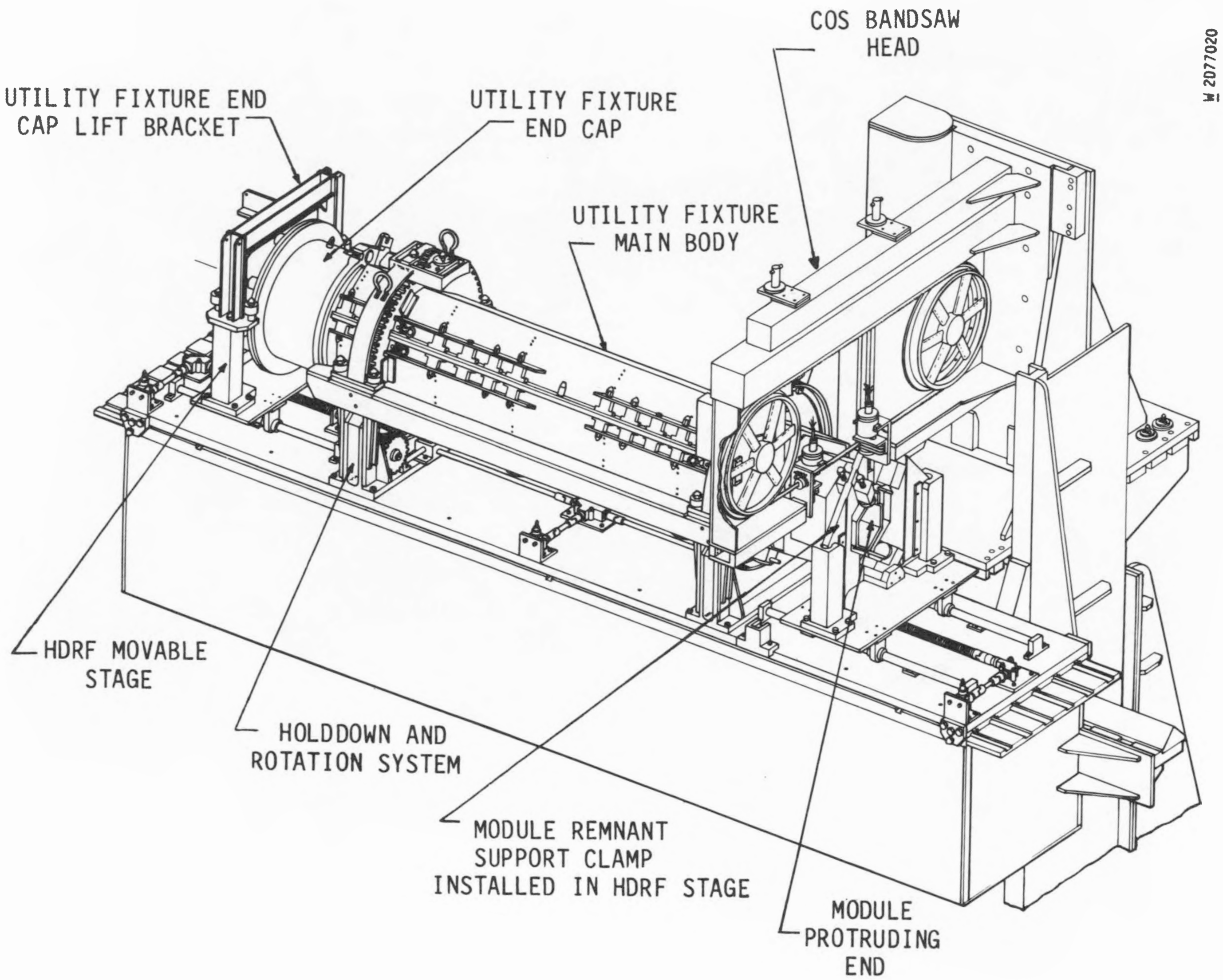


Figure 23 - LWBR Module Cutoff

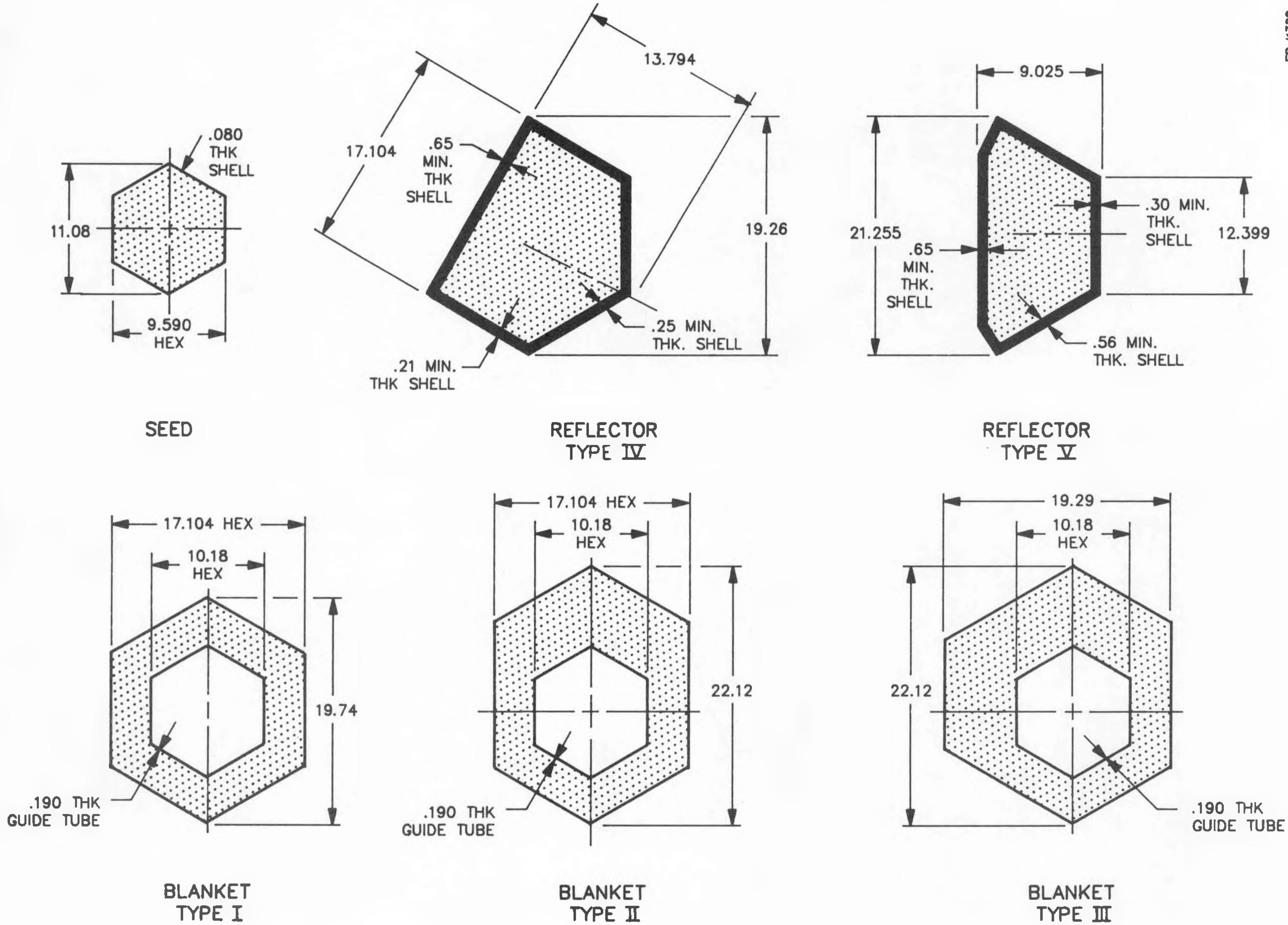


Figure 24 - MDA-COS Fuel Module Rotated Orientation for Baseplate Cutoff
(As Viewed from Top End)

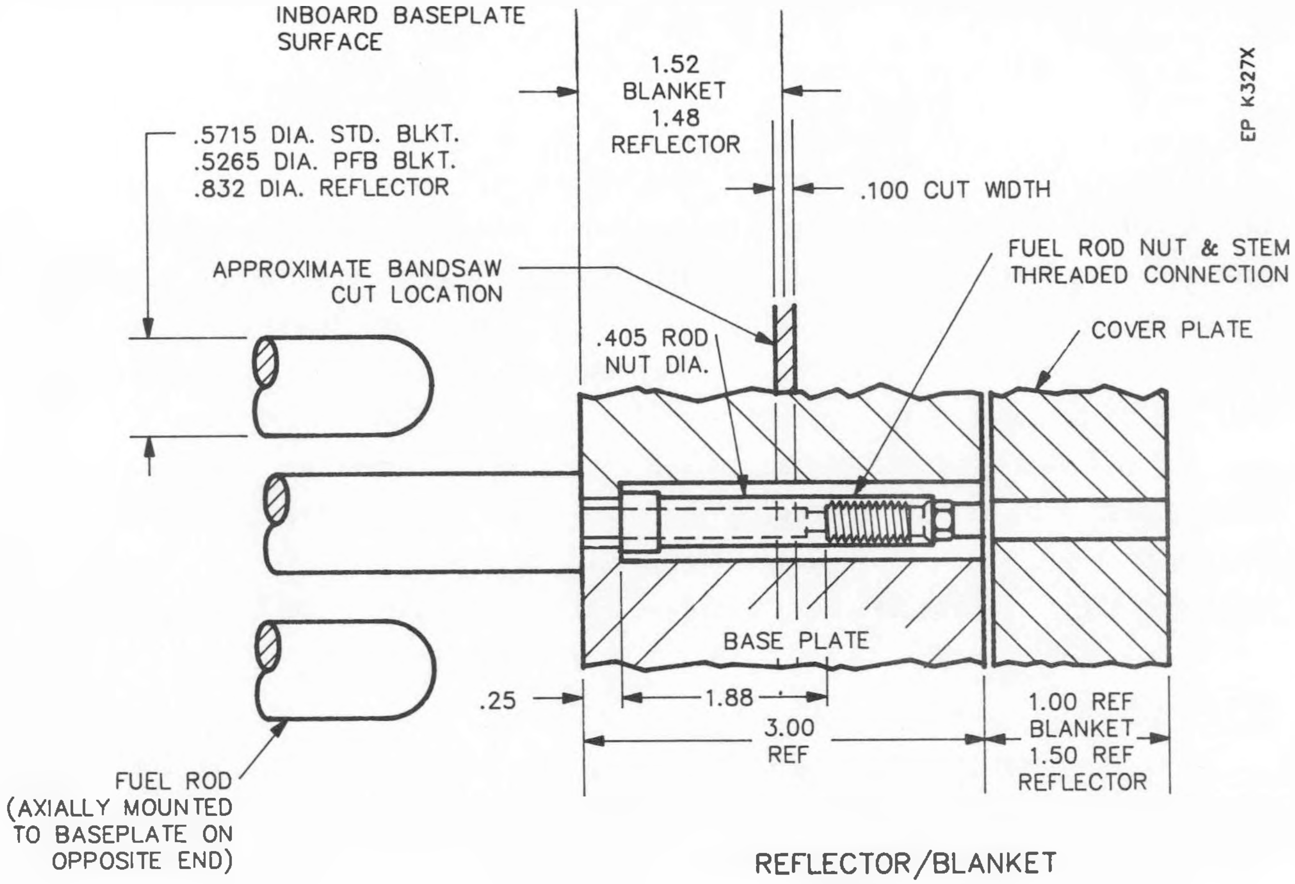
strain during cutting. The remnant clamps consisted of a 1-inch thick stainless steel support plate with a cutout of the module shape in the center. The bottom of the clamp contained a pivoting block to support the remnant weight. The upper section of the fixture had two screw clamps containing pivoting pads which were tightened against the outside remnant surface. The clamps were designed to be mounted in the HDRF vertical stage posts which provided movement and adjustment of the clamps in the module axial direction. Vertical clamp adjustment was obtained using leveling screws which contacted the top surface of the stage. Four clamps were built: one seed, one blanket, and two reflector clamps. Each assembly contained clamping pads on the front and back ends which enabled each remnant clamp to be used on the top and bottom ends of the module.

After the remnant clamps were installed, the bandsaw was aligned for baseplate cutting using the optical alignment camera, then rechecked using a gage bar. As shown in Figure 25, the cut locations through the baseplate were chosen to provide approximately two fuel rod nut diameters of length on each of the severed fuel rod nut pieces. This length reduced cocking and jamming of the loose cut pieces into the saw blade and kerf. The resulting cut location was approximately in the center of each baseplate which produced overall cutoff module lengths of 120.2 inches, 115.8 inches, and 123.6 inches for the seed, blanket, and reflector modules, respectively.

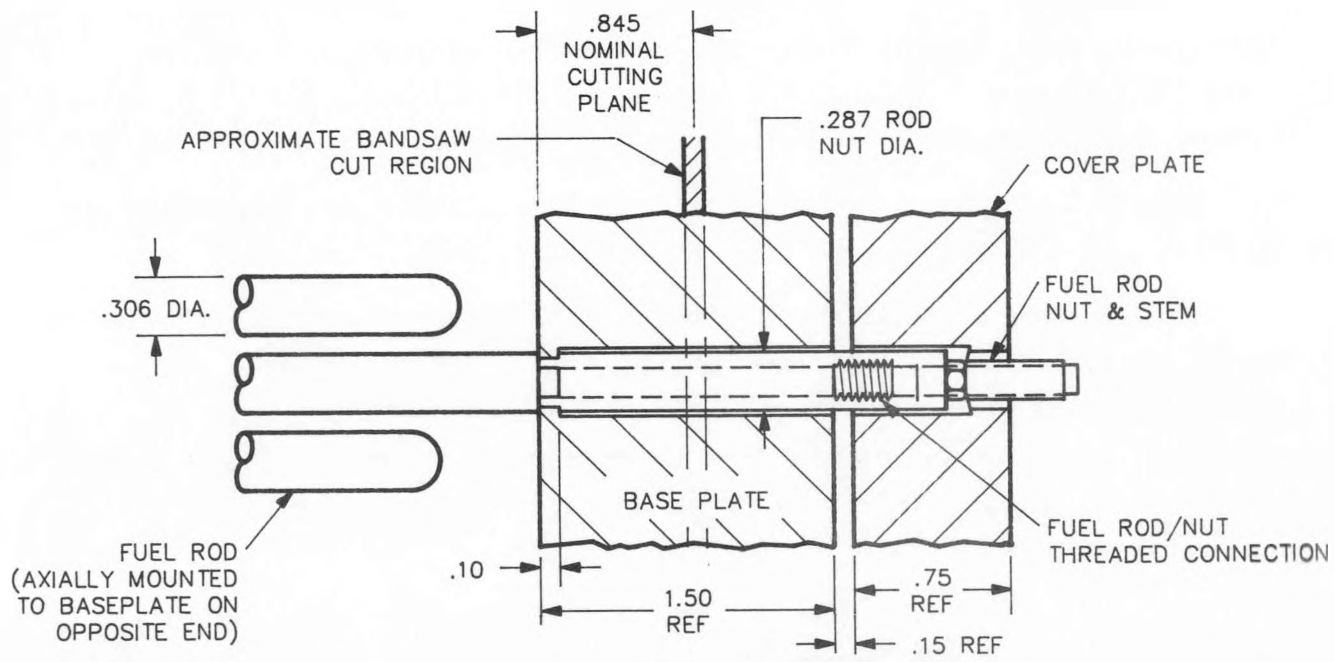
The cutting blade used was a commercially available, continuous grit edge material bonded on a 1 1/4-inch high by 0.042-inch thick steel band.

A blade speed of 300 surface feet per minute was used. Blade feed was controlled by monitoring force on the blade, which was limited to a maximum of 100 pounds or to a maximum feed rate of 0.100 inch per minute. Blade rotational direction was changed from the bottom end to the top end of the module to assure that blade rotation was in a direction to tighten the rod nuts and the other fasteners being cut.

Prior to cutting, the span between the blade guide arms was remotely adjusted to minimize the unsupported blade distance. Cutting operations began on the bottom end of the module. Initially the cutting force was restricted



REFLECTOR/BLANKET CUTTING PLANES (BOTTOM END SHOWN)



SEED CUTTING PLANE (BOTTOM END SHOWN)

Figure 25 - MDA-COS Baseplate Cutting Plane Locations

to approximately 60 pounds of blade loading for the first two inches of the cut. This restriction was used to minimize blade runout prior to having sufficient blade depth engagement in the work. Average blade life was approximately eight hours of cutting time. Normal module cutting time ranged from approximately eight hours per baseplate on the seed module to approximately 24 hours for the Type III blanket which required the largest cut area. A photograph of a Type III blanket module end after cutoff operations is shown in Figure 26.

When cutting on the bottom end of the module was completed, the cutoff remnant was moved outboard of the module and the cut sections and table were vacuumed with the debris collection system. The remnant was then moved back against the cut surface to provide axial module support during top end cutting. The saw was raised above the module and holddown equipment and was horizontally translated to the module top cut location.

Bandsaw blade rotational direction was reversed for machining the top cut. Setup, cutting, and post-cutting operations were performed in a similar manner as described for the bottom end. After cutoff was completed, both remnants were backed away from the module and lifted out of the HDRF stage supports. The UF top end cap had inserts added to fill the void area of the cutoff remnant and was repositioned in the stage posts for reinstallation on the UF top end. On the bottom end of the module, the bottom stabilization clamp was installed to replace the cutoff remnant length prior to UF end cap installation.

3.14 - STABILIZATION CLAMP DESCRIPTION AND OPERATION

Stabilization clamps were designed to provide a means for vertical lifting and handling capability of the cutoff modules. An illustration of a seed module stabilization clamp is shown in Figure 27. A detailed discussion of the stabilization clamps is presented in Appendix A5. The stabilization clamps consisted of a top clamp, bottom clamp, and five or six (depending on module type) tie rods, sleeves, and tie bolts to support the top and bottom clamps. The clamps were sized to replace the module length removed in COS operations. They were constructed of stainless steel weldments with the same

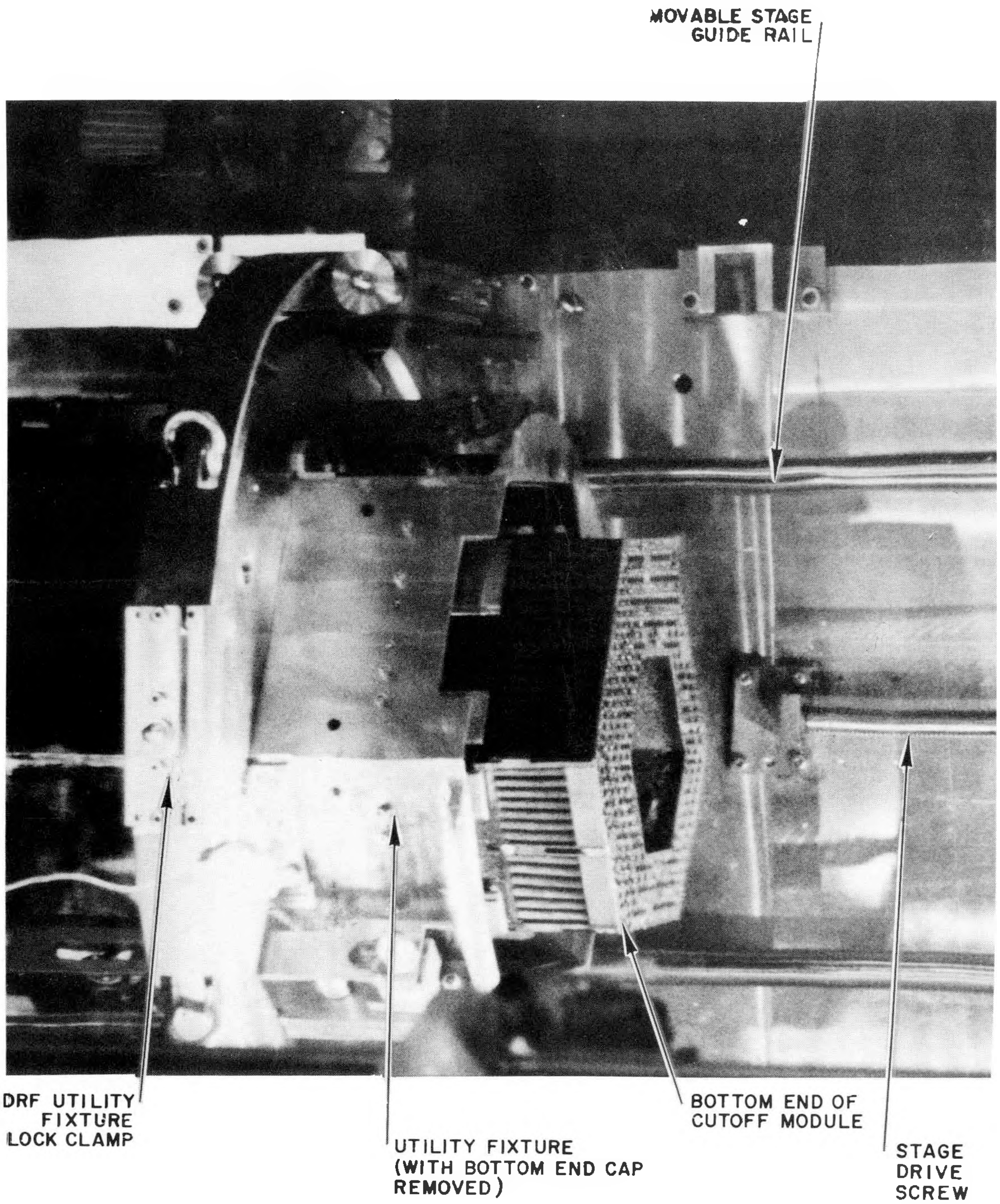


Figure 26 - LWBR Type III Blanket Module After Cutoff
(Viewed from above)

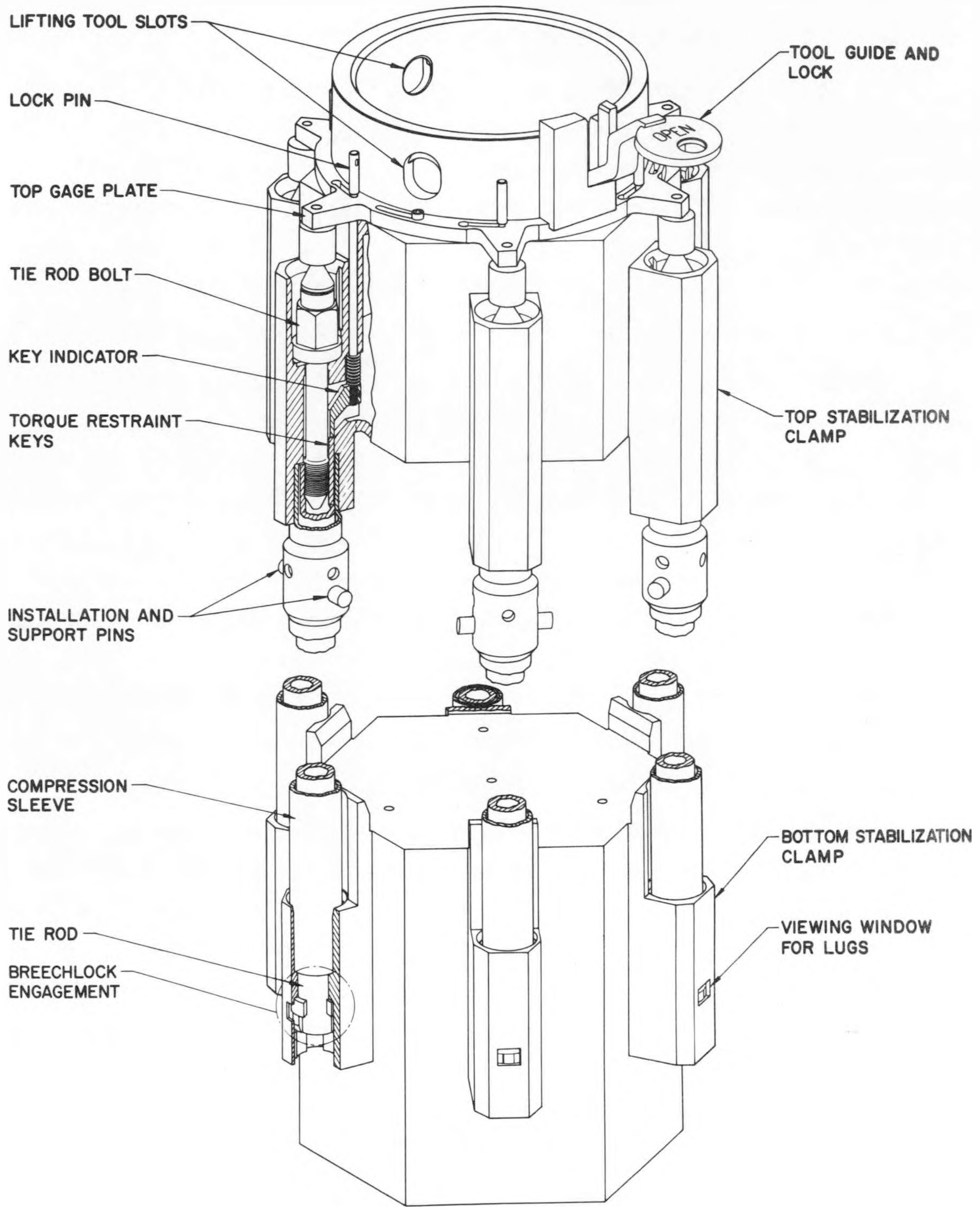


Figure 27 - LWBR Seed Stabilization Clamp Assembly

external shape as the module and contained rectangular lugs on each side for attachment of tie rod and sleeve connecting hardware.

A grapple ring similar in design to lift adapters with three equally spaced slotted holes was used for module lifting. Each top clamp lug contained a captured threaded bolt used for attachment to the tie rods. An intricate mechanical safety interlock system design was incorporated into the top clamp. This system provided assurance that all tie rods and sleeves were properly installed and tightened prior to allowing the grapple cavity to become accessible for lifting with the fuel grapple.

The tie rod and sleeve hardware consisted of 1.125-inch and 1.500-inch outside diameter stainless steel tubing approximately 125 inches long. The tie rods were installed within the sleeves, and together they provided tensile and compressive members to produce a preloaded joint between the top and bottom stabilization clamps. The internal tensioned tie rod contained a breechlock lug end on the bottom which mated with a matching lug on the bottom clamps. The top end of the tie rod contained a tapped hole which was attached to the captured bolts contained in the top clamps. The outer compression sleeve was designed to fit into socket ends in the top and bottom clamps. When the clamps were fully assembled, a small gap existed between the top of the module and the top clamp to avoid applying any compressive loading to the cutoff fuel rods.

Specialized design features incorporated into individual stabilization clamps included a center post attached to the bottom blanket stabilization clamps and skirt extensions incorporated into one seed and one Type IV reflector stabilization clamp assembly. The blanket center post was approximately 79 inches long and was bolted to the bottom blanket clamps. The post was installed into the blanket module guide tube to preclude nuclear criticality by inadvertent installation of a seed module into a blanket module prior to top clamp installation. Skirt extensions were added to one seed and one Type IV reflector stabilization clamp to provide support for the fuel rod ends on the two deshelled modules. The skirts consisted of side wall extensions approximately the thickness of the removed shell that extended along the module sides to approximately the first grid level from each end.

3.14.1 - Stabilization Clamp Installation

Bottom stabilization clamp installation was accomplished with the module horizontal on the MDA table after completion of cutoff. The seed stabilization clamp was installed by loading the clamp into the prepared UF bottom end cap and reinstalling the assembly onto the UF using the HDRF stage drive assembly. Due to the large size and weight, bottom blanket and reflector stabilization clamps were independently installed on the module, and the UF end caps were installed over the clamps. For the blanket stabilization clamp (SC), the bridge crane was used in conjunction with the HDRF stage to insert the long center post into the blanket guide tube. A fixture was designed which clamped onto the outboard end of the SC and engaged into the two vertical HDRF stage posts. The assembly was lowered onto the stage, and the center post weight was supported by the crane. The unit was partially translated into the module guide tube using the crane, and the crane attachment was then disassembled to permit full engagement using the stage drive assembly. When fully inserted, the stabilization clamp was supported in the module by a guide plate on the cantilevered end of the center post, and by six guide pins that engaged into the module guide tube at the cutoff end. This provided sufficient support and stability for the clamp during UF end cap reinstallation.

The bottom reflector stabilization clamp was installed onto the module using "V" blocks mounted to the inside edge of the stage bottom plate. The UF end cap was initially installed in the stage posts in a manner similar to all end cap installations. A "V" block was bolted to the stage bottom plate which provided movement with the stage. The bottom stabilization clamp was lowered onto and supported by the "V" block which was located between the UF end cap and the module. As the stage was advanced toward the module, the stabilization clamp moved against the module surface. Additional stage movement axially positioned the UF end cap over the SC and subsequently over the end of the module. End cap attachment to the UF was completed in the standard manner.

After installation of UF top and bottom end caps, the HDRF rollover ring clamp was removed and the UF was rotated to the horizontal position. The rotation drive gear assembly was removed, and the UF horizontal grapple was installed onto the UF. The fixture and horizontal cutoff module were then transferred to the upender assembly, and the module was upended to the vertical orientation.

With the module vertically oriented, the stabilization clamp tie rods and sleeves were installed into the bottom stabilization clamp. For installation, the sleeve was slipped over the tie rod and the pair were handled using a probe pole that was threaded into the tie rod top end tapped hole. The assembly was vertically lowered into the UF through guide holes in the UF top plate. The UF contained runners to guide and support the tie rods and sleeves into the bottom stabilization clamp breechlock lug. Once in the the breechlock lug, the tie rod was rotated 60 degrees and lowered to engage torque restraint keys into lug keyways, which permitted probe pole unthreading. All five (or six, depending on module type) tie rod sleeve pairs were installed in the bottom stabilization clamp in this manner. When completed, the UF top cover plate was removed to allow top stabilization clamp installation. The top stabilization clamp was handled using a rigid probe pole lifted by the crane which was threaded into three tapped holes in the clamp grapple ring. The clamp was positioned over the top of the module, and the clamp lugs were guided over the tie rods and sleeves using a tee handle attached to the probe pole. After seating the top clamp, each of the captured bolts were tightened using a combination of seating torque and bolt rotation to achieve the desired preload. When all bolts were properly tightened, the top clamp mechanical interlock plate was free to rotate, exposing the grapple ring for module lifting.

After stabilization clamp installation, the UF pressure plate was retracted to provide maximum clearance for module removal. The module was grappled using the fuel grapple and vertically lifted into the transfer cage. The assembly was transferred either to a storage location or to the rod removal/vertical disassembly station for rod pull or examination operations. Additional information on rod removal station operations can be obtained in Reference 5.

3.15 - PREPARATION FOR MODULE DESHELLING OPERATIONS

After ten of the twelve total core examination modules were processed through baseplate cutoff operations, shell removal operations commenced on one reflector module (IV-4) and one seed module (II-3). The purposes of shell removal were to remove the shell and shell attaching screws for visual and destructive evaluation, to provide visual external fuel rod examination, and to obtain accessibility to the module internals for grid section and grid bolt removal. Shell removal was performed prior to baseplate cutoff operations to provide intact exterior fuel rod arrays for in-bundle visual examinations. After shell removal, the module was processed through normal cutoff operations and sent to the rod removal station where insitu visual fuel rod gap examinations were performed during sequential rod removal. Additional rods were withdrawn at this time to provide access to a section of the module grid for subsequent disassembly. After rod removal, the module was returned to the MDA station to perform grid bolt and grid section removal.

The MDA was prepared for shell removal operations by changing over the COS head to the MDA milling machine head as previously discussed. The as-received module was loaded into the vertical UF and the assembly was upended to the horizontal orientation. The module and UF were transferred to the HDRF on the MDA table using the horizontal grapple. The HDRF rotation drive gear was installed and the module was rotated to permit top and bottom UF end cap removal. The end caps were removed, and the assembly was rotated to the horizontal position. When horizontal, the UF main body top cover was separated by unthreading twelve 1 1/8-inch diameter captured bolts, and the cover was temporarily stored during machining operations.

3.16 - REFLECTOR MODULE IV-4 SHELL REMOVAL

The Type IV reflector module shell consisted of a five-sided welded Zircaloy structure approximately 17 inches wide by 14 inches high by 122 inches long. The shell wall thickness varied from approximately 0.25 inch on the two parallel sides (module sides 2 and 4) to 0.68 inch on the wide module side 3. During module fabrication, the shell was attached to the module internals along the support posts using 42 0.500-13 UNC shoulder screws containing a 0.875-inch head diameter and a 0.312-inch internal hex socket. The screws were each lock welded to the shell in four places equally spaced around the screw head.

Half of the reflector shell was removed, which included the two apex sides (module sides 1 and 5) and approximately half of the two parallel sides (down to the support post location). All 28 shell attachment screws on these four sides were also removed.

The method used for deshelling the reflector module was to remove the shell attaching screws by drilling, then axially slitting the shell on the two parallel sides to permit horizontal shell removal in two segments. Shell attaching screws were each threaded into tapped holes centered in the support posts. Each post contained seven screws spaced along the module length. Four of the module sides contained one post, and one side contained two support posts. After shell slitting, hoist rings were installed into tapped holes that were machined into the shell to facilitate removal.

3.16.1 - Reflector Shell Screw Machining

Shell removal processing began with the UF in the horizontal position with the end caps and main body top cover removed. Module clamps were designed and installed to support the module in the separated UF. The clamps consisted of 1-inch thick rectangular stainless steel bars contoured to the module exterior shape. The clamps contained two screw driven pads that restrained the module top apex sides, and two right angle screw driven pads to support the module shell along the slit surfaces. The clamps were attached to the UF using the exposed 1 1/8-inch diameter UF main body attaching studs. An illustration of the setup used for shell screw removal is shown in Figure 28.

Prior to drilling operations, the UF required installation of a partial rollover ring to provide module rotation. The rollover ring assemblies were integral with the UF main body section and were removed with the top section of the UF. Two partial rollover rings were installed on the UF to replace the removed top section rings and permit UF rotation when the module was exposed. The HDRF rotation drive gear was installed above one rollover ring, and the module was rotated to position each side up and horizontal for screw drilling. The module side was leveled using a machinist's level placed on the horizontal surface. The HDRF rotation lock assembly was installed above the second rollover ring to prevent UF rotation during machining operations.

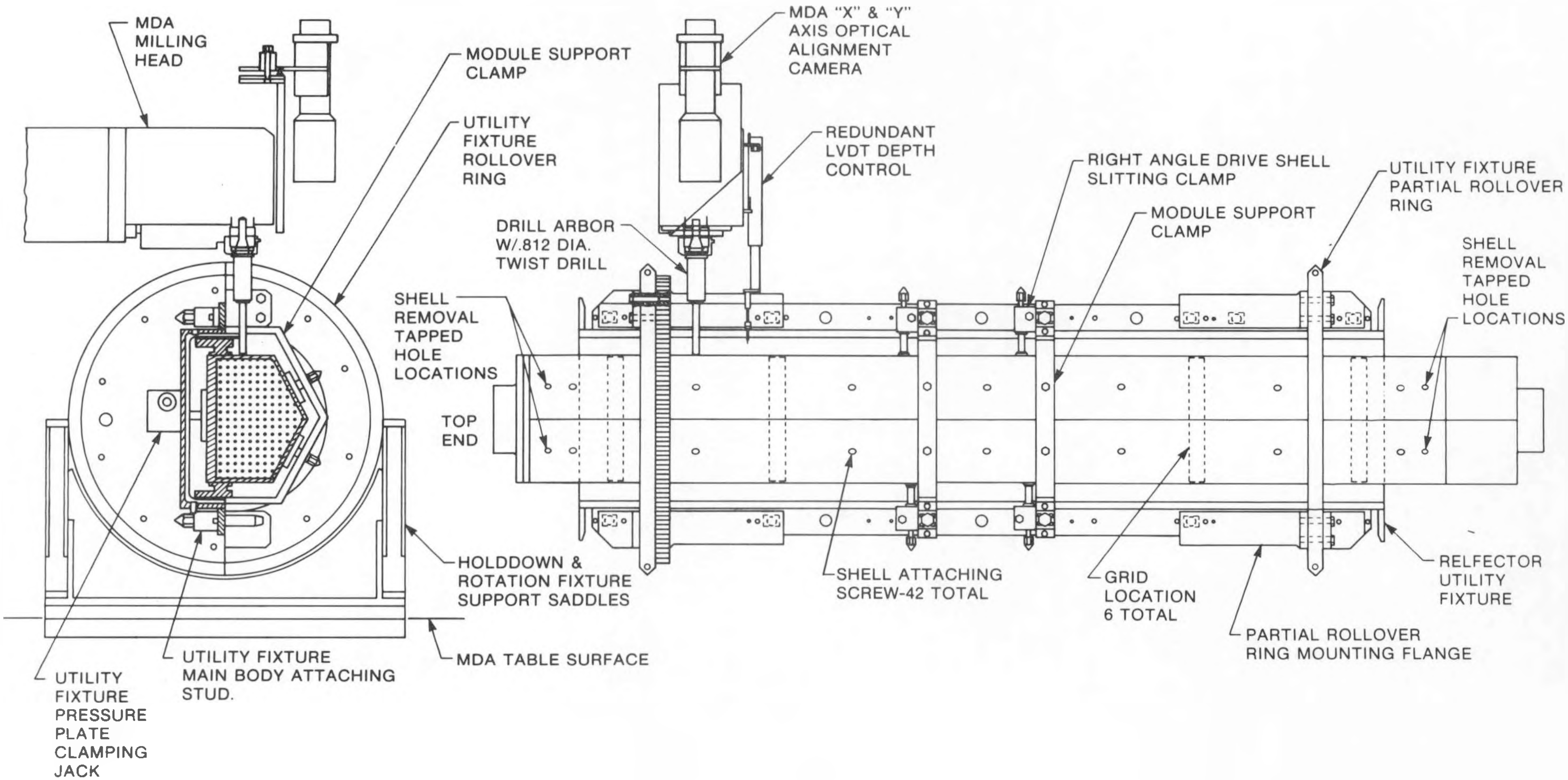


Figure 28 - LWBR Reflector IV-4 Shell Screw Removal - Side 4
(Shown with Utility Fixture End Caps And Top Cover Removed)
Rotated 90° From Horizontal Position

Shell attachment screw removal was completed by drilling out the screws using a standard high speed steel twist drill. An 0.812-inch diameter drill was used to drill through the 0.875-inch diameter screw head and to remove the 0.625-inch diameter shoulder region which separated the attachment. Two screws, identified for physical examination, were machined free from the shell using a trepan cutter and manually unthreaded using a hex key and probe pole. Trepan cutting of all shell screws was not the preferred removal method because of potential screw rotation during cutting. If the cutter was not accurately centered above the screws during initial setup, screw rotation would cause the eccentrically machined head to pinch the cutter between the head and the shell. In some cases this caused the cutter to break off and embed into the shell, in which case there was no good recovery method to continue operations. Preliminary screw machining testing revealed this problem and trepanning removal was limited to examination screws only.

The drilling arbor that was used consisted of a 14.3-inch long morse taper extension and drill. This extended length was required to access screw locations adjacent to partial rollover rings and the UF flanges. The drill spindle speed used was 35 RPM and the feed rate was 0.001 inch per revolution. Extremely slow drill speed and feed was necessary to minimize drill chipping that occurred as the screw broke free of the shell and rotated. In testing, it was found that standard drill bits were more durable for this type of machining than exotic carbide and high alloy material tools.

Similar speed and feed operating parameters were used during trepan removal of the two examination screws. The cutter used was a Rotobroach trepan cutter which contained a 0.750-inch inside diameter and a 1.125-inch outside diameter. The cutter machined away the four screw head lockwelds by machining to a depth of 0.140 inch below the shell, and the screws were unthreaded for removal. The cut depth was precisely controlled to avoid machining away the entire screw head depth which maintained the screw seating surface and minimized rotation.

X and Y axis screw location for drilling and trepanning was obtained using the MDA optical alignment camera. Z axis location was determined based on tool contact with the work surface. After contact, machining depth into the work was controlled using the MDA digital encoder readouts. Backup Z axis location was provided using an LVDT mounted on the millhead adjacent to the spindle. A digital readout of the LVDT was installed in the MDA control room. The leading drill edge was calibrated with the LVDT and was used for relative depth control after machining began. The LVDT unit contained a limit control which shut down MDA Z axis feed if the set point depth limit was exceeded.

A sound probe was also used during machining to confirm tool contact with the work and to indicate if cutting problems occurred. In use, the probe was held in contact with the component being machined. The probe consisted of an underwater transducer that was mounted on the end of a probe pole. The transducer output was amplified and monitored through a speaker in the control room. Sound feedback information was found to be extremely useful for underwater machining operations where the water normally damped most sounds, providing the operator with little or no feedback.

During screw drilling, four additional holes were drilled in the outboard ends of the shell for lifting purposes. These holes were tapped from above the water surface using a probe pole and standard tap, and four safety hoist rings were threaded into the shell.

After removal of the 28 screws on the four exposed module sides, the UF was rotated to the horizontal position to begin shell slitting. The horizontal module was leveled and the HDRF gear drive and UF partial rollover rings were removed to provide full length module accessibility for slitting operations. An illustration of the setup used for shell slitting is shown in Figure 29.

3.16.2 - <u>Reflector Shell Slitting</u>

Reflector module slitting was performed using a 4.00-inch outside diameter by 0.156-inch thick staggered tooth side cutting slitting saw. The saw material was conventional high speed steel containing a titanium nitride

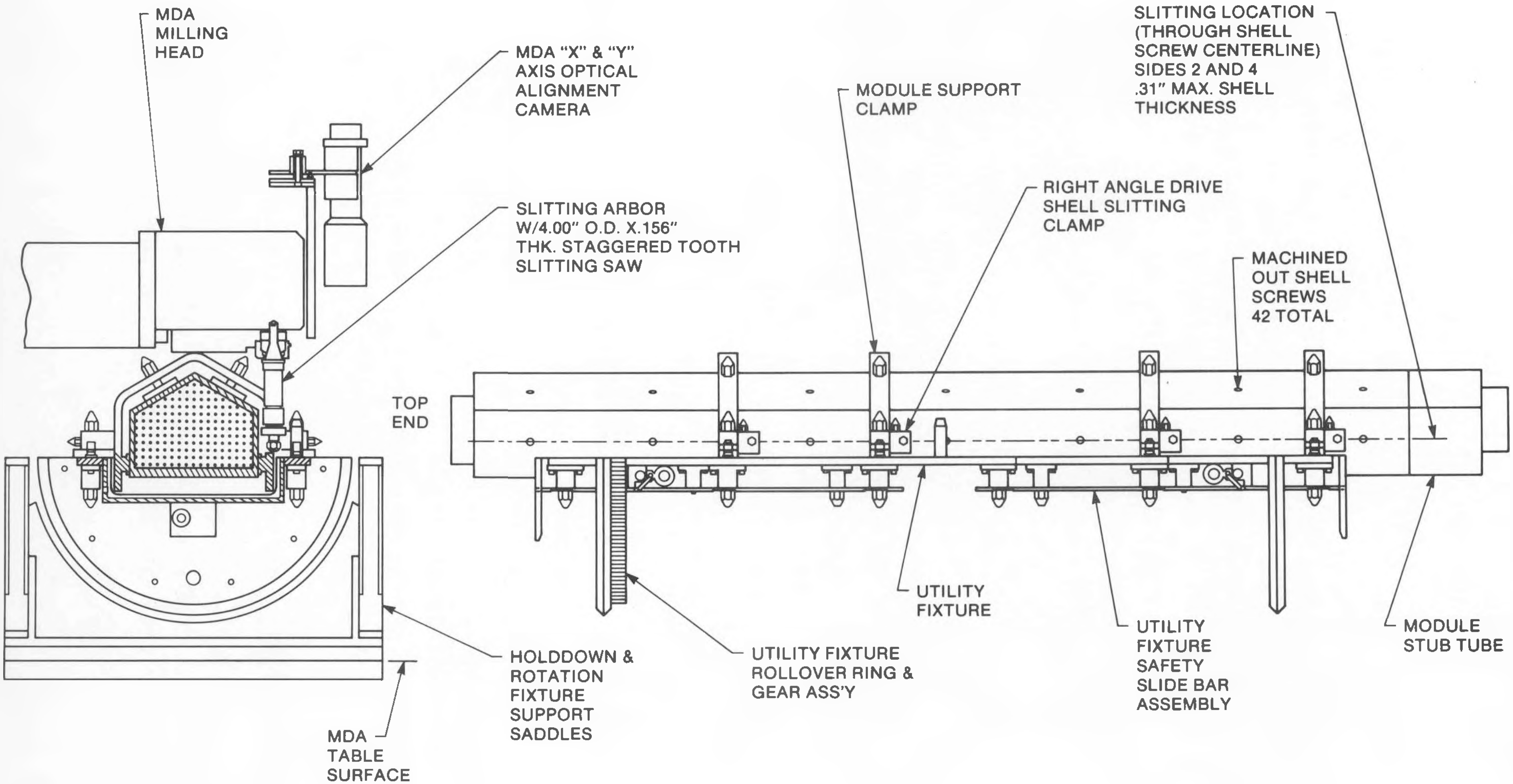


Figure 29 - LWBR Reflector IV-4 Shell Slitting - Sides 2 and 4
(Shown with Utility Fixture End Caps and Top Cover Removed
in Horizontal Orientation)

surface treatment coating. The saw was held in an 11.50-inch long slitting arbor which consisted of morse taper extensions and a 1 1/4-inch diameter stub arbor for saw mounting. All friction holding taper shanks were modified to incorporate a locking set screw to assure that the arbor did not disassemble during cutting. The long cantilevered arbor extension length was required to provide clearance of the angled millhead when reaching over the module, as shown in Figure 29.

The chosen slitting location cut the two parallel module sides for the full shell length in approximately the center of the sides. Module support post backing along the cut zone provided solid Zircaloy material behind the slit to minimize the possibility of cutting into fuel rods. The slitting arbor contained a 3.25-inch outside diameter which physically limited the maximum depth of cut into the shell to 0.38 inch.

To minimize shell vibrations during slitting, climb-cut milling was employed. This technique loaded the shell inward against the module rather than springing the shell away from the module, as is done in conventional type milling. Slitting parameters used were 50 RPM spindle speed and a maximum feed rate of 0.010 inch per revolution or 0.500 inch per minute. The full shell thickness of 0.310 inch was cut in one pass across the module. Module slitting clamps were installed behind the cut and were used to insert wedges into the kerf to prevent kerf close-in caused by radiation induced shell bow.

After shell slitting was completed, all module clamps were removed and the top shell segment was lifted off using a four point lift attached to the installed safety hoist rings. The shell was placed in a storage location and retained for visual examination.

3.17 - REFLECTOR IV-4 VISUAL EXAMINATION AND BASEPLATE CUTOFF

After shell removal, the module and UF were horizontally transferred to the upender, upended to the vertical orientation, and lifted out of the UF as previously described. The deshelled module was transferred to the vertical disassembly stand (VDS) for in-bundle visual rod-to-rod gap measurements. During visual inspection, the MDA was changed over from the milling head to the COS bandsaw head to perform module baseplate cutoff. Subsequent operations of the deshelled module were performed in a similar manner to the other reflector modules discussed herein. The stabilization clamp design used for deshelled modules contained a skirt extension to laterally support the cutoff fuel rod ends. The skirt was added only to the regions of the module where the shell was removed and extended approximately 4.00 inches over the module past the cutoff end.

3.18 - SEED MODULE II-3 SHELL REMOVAL AND PRE-CUTOFF MACHINING

Seed Module II-3 was the final LWBR module to be processed through deshelling and cutoff operations. The module shell design was considerably different than the Type IV reflector and required additional machining operations to free the shell from the module. The seed shell consisted of a hexagonal Zircaloy weldment 9.63 inches across flats, 0.080 inch thick, and 127.65 inches long. The shell was connected to the module at the support posts using 120 countersunk head attachment screws. The screws consisted of two sizes: the small screws contained 0.375-16 threads and a 0.453-inch diameter head, and the large screws contained 0.625-11 threads and a 0.750-inch head diameter. The small screws were installed in sixteen places along each module side and contained two lockwelds which were 180 degrees apart. The large screws were used to attach to the bottom support post foot at four places on each module side and contained four lockwelds equally spaced around each screw head. The screws contained two spanner holes drilled into the head that were used for installation. In addition to shell screw attachments to the module, the shell contained an integral lug on the top end of each module side which was bolted into the top baseplate.

3.18.1 - Seed Module Finger Plates

When the shell structure was removed from the seed module, it significantly reduced the module internal stiffness and compressive load carrying ability. The deshelled module could not be proven safe in the postulated worst case vertical drop accident in which the deshelled module landed on a crush block assembly designed to support a shelled module.

As discussed earlier, the method used to support fuel rods in the modules was to axially fix the rods at one end and allow the rods to be free at the other. About half of the rods were supported from the top end and the other half were supported from the bottom end of the module. Most of the free fuel rod ends (all but 78 rods) were axially in line with opposing baseplate flow holes.

In a drop accident, only the bottom mounted fuel rods and the module support posts initially carried the impact loading. After the support posts compressed to remove the end clearance between the free rod ends and the opposing baseplates, only the 78 rods not aligned with the flow holes contacted the baseplate surface. These rods received loading from all top mounted rods and would exceed the allowable stress values.

To more uniformly distribute the impact loading, a finger plate was designed. The assembly consisted of a flat plate containing approximately 250 0.25-inch diameter by 4.25-inch long stainless steel pins or fingers. The finger plates were installed on the top and bottom ends of the module through the accessible baseplate flow holes. The fingers filled the baseplate flow holes to provide a uniform contacting surface for all top and bottom mounted fuel rods, which provided more uniform impact loading capability.

Installation of the top finger plate was completed with the as-received module vertical in the upender. The plate was inserted through the lift adapter and shipping plate and into the baseplate flow holes. The finger plate was locked into position using three cam driven pins that were radially engaged in mating shipping plate holes. The bottom finger plate was installed horizontally after the module was on the MDA table for deshelling operations.

3.18.2 - Seed Module Top Shell Lug Machining, Shell Screw Removal and Slitting

Shell removal was performed by separating the top shell lug attachment (by machining through the shell around the lug), removing the shell screws, and axially slitting the shell into two halves and horizontally lifting off each segment.

Equipment preparation operations such as UF end cap removal and HDRF rotation drive gear installation were similar to other modules discussed. However, shell removal operations were considerably more complicated on the seed than those on the reflector module.

Shell removal began with the UF end caps removed and the main body intact. At the top end of the module, a "U" shaped cutout was end milled through the shell to separate the shell lug attachment. An illustration of the seed module machining setup is shown in Figure 30. This milling was performed using a high speed steel 0.375-inch diameter four flute roughing end mill. A speed of 120 RPM and a feed of 0.002 inch per revolution were used. Using the same cutter and cutting parameters, a rectangular slot was milled into the apex of the shell. This slot was used for attachment of a modified safety hoist ring for shell lifting. An illustration of the machined shell lug and removal slot is shown in Figure 31. The shell was indexed to each module side, and top end machining operations were repeated.

Next, machining operations were performed at the bottom end of the module in the area accessible from bottom end cap removal, as shown in Figure 30. Trepan cutting of the four large shell screws was completed using a 1.00-inch outside diameter, 0.625-inch inside diameter Rotobroach trepanning cutter. A spindle speed of 46 RPM and a feed rate of 0.002 inch per revolution were used. The cut depth was 0.170 inch in a localized region of the shell that was 0.120 inch thick. After trepanning, the screws were unthreaded using a spanner wrench attached to a probe pole. With the module positioned for large screw machining, holes were also drilled in the bottom end of the module for shell removal. The module was rotated to each of the six sides, and the bottom end machining was repeated.

After machining the accessible top and bottom ends of the shell, the UF was rotated to the horizontal position and the top main body cover was removed to expose the module surface. The UF partial rollover rings, module clamps, and the HDRF drive gear and lock clamp assemblies were installed to permit module rotation with the top main body cover removed. Machining of twelve of

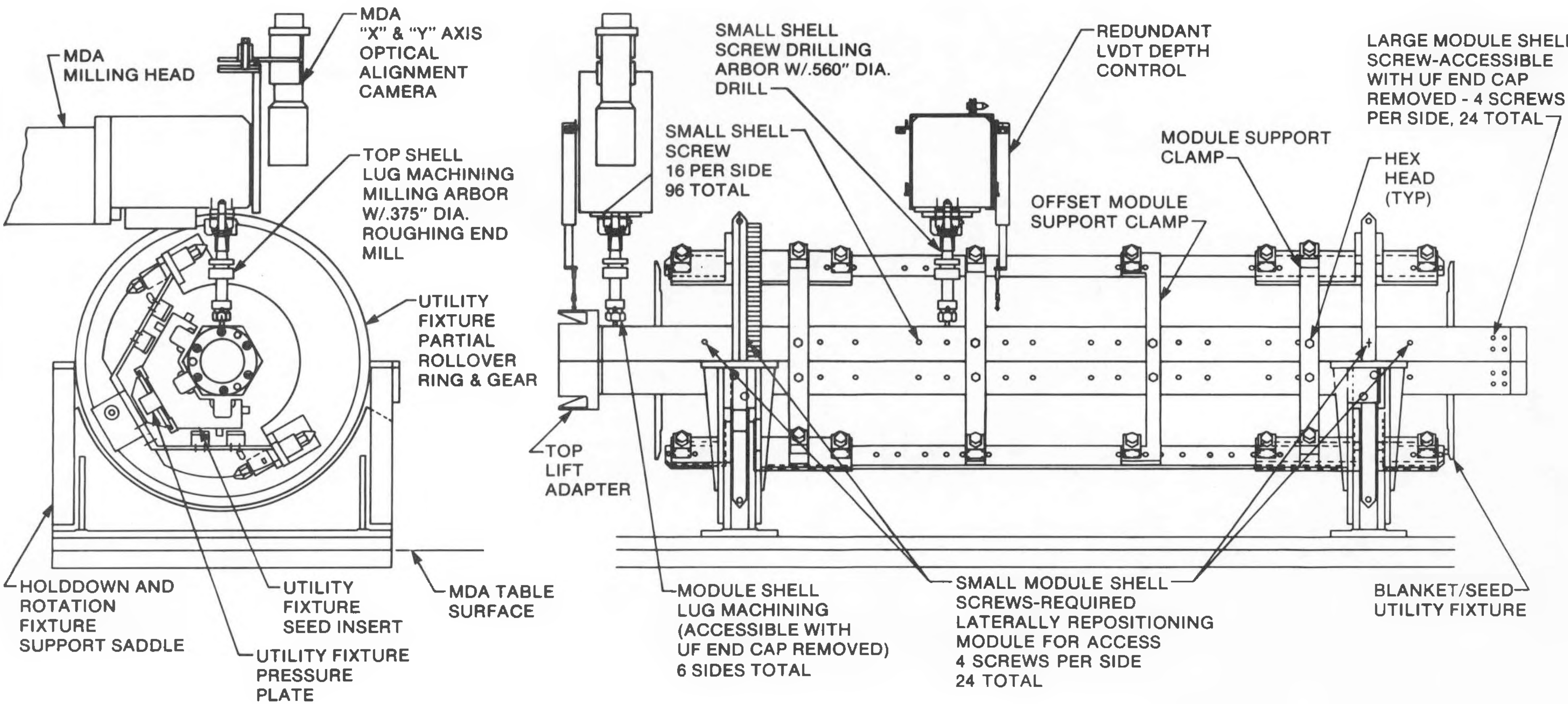


Figure 30 - LWBR Seed II-3 Shell Screw Removal and Lug Machining
(Shown with Utility Fixture End Caps and Top Cover Removed)
Rotated 60° From Horizontal Position

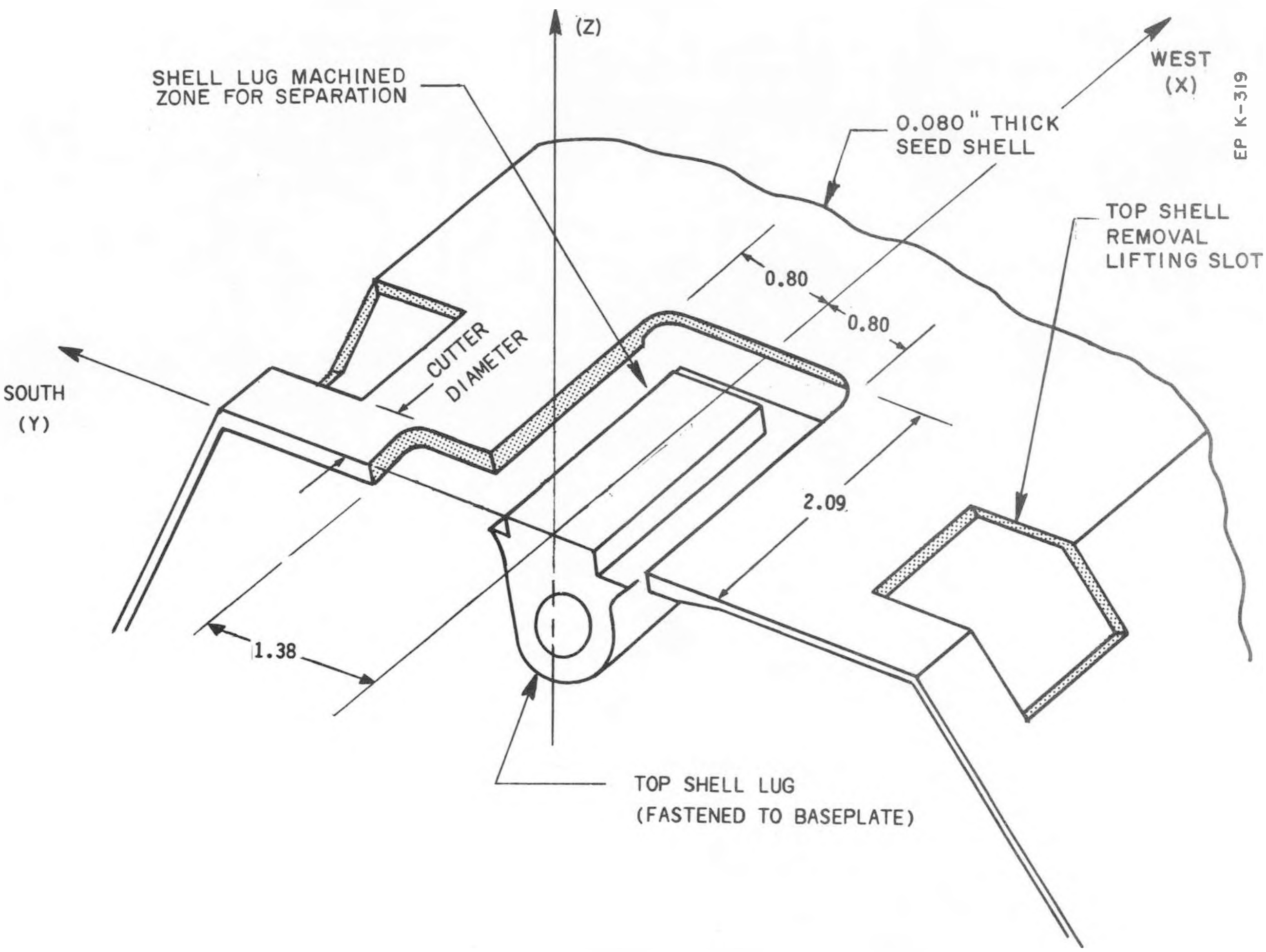


Figure 31 - LWBR Seed Shell Top Lug Machining

the sixteen total accessible small shell screws was performed on each module side. The remaining four shell screws on each side were blocked by the partial rollover rings.

Small shell screw removal was performed using a 0.560-inch diameter high speed steel drill rotated at 120 RPM and a feed rate of 0.002 inch per revolution. Drill depth was limited to 0.360 inch in an area of the shell that was 0.080 inch thick and contained 0.321-inch thick support post backing. Approximately 0.100 inch of shell deflection (approximately 100 pounds normal force) was required to provide enough shell resistance to initiate cutting.

Two large and one small shell screws were required for examination purposes. Two of the large screws removed by trepanning and unthreading were provided. For the small screw removal, a similar trepan and unthreading operation was performed using a 0.560-inch outside diameter trepan cutter. The cutter speed was 28 RPM and a feed rate of 0.003 inch per revolution was used. The cut depth was limited to 0.200 inch below the shell surface.

After all accessible shell screws were removed, the module was horizontally translated to access screw locations blocked by the partial rollover rings. Module sliding was performed with the UF in the horizontal orientation. Controlled positioning was obtained using the HDRF stage assembly with a pushing bar mounted between the stage posts. After sliding, exposed screws on all module sides were removed. For access to all blocked shell screws, it was necessary to slide the module in both directions.

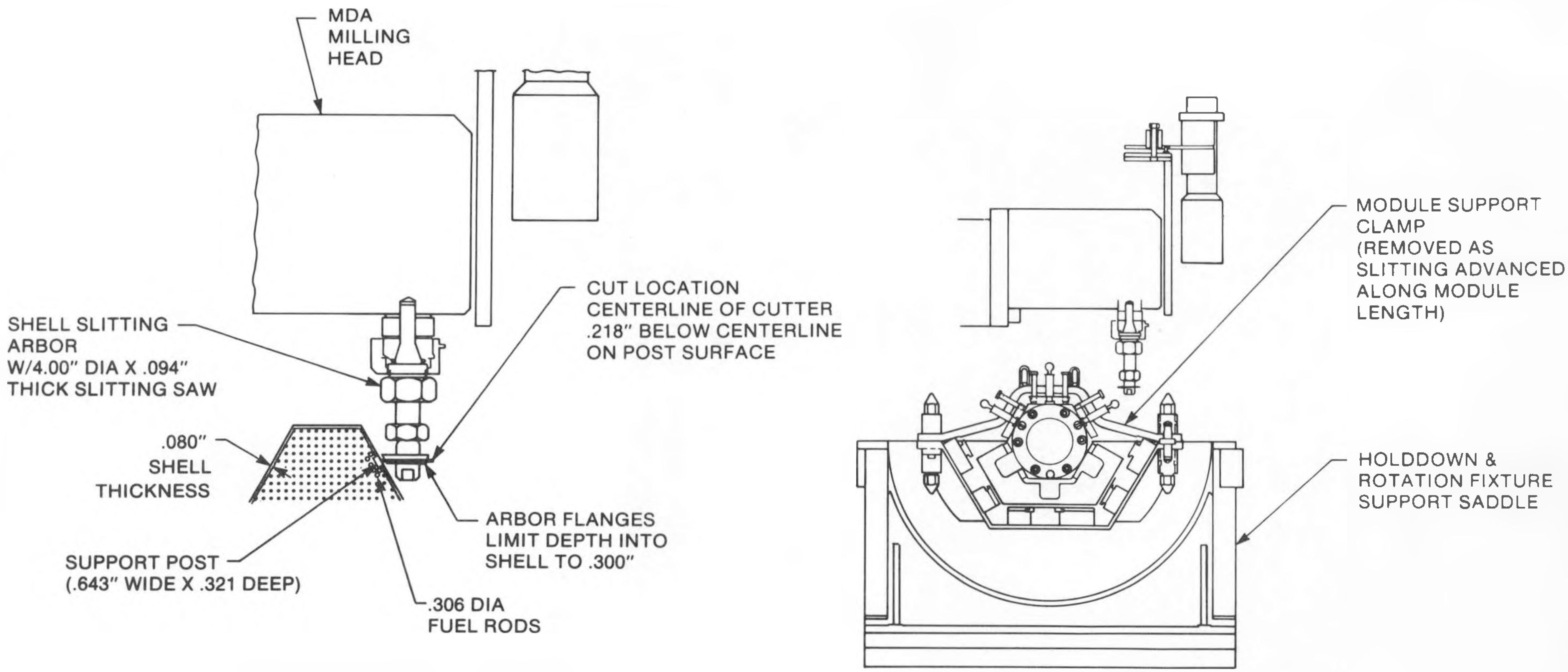
During module assembly, small shell screw lock welding had been used to fuse the screw head to the shell in two places on each screw head. Because the shell thickness in this area was only 0.080 inch, there was concern that the shell could potentially be welded to the post. To assure that the shell was completely separated after machining, a post separation tool was used. The tool consisted of a probe pole which contained a rod within a tube. The rod was positioned onto the drilled out post surface, and the outer tube rested on the shell surface. A dial indicator measured differential travel of the shell and the post when a compressive force was applied to the post. If no differential travel was measured, the shell and post were assumed to have moved as a unit and were attached. Differential travel assured that separation was achieved.

After all shell screws were removed on the three exposed module sides, the UF was rotated to the horizontal position and leveled for shell slitting of one of the two total required sides. The setup used for seed shell slitting is shown in Figure 32. The HDRF drive gear and lock assembly were removed, and module clamps were installed to support the module. The slitting arbor setup was installed in the MDA spindle. The slitting saw used was a 4.00-inch diameter, 0.094-inch thick side cutting blade. The saw was operated at 75 RPM and a feed rate of 0.009 inch per revolution. The depth of the saw cut into the shell was set at 0.232 inch after shell contact. Excessive cutter penetration into the module was limited by using flanges mounted on both sides of the blade.

Seed shell slitting was performed on a module side that was inclined at 30 degrees to the vertical. This orientation was selected because installation of the partial rollover rings was not required, thus permitting continuous uninterrupted slitting and eliminated the need for module translation. The slitting location was approximately in the center of the module side and was performed in the region of the shell containing support post backing. The cut was slightly offset from the 0.643-inch wide post center to avoid cutting into the hardened AM-350 grid attachment material.

Because of the orientation of the hex shell in the UF, only one of the two required slits could be made with the top UF main body cover removed. After completion of module side 4 slitting, the top main body cover was reinstalled, the UF was rotated 180 degrees, and the bottom cover was removed for shell screw removal and slitting operations on the other module half.

After all shell machining was completed, the bottom shell half was lifted off the module using safety hoist rings and probe poles. The UF bottom main body cover was reinstalled, and the UF was rotated 180 degrees to again remove the top cover. With the top cover removed, the top shell segment was lifted from the module, completing shell removal operations.



ENLARGED VIEW OF SLIT LOCATION

NOTE: SLITTING OF 2 OPPOSITE SIDES REQUIRED DISASSEMLBY OF BOTH UTILITY FIXTURE MAIN BODY HALVES.

Figure 32 - LWBR Seed II-3 Shell Slitting of Module Sides 1 and 4

3.18.3 - Seed Module Top Support Post Thinning Machining

During rod removal on prior seed modules, it was found that the bottom mounted fuel rods adjacent to the support posts could not be removed. Interference with the flared out section of the post where the top baseplate attachment was made prevented rod grappling for removal. It was necessary to remove these rods to provide access for grid section removal on module sides 2 and 3. Therefore, a post thinning machining operation was required. This machining reduced the post width to 0.643 inch for a depth of 0.321 inch to resemble the necked down post shape along the remaining length. This machining was performed using a 0.188-inch diameter four flute end mill operated at 160 RPM and a feed rate of 0.001 inch per revolution. The required depth of cut (0.31 inch) was obtained in three passes, each 0.107 inch deep. The total post length required to be thinned was approximately 1.60 inch long. An illustration of the thinned post section is shown in Figure 33.

3.19 - SEED MODULE II-3 VISUAL EXAMINATION, COS, AND PREPARATION FOR GRID SECTION REMOVAL

After shell removal, the UF main body top cover and top and bottom end caps were reinstalled. The assembly was horizontally transferred to the upender, upended to the vertical orientation, and lifted out of the UF as previously described. The deshelled module was transferred to the vertical disassembly stand (VDS) for in-bundle visual rod-to-rod gap measurements. Additional information on work performed in the MVS and VDS can be obtained in References 6 and 9.

During visual inspection, the MDA was changed over from the milling head to the COS bandsaw head to perform baseplate cutoff. Subsequent deshelled module cutoff and bottom stabilization clamp installation was similar to that of seed modules previously discussed.

Rod removal and examination operations were completed in the usual manner for designated rods. Additional rods were removed at this time to provide access for grid section removal. A cross sectional view of the derodded module is shown in Figure 34.

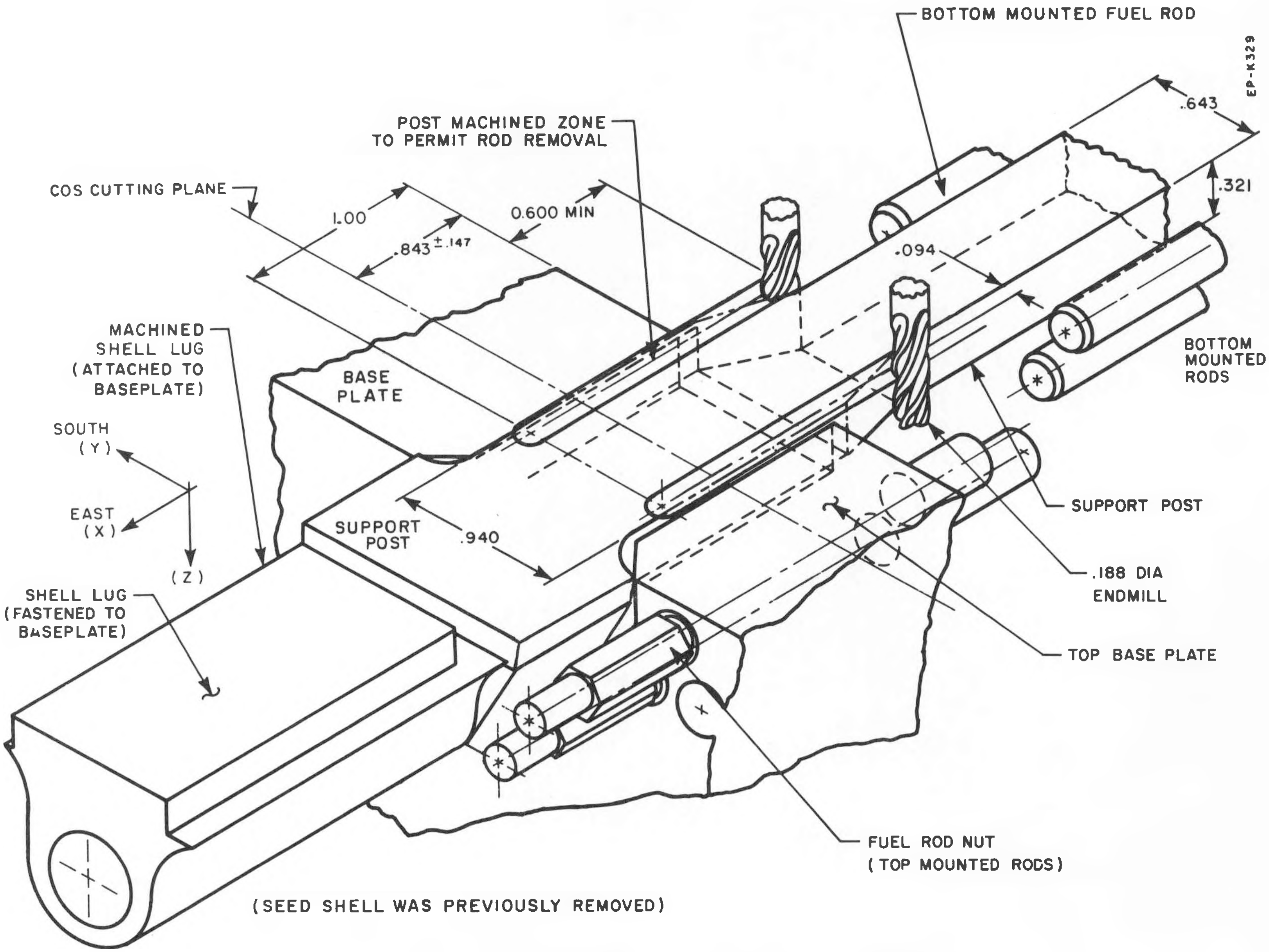


Figure 33 - LWBR Seed Module Post Thinning Machining

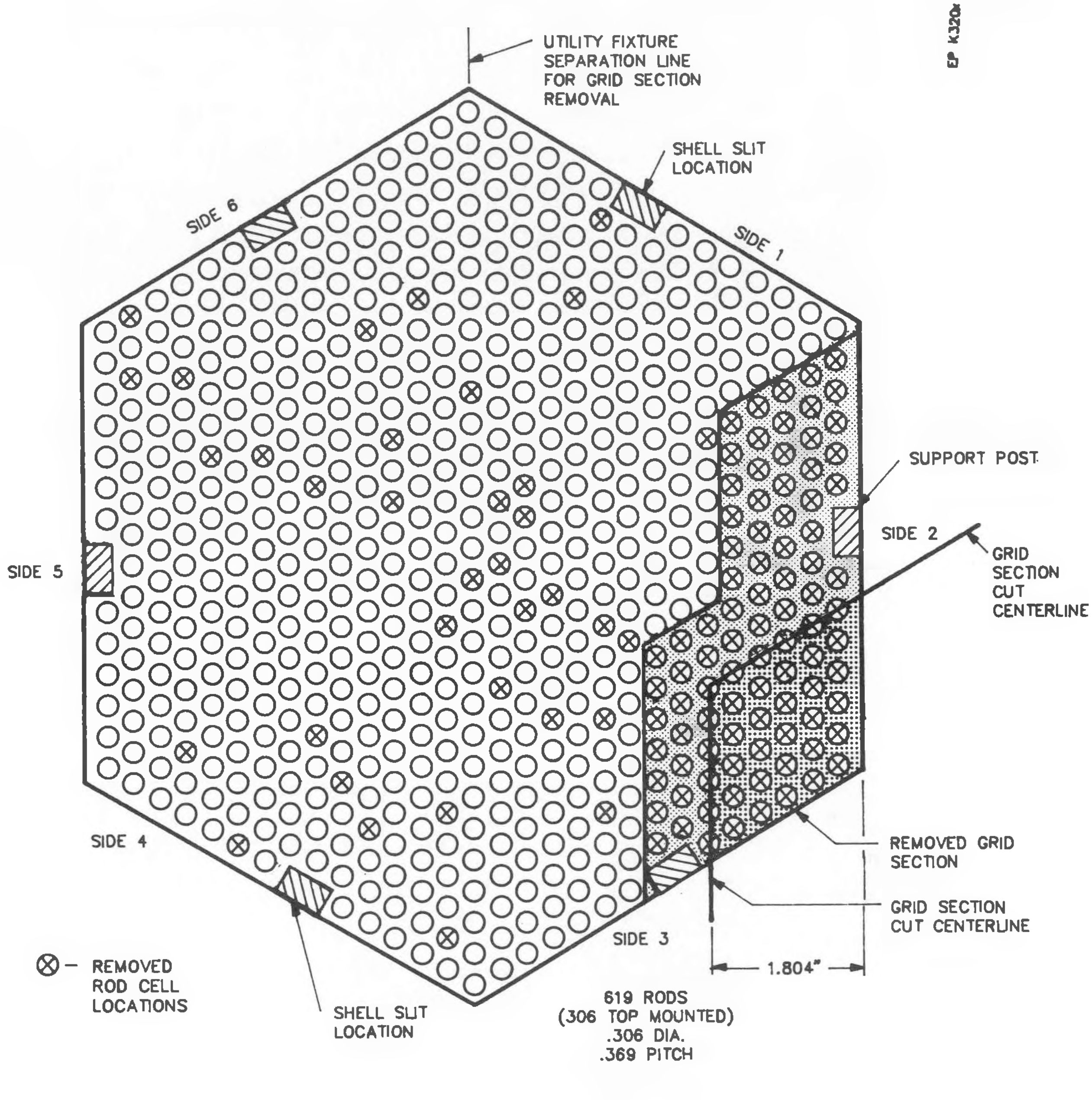


Figure 34 - LWBR Seed Module Derodded Grid Cell Locations for Grid Section Removal

Upon completion of rod removal operations, the module was returned to the vertical upender station. In the upender, the top stabilization clamp and three tie rod and sleeve assemblies were removed to permit utility fixture main body separation and provide grid section machining access. The top clamp was reinstalled to retain the bottom stabilization clamp and tie rods and sleeves remaining during grid section machining.

The assembly was upended to the horizontal position and transferred to the MDA table. The module was rotated for UF end cap removal, and the top and bottom utility fixture end caps were removed.

The UF was rotated to the horizontal position for top main body cover removal. Module clamps and partial rollover rings were installed and the HDRF rotation drive gear and lock clamp were installed.

3.20 - SEED MODULE II-3 GRID SECTION AND GRID BOLT REMOVAL

Seed Module II-3 was the only LWBR module to provide grid attachment and grid section specimens for visual and destructive examinations. Two parallelogram-shaped sections approximately 2 inches by 2 inches were removed by cutting through the grid with a circular abrasive cutoff saw. The grid sections were located at the fifth and sixth grid levels from the bottom of the module and were positioned on the apex between module sides 2 and 3. The removed sections each contained 25 intact grid cells.

Three grid-to-post attaching bolts and one grid bolt lock nut were also removed from the seed module. The components were freed by machining away the grid bolt and nut crimped end and mechanically unthreading the bolts. The grid bolts were removed from grid levels 3, 4, and 6 (as counted from the bottom) on module side 2. The grid bolt lock nut was removed from grid level 3 on module side 2. The material composition of the grid and grid bolts was AM-350 stainless steel. The lock nut material composition was 304 stainless steel. Additional information on the examination of the removed grid components can be found in Reference 10.

Fuel rod protective sheet metal covers were installed over the fuel rods on both sides of the grid sections removed. The covers were designed to minimize the potential of exposed fuel rod damage while working on the grid section. The covers contained pins that engaged into the void grid cell holes. The pins were used to prevent lifting of the covers into the cutoff blade due to the negative pressure caused by high blade rotational speeds.

Grid section removal was performed first. This was completed by rotating the module to position the cut zone horizontally, and traversing back and forth across the 1.60-inch grid width using a circular abrasive cutoff saw rotating in the horizontal plane. A view of the grid machining setup and cut positions is shown in Figure 35.

After each pass, the blade depth was advanced into the module by one grid cell. The first series of cuts was made on module side 2 which had an adjacent area of rods removed during rod pull operations (see Figure 34). After completing the first series of cuts, a clamp was installed over the grid. The clamp extended into the solid undisturbed grid region where the additional rods were removed and provided support for the cut section as it was machined free during the final severing cut.

The grid clamp used to support the cut section consisted of two flat aluminum jaws in the shape of the void rod area. The installed grid clamp is shown in Figure 35. The jaws were driven from above using a set of miter gears to rotate a leadscrew which translated one jaw relative to the other. The inside jaw surfaces were covered with rubber pads to prevent damaging the grid and to obtain increased contact area over the irregular protruding grid pin surfaces.

The blade used for cutting was a specially designed, 12-inch diameter by 0.060-inch thick metal core, cubic boron nitrite (CBN) abrasive cutoff blade. The 150 grit abrasive material was bonded to the outer rim of the metal core using a nickel plating process. Cutter operating parameters were 1000 RPM and a feed rate of 1.50 inches per minute. To minimize the cutting loads and possible grid cell distortion, cutting feeds used were extremely slow for the 0.013-inch thick grid honeycomb material.

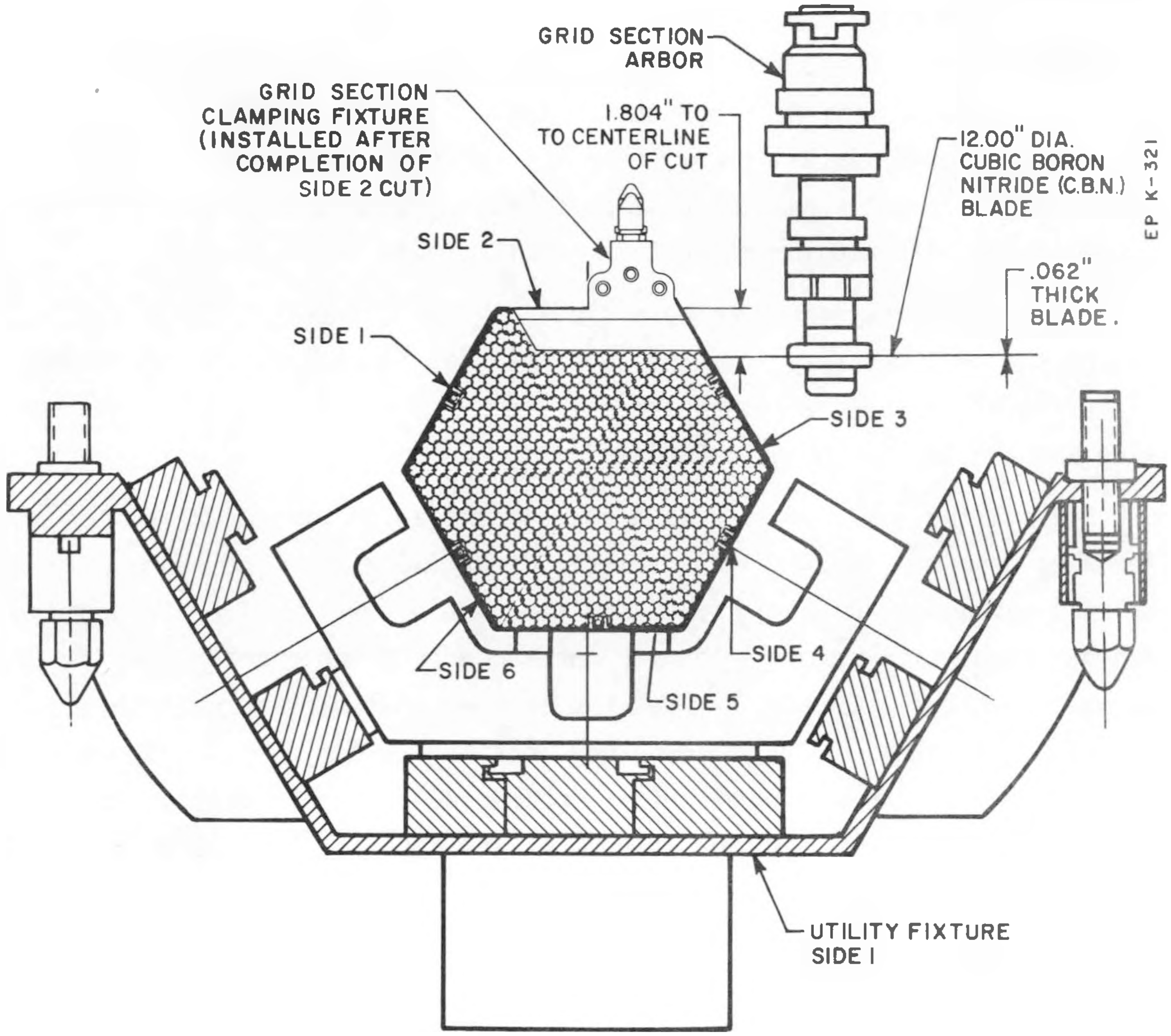


Figure 35 - LWBR Seed Module Grid Section Removal

After the final severing cut, the grid section and the clamp were removed from the module, and the grid was carefully packaged for shipment. The abrasive cutoff arbor was removed from the millhead and changed out with an end mill for grid bolt machining operations.

The seed module grid attachment to the support post consisted of a nut and bolt connection into the projecting grid lug which was recessed in support post cutout pockets. A view of the assembly is shown in Figure 36. The region of the nut and bolt that extended past the 0.164-32 threaded end were formed into two concentric rings containing approximately 0.015-inch thick walls. After bolt installation, these ends were crimped together to prevent unthreading. In addition, the bolt head was captured with a thin locking tab to retain the bolt within the post in case the bolt shank failed.

Disassembly was performed by end milling the crimped nut/bolt end, bending the lock tab away from the bolt head, and mechanically unthreading the bolt using a specially designed removal tool. A view of the grid bolt removal setup and tooling is shown in Figure 37.

End milling was conducted in a manner similar to other cutting operations discussed herein. A 0.375-inch diameter, four flute standard high speed steel end mill was used. Cutting speeds and feeds were very low (50 RPM and 0.001 inch per revolution) to minimize tool breakage from loose cut pieces as the end mill advanced. Cutting removed the crimped bolt end approximately 0.10 inch past the threaded connection. The locking tab on the bolt head was bent out of the way using a standard offset probe pole. Remote bolt unthreading required a special removal tool because of the recessed bolt location within the post.

The removal tool (shown in Figure 37) consisted of a 7/64-inch spherical hex ball end driver that was inserted into the bolt head hex socket. The driver was inclined to the axis of the bolt at approximately 17 degrees and was rotated through a universal joint and a right angle miter gear set to remotely unthread the horizontal bolt from above.

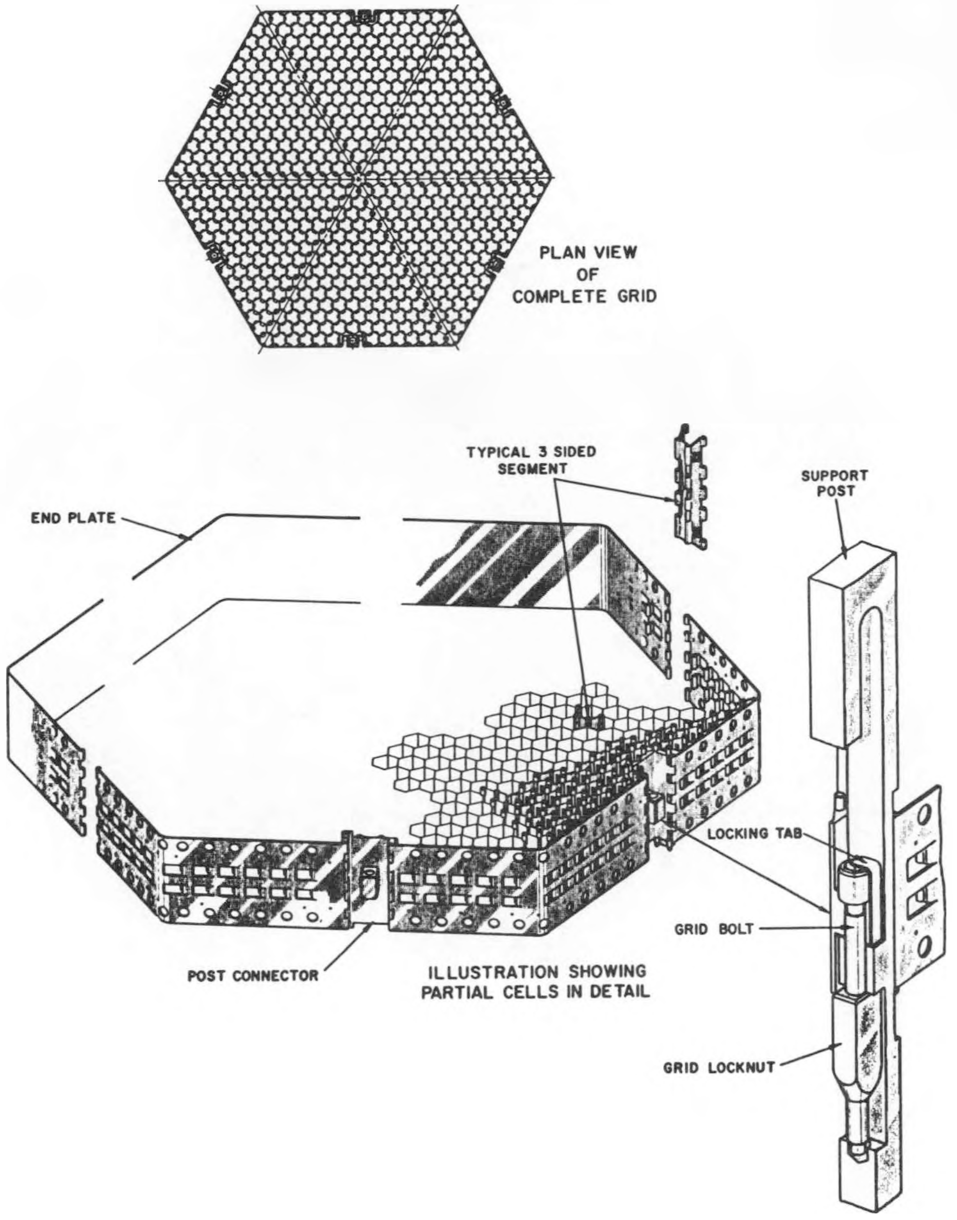


Figure 36 - LWBR Seed Module Grid-to-Post Attachment

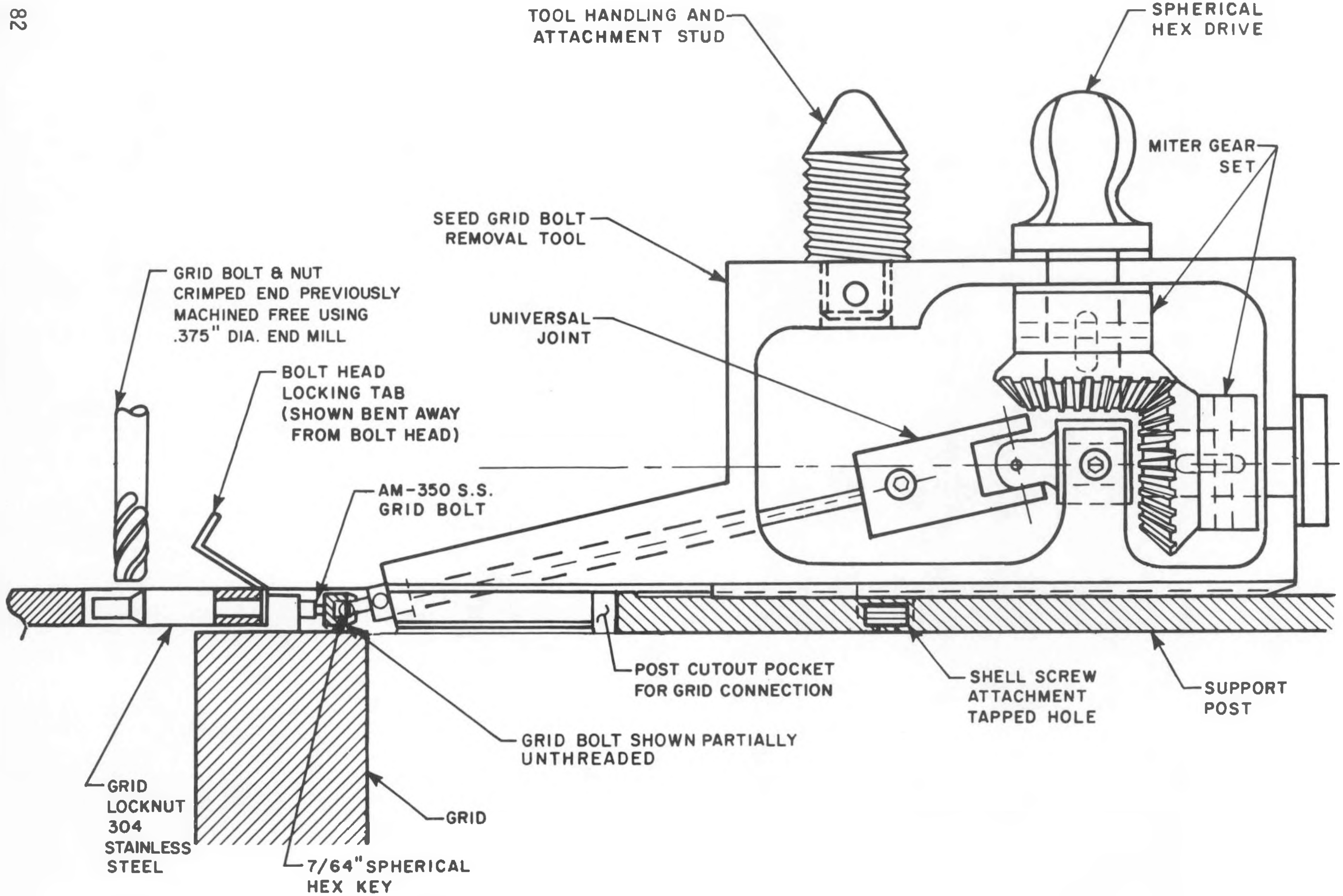


Figure 37 - LWBR Seed Module Grid Bolt Removal

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A grid bolt support post retaining tool was installed below the post to prevent the unthreaded grid bolt and nut from dropping through the cutout and into the fuel rod bundle. After the bolt was unthreaded, it was retrieved using a magnetic pick-up tool and deposited into a storage container.

The disassembled module was rotated for UF main body top cover reinstallation and end cap installation. The assembly was horizontally transferred back to the upender and upended. The top stabilization clamp was removed to permit installation of tie rod and sleeve assemblies that were disassembled for machining access. The top stabilization clamp was reinstalled and the module was then lifted out of the UF and transferred to a storage liner to await final fuel disposal operations.

SECTION 4 - SUMMARY AND CONCLUSIONS

Disassembly of twelve LWBR modules was performed to provide components for proof-of-breeding and core examination. Specialized fuel module handling, disassembly, and support equipment was designed and fabricated for remote underwater operations. Handling equipment incorporated mechanical and electrical interlock features to assure proper component installation and assembly. For safety, fuel lifting operations were performed using a double-rigged redundant lifting system which employed two independent sets of lift rigging.

The module disassembly apparatus (MDA) and the cutoff saw (COS) were the primary systems designed and used for underwater machining operations. The MDA consisted of a remotely operated milling machine which contained a 48-inch wide by 212-inch long table and a vertical spindle. This component was used to perform end milling, drilling, slitting, and abrasive cutoff operations on two LWBR modules.

The COS was a vertically mounted bandsaw which contained 26-inch diameter wheels and a 1.25-inch high steel blade. The bandsaw was used to cut off the top and bottom ends of the LWBR modules to release the fuel rods for rod removal operations. The modules were horizontally positioned for cutting, and the ends were severed in the baseplate region.

Two modules (a seed and a reflector) had the shell attachment screws and shells removed to allow examination of the interior. The shells were removed by drilling and trepanning out the attaching screws, and axially slitting the shell on two opposite sides to permit removal of the top segment of the reflector shell and both the top and bottom of the seed shell.

Additional machining was performed on the seed module to remove two grid sections and grid-to-post attachment bolts and nuts. The grid section was disassembled by horizontally cutting through the honeycomb material with an abrasive cutoff saw. The grid bolts and nuts were removed by machining away the locking crimp and unthreading the assemblies.

Table 1 contains a summary of the disassembled LWBR modules. Included in the table are the module type, core position, serial number, and core examination disassembly operations completed in addition to baseplate cutoff.

The LWBR module disassembly program successfully performed the disassembly of all required proof-of-breeding fuel rods and examination components. The unique remote handling and lifting equipment and disassembly machinery performed well to complete this comprehensive core evaluation program without incident.

Table 1 - Summary of LWBR Module Disassembly

Module* Type	Core Position	Module Serial No.	Disassembly Operations Completed in Addition to Baseplate Cutoff (As discussed in this report)
Seed	I-1	L-BB01-04	
Seed	II-3	L-BB01-13	1) Complete shell screw removal (120 screws total) 2) Complete shell removal 3) Removal of two grid sections 4) Removal of three grid bolts 5) Removal of one grid nut
Seed	III-1	L-BB01-07	
Seed	III-2	L-BB01-08	
Blanket	I-3	L-GU51-01	
Blanket	II-2	L-GS22-01	
Blanket	III-2	L-GW52-01	
Blanket	III-6	L-GT22-03	
Reflector	IV-3	L-RA01-10	
Reflector	IV-4	L-RA01-09	1) Shell screw removal from four module sides (28 screws total) 2) Shell removal (from module sides 1, 2, 4, and 5)
Reflector	IV-9	L-RA01-03	
Reflector	V-4	L-RB01-08	

*All modules listed were processed through baseplate cutoff operations.

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SECTION 6 - ACKNOWLEDGMENTS

The authors gratefully acknowledge the contributions of the following persons who played important roles in the work reported herein:

Messrs. W. J. Babyak, W. S. Bacvinskas, S. W. Ballash, J. E. Bayer, K. L. Erdman, D. F. Faber, B. W. Hodges, M. Huba, J. S. Kartik, W. D. Kimball, J. R. Knight, M. E. Leibson, R. J. Nilsen, D. M. Oster, C. A. Pruss, D. R. Roof, K. V. Smith, J. M. Spear, and D. Tunstall for their efforts in the design, assembly, and testing of the LWBR Module Disassembly Equipment.

Messrs. D. L. Amen, A. R. Beale, D. G. Bruhn, R. E. Brower, S. R. Crow, C. R. Denure, S. A. Hansen, K. D. Henderson, B. R. Gourley, P. E. Ireland, W. F. Irvine, R. R. Kragness, W. Ledford, D. F. Meyer, P. K. Stirn, D. D. Streett, R. Thompson, and the LWBR-ECF Technicians for the installation and operation of the LWBR Module Disassembly Equipment.

Mr. R. T. Winkler from Engineering Publications for his assistance in preparing this report.

The authors are also indebted to Messrs. W. J. Babyak, C. A. Pruss, I. Goldberg, B. C. Smith, and Drs. W. E. Franzen and J. A. Redfield for their careful review and helpful suggestions.

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APPENDIX A1 - MODULE DISASSEMBLY APPARATUS DEVELOPMENT

A1.1 - INTRODUCTION

The module disassembly apparatus (MDA) was a large underwater milling machine designed for disassembly of irradiated core components in the underwater environment of the ECF water pits. The design and build contract for the MDA included requirements for maintenance and instruction manuals, special tools, proprietary lubricants, and equipment necessary to install, operate, and maintain the apparatus. The design requirements and features of the MDA are discussed in the following paragraphs. An illustration of the MDA is shown in Figure 14.

A1.2 - GENERAL PROVISIONS

The MDA was designed to operate on available ECF facility shop services and to be installed with the existing facility crane. The shop services within the facility were:

Shop Air: 83 to 103 psig, 150 SCFM

Electrical Power: 480V, Three Phase, 40 amp, 60 hz AC

Water: 60 psig Demineralized Water

Crane Capacity: 111-ton capacity crane with a 37-foot maximum lifting height.

A1.3 - GENERAL PROVISIONS FOR OPERATION IN WATER PIT ENVIRONMENT

1. When feasible, a modular component concept was used in the design of the equipment to facilitate the removal and replacement of defective components. Lifting features were incorporated into each modular component for independent remote lifting and handling capability.
2. Controls and necessary adjustments were remotely operable from above the pit.
3. To facilitate radiological decontamination, the equipment design minimized entrapment of contaminants. Component surface finish could not exceed a maximum roughness of 125 (AA) microinches. Recesses, pockets, open interfaces, threaded fastenings, etc., were eliminated as much as possible.

4. All welds were continuous to minimize entrapment of contaminants in interfaces. External weld surfaces were machined so that they had a maximum roughness of 125 (AA) microinches.
5. Materials and equipment located in the water were resistant to functional damage from a beta and gamma radiation level of 10^9 Rads.
6. All processes that could potentially promote corrosion on the surfaces of the equipment were avoided in the manufacturing phase. These included, but are not limited to, (1) prohibition of shot-blasting and grit-blasting, (2) specification that all grinding shall be done with silicon carbide or aluminum oxide wheels, papers, or stones that had not been previously used on carbon steel, and (3) all wire brushing was done with stainless steel tools that had not been previously used on carbon steel.
7. Where damage could occur to the equipment by immersion and operation in demineralized water between 46-47 degrees F, measures were taken to prevent such damage. For example, internally pressurized sealed motor box housings and enclosures were used.
8. Corrosion resistant materials were required where the material was exposed to the water pit environment. Most components were fabricated from 300 series stainless steel.
9. Lubrication points were required for proper lubrication of all ways and drive mechanisms using an automatic lubrication injection system.
10. To prevent contamination of the pit water with oil resulting from a failure of a high pressure oil system, the use of oil hydraulic systems was prohibited and water hydraulics and air systems were substituted.
11. Leakage of air into the pit water under normal operations was not permitted in order to avoid radiological contamination problems.
12. All non-corrosion-resistant bearings, gears, and mechanisms were enclosed and sealed to prevent damage from water.
13. All screws, pins, bolts, and similar fasteners were retained in such a manner as to prevent loosening. Those subject to removal or adjustment were not swaged, peened, welded, staked, or otherwise permanently installed.

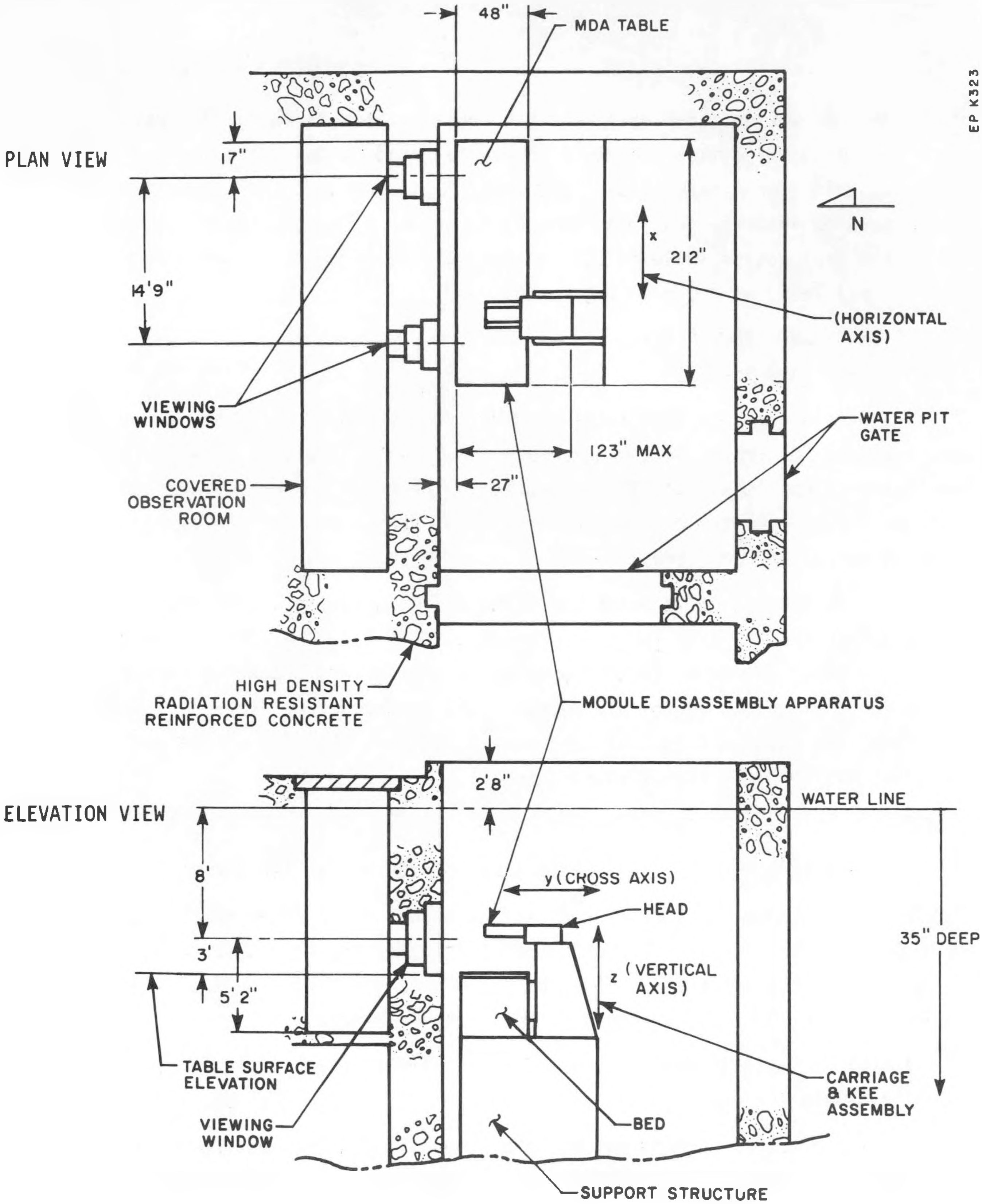

Figure A1-1 - Module Disassembly Apparatus Location in ECF Water Pit

14. The MDA was designed utilizing the concepts of a fixed table, traveling column milling machine with a horizontal head containing a vertical spindle (see Figure A1-1). The vertical and cross travels were incorporated into the design of the column and head, respectively. Also, the head design included 360 degrees rotation capability about the cross axis, as shown in Figure 16.

A1.4 - PERFORMANCE REQUIREMENTS

A1.4.1 - Feeds and Speeds

Infinitely variable feed rates ranging from 0.0625 to 7 inches per minute were provided for travel in the three principal axes. The feed drive motors were rated at not less than five horsepower. The motor controls provided a constant torque over the entire specified feed range. Each of these principal axes had normal and jog feeds.

The head spindle drive motor was rated at 10 horsepower. The head contained a high and low gear range to provide spindle speeds within the range of 10 to 2300 RPM. The motor control provided a constant horsepower over the entire range of specified spindle speeds. The horsepower delivered to the spindle by the drive and control systems was not less than 50% of the motor rating (i.e., not less than five horsepower).

A1.4.2 - Travel Requirements (See Figure 16)

Travel distance (x) in the longitudinal direction was 160 inches.

Travel distance (y) in the cross direction was established so that at the maximum travel in the south direction, no portion of the head extended over the table. In the north direction, the spindle center line travel was 13 inches north of the table center line (48-inch wide table).

Travel distance in the vertical (Z axis) direction was 13 to 63 inches above the table surface.

All three travel directions were provided with positive acting noncreep positional way locks that automatically actuated when feed was disengaged.

A1.4.3 - Alignment Tolerances

The following table of alignment tolerances was utilized in the design and manufacture of this apparatus:

Description	Allowable Deviation (not more than)
Spindle periphery runout	0.0005 TIR
Spindle taper runout	
1 inch from spindle nose	0.0004 inch
12 inches from spindle nose	0.0008 inch
Table top flatness in cross and longitudinal axes	0.002 inch per foot
Table top square with cross and longitudinal axial movement of the head	0.002 inch per foot
Head movement in cross, longitudinal and vertical axes relative to true position plane established by the table	0.002 inch per foot

A1.4.4 - Position Indication System

An electrical digital encoding type position indicating system was used for remote X, Y, and Z axis readout of head location. Readouts were displayed on the MDA control console located in the water pit control room.

A1.4.5 - Positioning Controls System

The controls system provided the following positional accuracies:

Description	Allowable Deviation (not more than)*
Positional (i.e., the positioning of the spindle center line between any two points, along any of the three major axes).	0.004 inch per foot
Repeatability (i.e., the ability of the spindle center line to repeatedly return to any position, along any of the three major axes).	0.002 inch

*All values certified to be applicable at 46 degrees F.

A1.4.6 - Design Lifetime

The MDA was designed for 75% operating time for the first 3 years and 20% operating time for 20 years beyond the initial 3-year period.

A1.5 - TEST PROGRAM

An extensive test program was performed on the MDA at the vendor's plant. This program included the following tests:

A1.5.1 Underwater Test

Underwater tests were conducted in 41 to 46-degree F water to confirm submerged application in 46 to 47-degree F water at ECF. The following tests were performed:

1. Operation at five feed rates in each of the three principal axes over the entire distance of travel (performed twice).
2. Jog feed over the entire travel distance of each of the three principal axes.
3. Rapid traverse feed over the travel distance twice in each of the three principal axes.
4. Variability of the feed rates over their entire range along each of the three principal axes.
5. Fifty stop-start cycles along each of the three principal axes during Items (1), (2), (3), and (4) above.
6. Operation of the spindle at a minimum of ten speeds for one hour per speed. Twenty stop-start cycles at each speed were required.
7. Variability of the entire spindle speed range with twenty stop-start cycles.
8. All pressurized compartments were leak tested.
9. The spindle drive motor was loaded to its maximum rated electrical input during a machining operation to demonstrate that the apparatus had a smooth feed at full power capacity along each of the three principal axes.
10. A range of machining operations, over the full range of speeds and feeds, was utilized to identify any undesirable operating conditions.

11. Machining of test pieces was performed to demonstrate that the apparatus was capable of achieving the following tolerances during machining operations:

	Allowable Deviation (not more than)
Squareness:	0.004 inch per foot
Flatness:	0.002 inch per foot
Parallelism:	0.004 inch per foot

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APPENDIX A2 - COS DESIGN AND DEVELOPMENT

A2.1 - INTRODUCTION

The MDA-COS consisted of an underwater bandsaw head mounted onto a support adapter, which was attached to the MDA (the MDA millhead and Y axis drive were removed). Several auxiliary systems were included with the COS: an alignment system which used closed circuit television and module feature targets to position the saw at the module cutting planes; a debris suction system to recover cutoff nuts and clean up the station after cutting; and a COS control console to control the bandsaw drive system, augment and interface with the MDA X axis and Z axis drive controls, and to display and provide feedback of blade speed and force. Servicing tools were also required to install new saw blades, attach the COS to the MDA, operate the remnant support system clamps, and service and maintain the various systems.

This appendix describes the attachment of the bandsaw head to the MDA, mechanical arrangement of the bandsaw head including instrument transducers, the blade change system, and the COS and MDA control systems.

A2.2 - MDA-COS GENERAL ARRANGEMENT

The general arrangement of the MDA-COS is shown in Figure 17. The bandsaw support adapter was attached to the MDA knee assembly, with the MDA millhead and Y axis drive assemblies removed as a unit. The seventeen bolt locations that secured the MDA head and slide assemblies were used to fasten the support adapter to the MDA knee. Keyways on the adapter matched with those on the MDA knee to perpendicularly align the bandsaw head to the MDA X and Y axes.

The bandsaw head was mounted to the vertical face of the support adapter using a combination of guide slots and cap screws. Using this attachment method, the bandsaw head was cantilevered across the long axis of the MDA table. This allowed the bandsaw blade to be fed down through the cut by the MDA Z axis drive. It could also be moved to any cutting position along the 160-inch X axis travel permitted by the drive systems. Figure 23 shows the general arrangement of the bandsaw head and its relationship to the MDA table.

A2.3 - BANDSAW SUPPORT ADAPTER

The bandsaw support adapter was a knee shaped weldment of 1 1/2-inch and 2-inch stainless steel plates. A photograph of this structure is shown in Figure A2-1. The plates were fabricated to fit up with the existing MDA mounting surface created by removing the milling head and Y axis drive, and to provide a mounting base for the cantilevered bandsaw head. The two mounting plates were reinforced by four welded gussets - two in front and two in the rear.

For aligning the saw in the north-south Y axis direction relative to the MDA table, there were three hourglass shaped keyways integral with the base-plate. The keyway closest to the work table pivoted the support adapter for adjustment. During the alignment procedure, most of the weight of the support adapter and saw was supported by a crane. Realignment was required each time the support adapter was reinstalled on the MDA.

A2.4 - BANDSAW HEAD

The bandsaw head consisted of a main frame to which the various subassemblies were mounted. These were the main drive and housing assemblies, the idler wheel assembly, the tensioning system, the guide and guide arm assemblies, and the blade load cells. These principal components are described in the following subsections.

A2.4.1 - Main Frame

The main frame was constructed of a welded fabrication of box beams and flat stainless steel plates to which was mounted the drive system, the idler wheel housing, the tensioning system, and the guide arms. A photograph of the main frame assembly is shown in Figure A2-2. The box beams were cantilevered from the mounting plate and extended over the table. Two separate vertical plates were suspended from the overhead box beams and were used to mount the wheel assemblies. The plate structures had stiffeners and gussets for added rigidity.

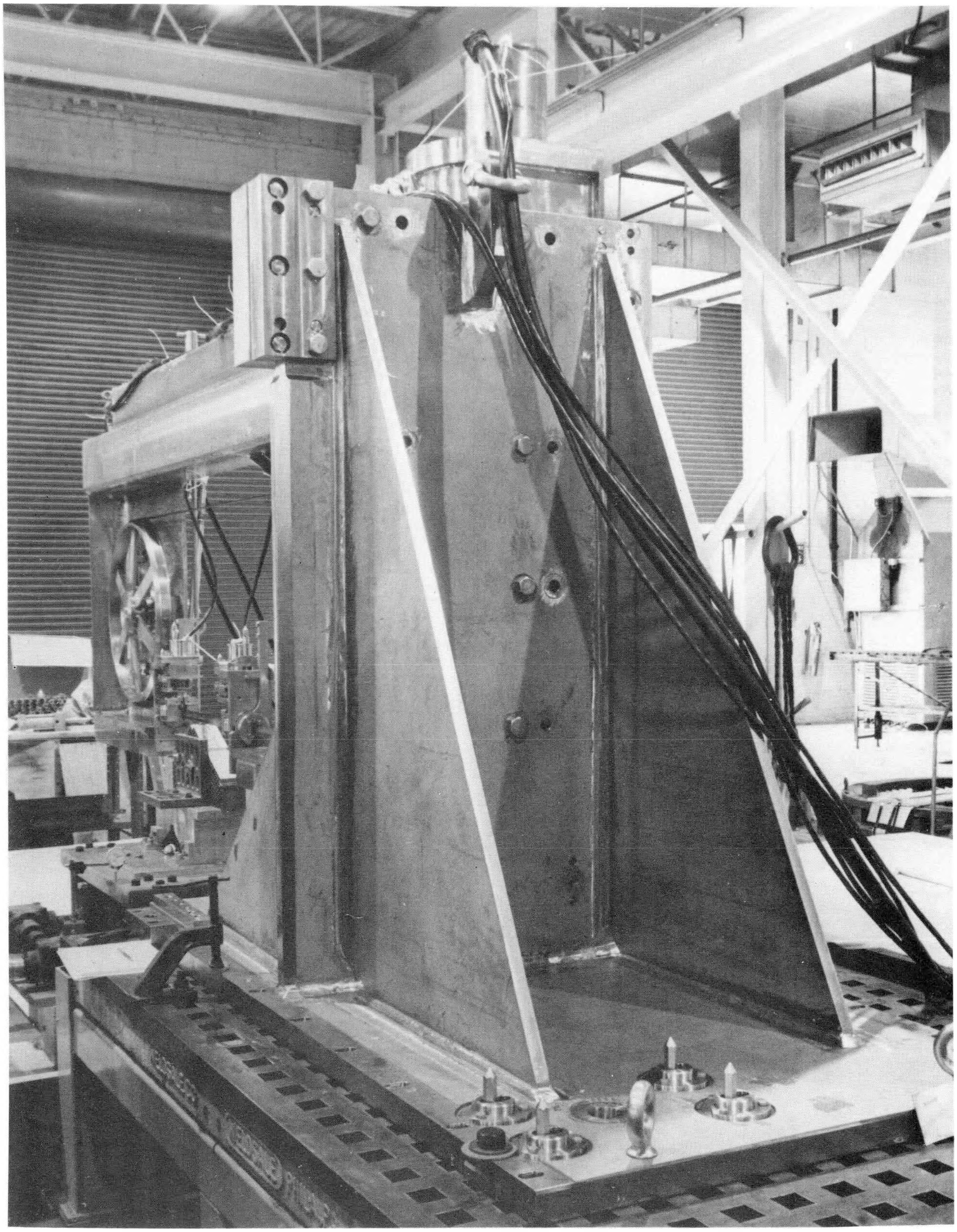

Figure A2-1 - MDA-COS Bandsaw Profile Viewed From Adapter Stand

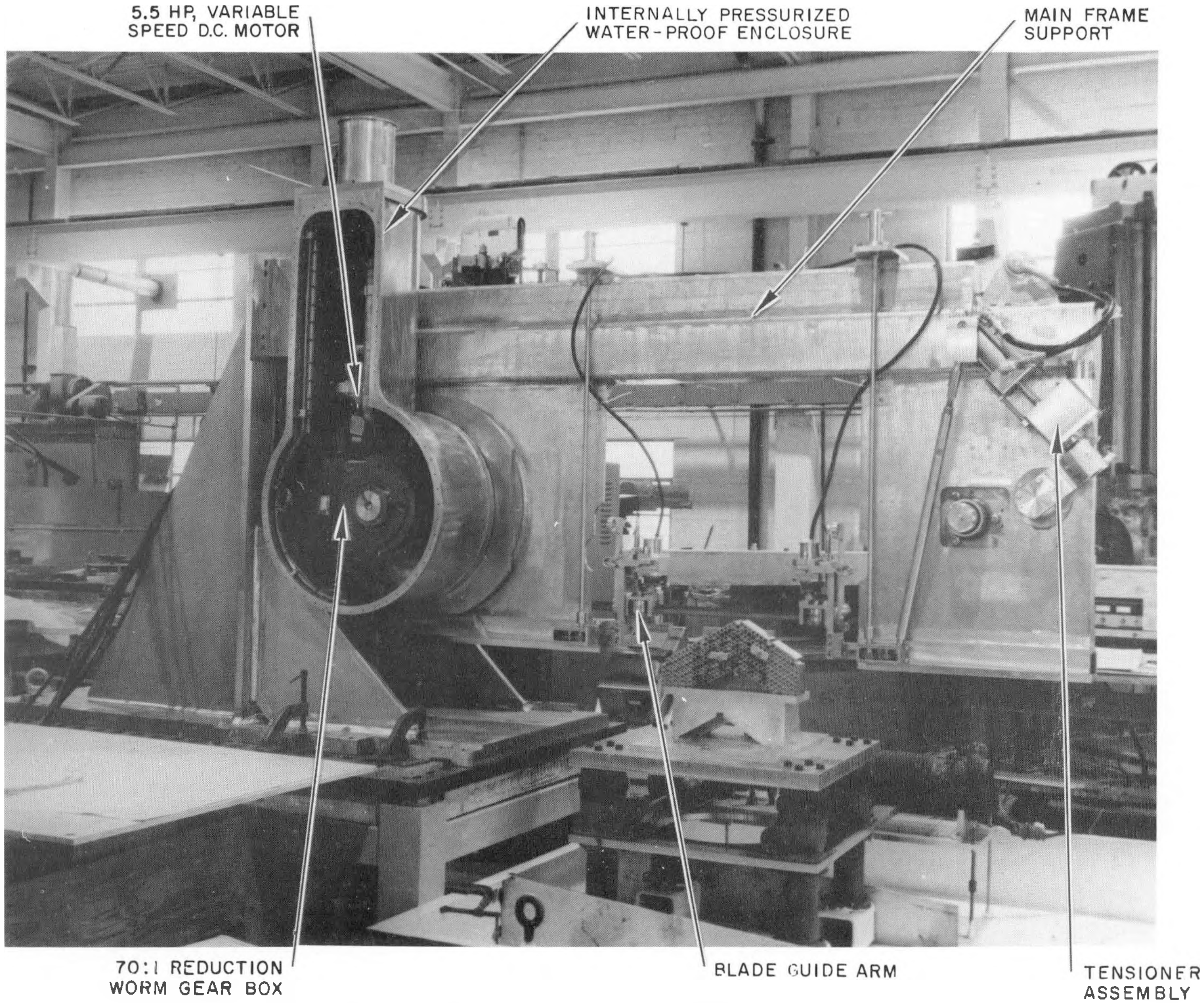

Figure A2-2 - MDA-COS Bandsaw Main Frame Back Side
(Shown With Gearbox Assembly Housing Back Cover Removed)

A2.4.2 - Motor and Drive Housing

The motor and drive housing was an integral sealed assembly containing the drive motor, single reduction worm gear speed reducer, blade driving wheel, and power and control cable electrical leads. A photograph of the gearbox housing subassembly is shown in Figure 18. The components were mounted in a sealed enclosure which was bolted to the main frame. The blade drive wheel was mounted directly to the speed reducer output shaft.

The drive motor was a variable speed, 5.5 horsepower DC motor that was operated at a reduced torque to provide the equivalence of three horsepower. This enabled use of the same type of motor as was used for the three axis drives of the MDA, permitting interchangeability and reduced spare motor inventory. Spare parts reductions were also achieved in the electrical control and power supply components. The motor operated at approximately 3100 rpm, which reduced the size, weight, and reduction ratio of the gearbox required to produce a cutting speed of 300 feet per minute. Adequate motor speed adjustment existed to provide lower or higher blade cutting speeds if required.

The commercially available speed reducer (70:1 reduction) was a single reduction worm gear type with a NEMA "C" motor mount adapter on the input shaft. The speed reducer was mounted to the drive mounting plate with the output shaft projecting through the plate.

An elastomer-bellows type rotating face seal was used between the mounting plate and output shaft. The blade drive wheel was bolted directly to the end of the speed reducer output shaft. A three-jaw coupling connected the speed reducer input shaft to the drive motor.

The enclosure housing, bolted and sealed to the drive mounting plate, had a top cover plate and a front cover plate which were sealed by O-rings and closely spaced capscrews. The top cover plate contained potted cable bulkhead type seals for all electrical lead penetrations.

A2.4.3 - Bandsaw Idler Wheel and Housing Assembly

The idler wheel and housing assembly was located at the outer cantilevered end of the frame, in line with and parallel to the drive wheel assembly described above. A photograph of this assembly is shown in Figure 19. This assembly consisted of a 26-inch diameter wheel mounted to a short (7.4-inch) axle which rotated inside a pair of 2.83-inch diameter ball bearings. These commercial alloy steel bearings were mounted inside a bearing housing and were secured by a retainer. Two O-rings were used to seal the retainer to the housing and the outside diameter of the face seal seat. The remainder of the face seal (elastomer bellows) sealed the shaft outside diameter. The resulting assembly featured commercial bearings enclosed and protected from the pit water. The assembly was designed to be replaceable as a watertight unit and to be replaced without the need to drain the pit. The idler wheel and housing assembly was mounted to the tensioning plate.

The idler wheel tensioning plate was mounted in a horizontal slide assembly attached to the main frame that was in line with the drive wheel. By placing a force on the tensioning plate in the opposite direction to the drive wheel, the bandsaw blade was tensioned.

A2.4.4 - Tensioning System

Bandsawing depended upon having sufficient tension on the blade to make it taut. To provide this force, the idler wheel and housing assembly were mounted onto a movable tensioning plate. The tensioning plate consisted of a "T" shaped slider assembly that was mounted to the main frame in upper and lower horizontal support guides. The lower part of the "T" acted as a tongue which was mounted in a forward support guide. Translation of the tensioning plate was obtained through a crank arm connected to a hydraulic cylinder.

The power source consisted of a double-acting water hydraulic cylinder which was mounted at the top of the frame opposite to the idler wheel. A photograph of the tensioning mechanism is shown in Figure A2-3. The hydraulic cylinder rotated a shaft which was pinned to the yoke end of the long arm of a 3:1 crank. The crank journal passed through a bearing mounted through the

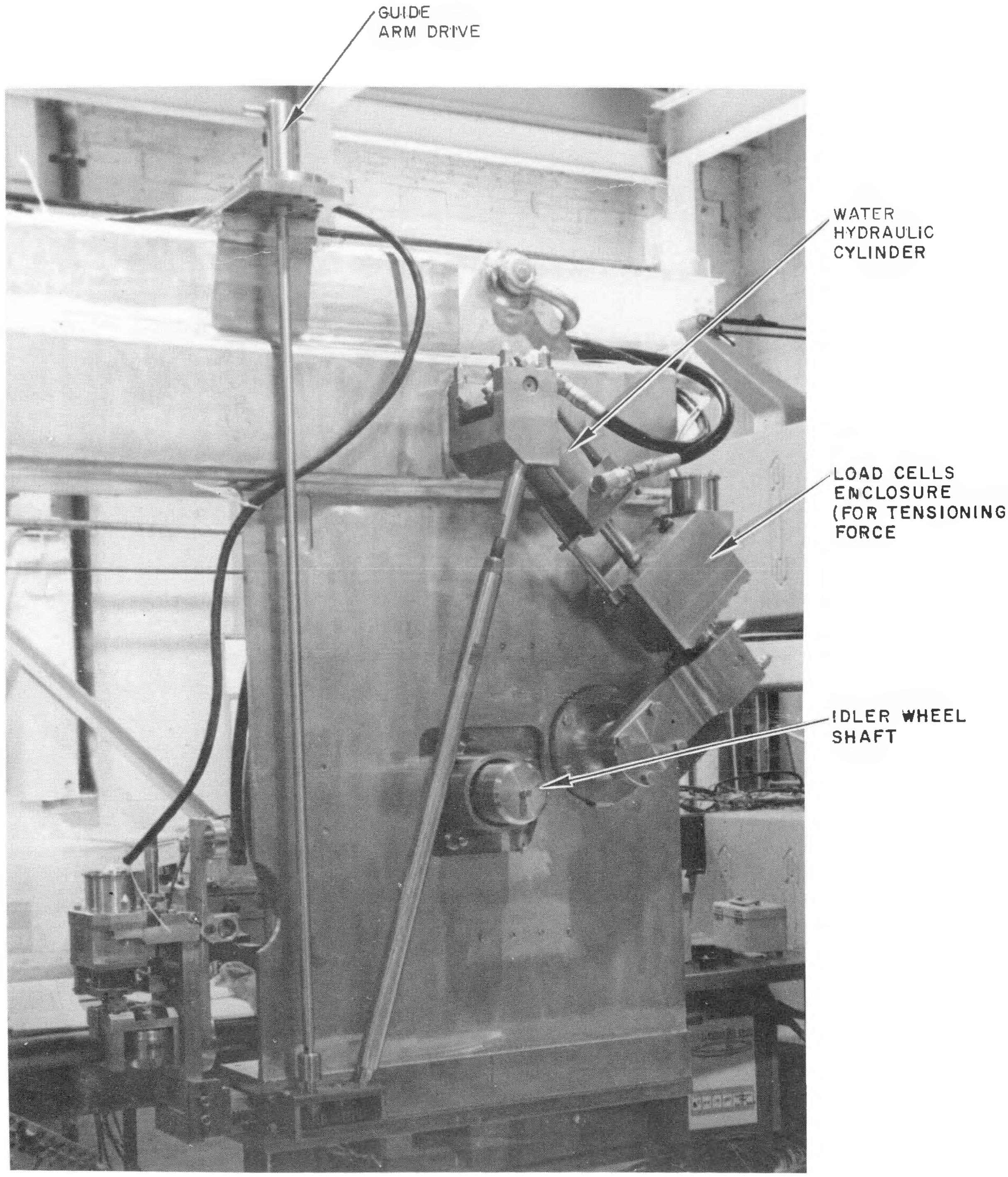

Figure A2-3 - MDA-COS Bandsaw Tensioning System Assembly main frame. The short arm of the crank was attached to the front side of the frame. A load cell was provided in series with this mechanism to provide the primary method of verifying the blade tension. Hydraulic cylinder pressure was used as a secondary backup indication.

The hydraulically actuated crank was connected to the tensioning plate by a short link with pinned ends. It was through this mechanism that the tension was either relieved to remove the saw blade or applied to make the blade taut for cutting.

A2.4.5 - Blade Guide Roller and Load Cell Arrangement

The blade guide rollers and load cells were located at the bottom of the main frame on each side of the work piece below the blade wheels. Within the span between the guide roller assemblies, the saw blade was twisted to a vertical position. The blade was laterally positioned by close fitted carbide guide pads, and supported vertically by the blade backup pad. The backup pad was reacted by the load cell plunger. The system of guide rollers, pads, and load cells was attached to a support arm assembly. The support arms were adjusted prior to each cut to minimize the unsupported blade span across the work and provide maximum blade stiffness. Adjustment was performed using a gear rack attached to the blade guide support arm which was engaged by a spur gear mounted to the main frame. The spur gear was connected to a vertical shaft that was mounted on the top surface of the frame and actuated using a hex drive nut.

The load cell was commercially available and was mounted inside a watertight enclosure which was fastened to the support arm. The guide roller assembly, which included fixed lateral pads and vertical backup pads, could be rotated 90 degrees using a worm and worm gear drive. Support arm rotation was performed to eliminate blade twist and simplify remote blade replacement. A photograph of the load cell housing with the roller guide rotated for blade installation is shown in Figure 20.

A2.4.6 - Kerf Keeper

The kerf keeper plate assemblies were used to maintain an open kerf above the blade as the saw advanced into the cut. The presence of loose cut pieces of fuel rod nuts and stems had the ability to vibrate back into the kerf. This made new blade insertion into the cut extremely difficult during blade changeout. A photograph of the kerf keeper assembly is shown in Figure 21.

The kerf keepers consisted of 0.043-inch thick stainless steel sheet. Each module type had a different kerf keeper that was sized for the width of the cut. The plates were installed onto the saw using two probe poles inserted into lifting holes at the top end. The assemblies were suspended from two pins projecting from the frame top main support beam. The plates were held in position using spring loaded pivoting arms that pressed against the plate surface. The bottom end of the kerf keeper was aligned and positioned above the blade using guides located in the adjustable blade guide arms.

The kerf keeper system included an alarm to indicate resistance of the plate to enter the kerf. The alarm was operated using an underwater limit switch which tripped upon upward movement of the plate relative to the saw frame. This system helped assure that the cut progressed in a straight plane through the module.

A2.4.7 - COS Pneumatic System Description

The COS Pneumatic System was designed to internally pressurize the gearbox, minimizing the chance of pit water entering the enclosure, and to aid dissipation of heat produced by the speed reducer and motor.

As shown in Figure A2-4, the pneumatic system was supplied with 100 psig air from a chiller. A pilot-operated regulator and pilot regulator reduced the input pressure. The actual pressure setting was determined by the volume of air which flowed through the gearbox. From the regulator, the air flowed through a visual flow meter and a flow switch. The flow switch was set to activate when the flow fell below 20 SCFM. A pressure transducer, located after the flow switch, monitored the inlet pressure to the gearbox enclosure.

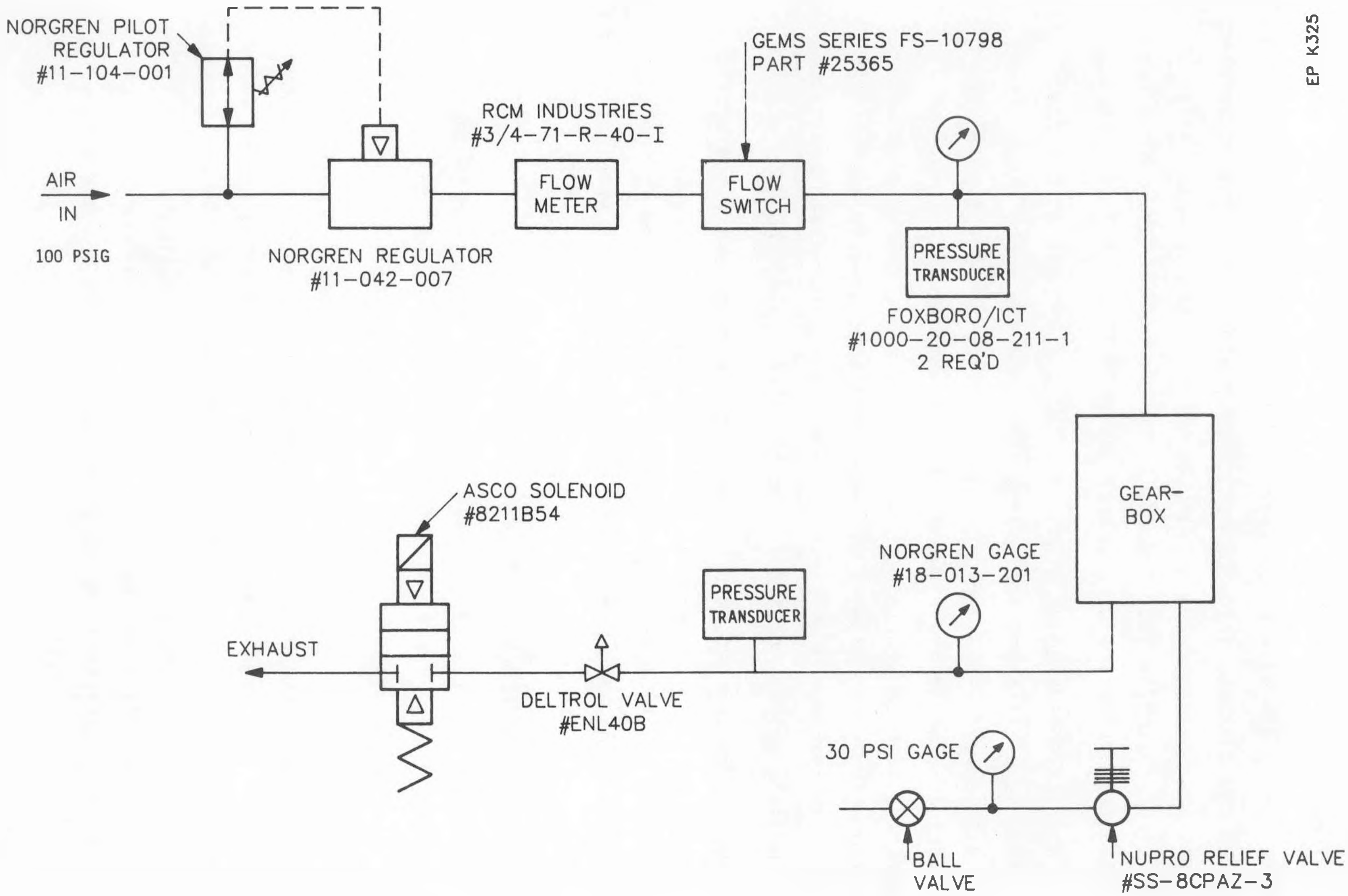

Figure A2-4 - MDA-COS Pneumatic System Schematic

The air flowed through the gearbox and back to the pneumatic panel. A second pressure transducer at the pneumatic panel monitored the outlet air pressure. Using the inlet and outlet pressures, the Modicon microprocessor calculated the average gearbox pressure. The result was displayed on the COS operators panel via a high, normal, and a low pressure light.

At the control panel, a needle valve was used to regulate the flow through the gearbox. A normally closed solenoid valve was used to maintain positive internal gearbox pressure (with no flow) when the COS was not in use or stored at the bottom of the pit. The valve was opened when COS power was turned on, and closed when power was turned off.

The pneumatic system included a drain line from the bottom of the gearbox which was regulated by a ball valve. Under normal operations, the ball valve was closed. However, if water was detected in the gearbox or if a periodic dry out was desired, the ball valve was opened. Included in the drain line was a pressure gage which monitored the static pressure in the gearbox.

A2.4.8 - COS Hydraulic System Description

The COS hydraulic system was used to pressurize a double acting hydraulic cylinder which controlled the tension on the blade. As shown in Figure A2-5, the hydraulic system was supplied with 800 psig water from the MDA hydraulic system pump. A pressure regulator reduced the water pressure from 800 psig to 115-130 psig. A check valve between the pressure regulator and a four-way solenoid valve held pressure in the hydraulic cylinder in the event that the MDA water pump failed.

A four-way, three-position electrically operated solenoid valve controlled the water distribution to the "tension" and "detension" sides of the cylinder. The solenoid valve was operated via two switches on the COS operators console. Each of these switches contained an OFF, an ON, and a MOMENTARY ON position. The MOMENTARY ON or jog position was normally used for the initial tension and detensioning of a blade.

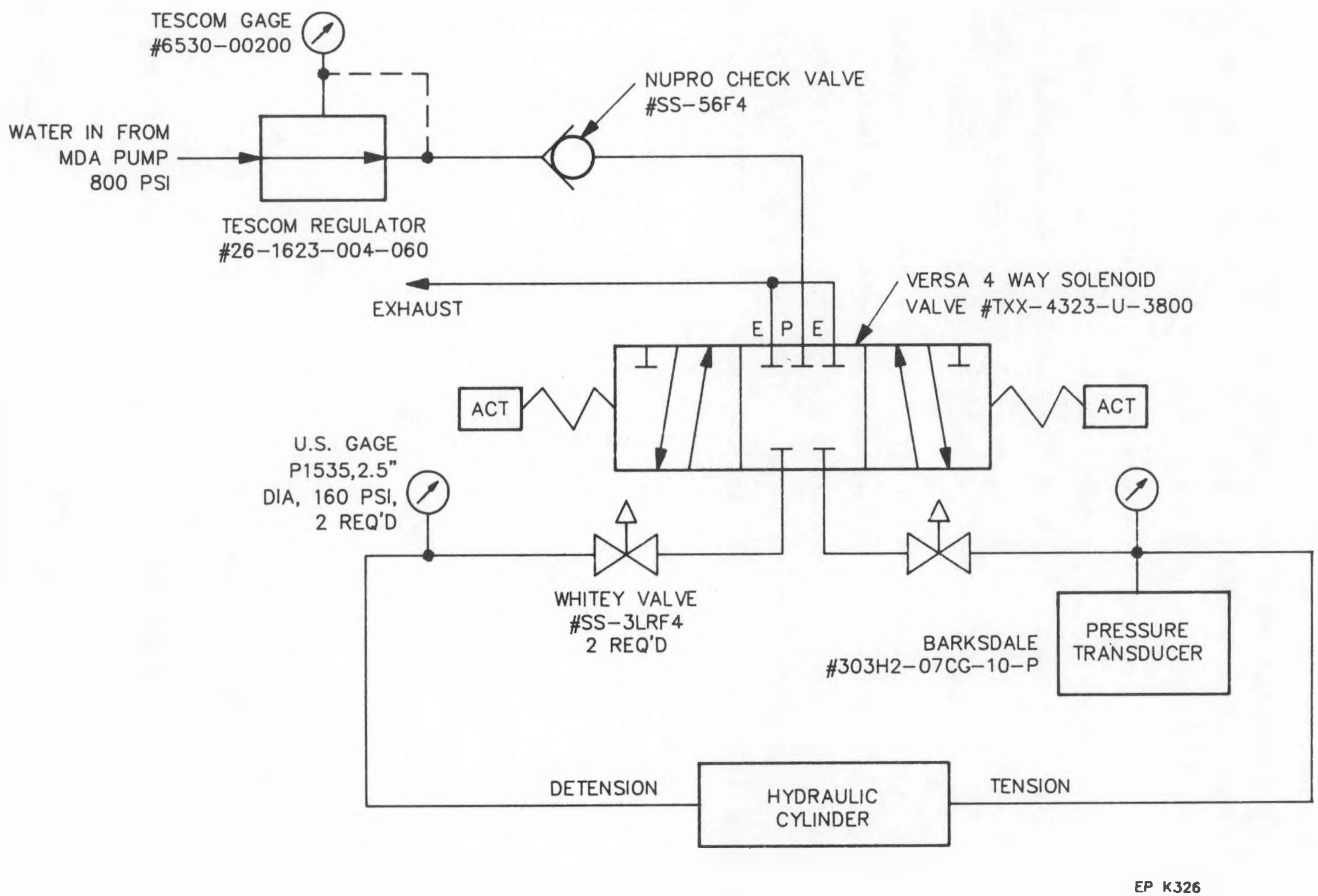

Figure A2-5 - MDA-COS Hydraulic System Schematic

Once the tension or detension position was selected, the water flowed through a regulating valve which reduced the flow to the hydraulic cylinder to an acceptable speed. A visual indication of the water pressure was provided at the outlet of both the tension and detension lines. A pressure transducer was located at the outlet side of the tension line. The transducer signal was sent to the Modicon and the display was shown on the COS operators console. The pressure transducer acted as a backup to the tension load cell.

A2.5 - BLADE CHANGE FIXTURE

The remote bandsaw blade installation tool or fixture was used for remote assembly of a conventional grit-edged or tooth edge blade on the underwater bandsaw. A view of the fixture is shown in Figure 22. The blade installation tool design consisted of an aluminum frame containing magnetic blade supports to retain the blade in position on the fixture. When the installation fixture was lowered onto the saddles of the saw frame, the fixture assembly pivoted and the blade assembly rotated inward over the bandsaw wheels.

The COS bandsaw blade installation tool was designed to satisfy the following requirements:

a. Remote underwater blade changeout.
b. Provide a method of holding the blade in a manner that permits accurate and quick replacement.
c. A light weight, easily manipulated, manually operated fixture for both assembling the blade to the fixture and remotely installing the blade on the saw.

To install a new bandsaw blade, the replacement blade was assembled on the fixture either above the water or with the fixture horizontal near the water surface. The blade was supported and retained in the fixture by spring-loaded support pins and magnetic supports located in both fixed and pivoting positions. The support pins and magnetic supports retained the blade on the frame in a position such that it could be slipped over the bandsaw wheels and be tensioned without additional adjustment. Tensioning of the blade transferred the blade to the bandsaw wheels, allowing the frame to be pulled outward with the blade remaining in position on the wheels.

During insertion of the blade, the fixture was designed to hang at an angle of 20 degrees with the vertical. The use of this lifting angle, along with two vertical support shafts mounted on the top of the fixture, permitted the frame to be set into the locating saddles on the top of the main frame. When seated, the fixture would swing in at the bottom, positioning the blade over the bandsaw wheels and between the guide rollers.

After the blade was over the wheels, the idler wheel of the saw was translated horizontally until the blade was snapped free from the magnets and was taut on the wheels. The pivoting supports on the installation fixture moved outward with the idler wheel as it tensioned the blade. The supports were spring-loaded so that they automatically moved back to their original position when the fixture was removed from the bandsaw.

A2.6 - MDA-COS INSTRUMENTATION AND CONTROLS

A2.6.1 - Introduction

The COS Instrumentation and Controls provided the necessary functions to monitor and perform the module cutting operation remotely. This process was accomplished by the following four subsystems: (1) the MDA X axis (along the module center line) and Z axis (vertical travel) drive systems; (2) the COS blade drive assembly; (3) the COS central processor system; and (4) miscellaneous COS instrumentation.

A2.6.2 - Use of Module Disassembly Apparatus (MDA) Controls

The MDA system controls were incorporated into the COS whenever possible. Two such MDA systems were the X axis and Z axis drive assemblies. The X axis was utilized by the COS to obtain precise horizontal positioning of the head assembly. The MDA Z axis was used to control the vertical cutting rate of the saw into the module. Each of these drive systems had the capability for variable speed control, down to very low speeds, and contained absolute position readout readily available for use by the central processor system. Both of these systems required only minor additions to their respective controls to adapt them to COS usage.

A2.6.3 - COS Control System Description

The COS blade drive control system consisted of a DC motor with a tachometer generator to provide feedback, a controller to provide speed control and torque limit, and a detector to sense blade motion and speed. The motor and controller were identical to the axis drives in the MDA system. The blade detector was incorporated to provide the operator with a display of the blade speed and to detect the possibility of the blade becoming slowed or stopped in the module cut.

The central processor unit was the fundamental control system for the COS. This device monitored all significant operating parameters and provided appropriate control signals to the system, thereby minimizing the need for operator interface once the cutting process had been initiated. A Modicon Model 384 programmable controller was used for this purpose. This system was a very versatile machine which allowed changes to be made to the system with minimum effort. It was also compatible with other systems designed for LWBR core evaluation work at ECF.

Two of the most significant parameters monitored by the central processor unit were the horizontal and vertical positions of the bandsaw head and the blade cutting force. In monitoring the horizontal and vertical positions of the head assembly, the processor could determine and restrict COS travel to within allowable zones for either horizontal or vertical motion. This prevented possible damage to the bandsaw head and the module.

The blade cutting force was compared to a predetermined maximum set value by the central processor unit and the feed rate (Z axis speed) was controlled to produce the desired force.

Additional information required to operate the COS included blade speed, blade tension, and stopped blade detection. Again, the central processor system was used to monitor the signals from these parameters, outputting necessary control responses to produce variances in their operation.

Housing the electrical controls for the COS required two consoles, one for the operator's controls, and one to contain the Modicon system. The COS operator's panel was located adjacent to the MDA operator's panel, and the Modicon panel was located near the MDA main electrical panel in the water pit observation and control room.

APPENDIX A3 - UTILITY FIXTURE SYSTEM DESCRIPTION AND OPERATION

A3.1 - BACKGROUND

The proof-of-breeding (POB) and core examination (CE) programs required that twelve LWBR modules be severed in a plane transverse to its longitudinal axis in the baseplate of both the top and bottom module ends. Four seed, four blanket, and four reflector modules were disassembled for rod removal, examination, and inspection. Of these twelve modules, three of the seeds, all four of the blankets, and three of the reflectors were severed in their as-received (from SAPS) condition. The remaining seed and reflector module had their shell removed prior to cutting at the baseplate elevations.

Both the cutoff system (COS) and the module disassembly apparatus (MDA) were designed to position the module horizontally for support and machining. A horizontal module position provided the best access and visibility and made both ends of the module accessible for machining without repositioning.

The LWBR modules were relatively flexible and required additional support for horizontal transfers and rotation. The utility fixtures were designed to provide this support. In addition, the fixtures provided access for core examination component machining, removal, inspections, guidance for installation of stabilization clamps, and geometric criticality control. Two utility fixtures were built to accommodate the six different module types. The seed/blanket UF was used for the seed module and three blanket module types, and the reflector UF was used for the Type IV and Type V reflector modules.

A3.2 - DESCRIPTION AND OPERATIONAL USE

As shown in Figure 10, the utility fixtures consisted of an enclosure with the same internal shape as the module. Inserts were used to configure the UF internal shape for the geometrically different module cross sections. The inserts consisted of flat plates which provided guide runners and filled the necessary void areas of the cavity. The inserts were supported within the UF using dovetail-type ways. The inserts were installed with the UF vertical and the top end cap removed. The top and bottom end caps also contained inserts which were retained in position using locking bolts or pins.

The fixture supported the module on three opposite sides 120 degrees apart. The top and bottom end caps were removable to expose the baseplate region and outer module ends for cutoff machining. It was also separable along its longitudinal axis for use in MDA machining operations.

The utility fixture (UF) was designed to be handled vertically only when it was empty. For this purpose, a special lifting plate was attached onto the top end cap. As a safety feature, the blanket/seed vertical lifting plate contained an insert that extended into the internal cavity of the UF so that the lifting plate could not be installed if a module was in the fixture. The empty UF was transferred vertically and loaded into the upender.

When in the upender, the vertical lifting plate was removed. The module clamping jacks were checked to verify that the clamping plate was in the full retracted position, and the module was vertically loaded into the UF.

After installation of the module, the module clamping jacks were tightened to restrain the module in the fixture, and the top end cap plate was installed. The top plate was designed to accept two different length inserts. A short insert was used for the as-received module and a longer insert was used after COS to retain the end of the cutoff fuel rods replacing the cutoff module length.

Both the top and bottom UF end caps were attached to the main body of the fixture with ring clamps contained on each end cap. An acme screw thread was used to open and close the clamps.

After end cap top plate installation, the module was rotated to the horizontal position by using the upender and transferred to the MDA table using a special double-rigged lifting system. This system is illustrated in Figure A3-1. The grapple consisted of a lifting frame with primary and secondary grappling pins that engaged in both the end cap lifting lugs and in lifting holes incorporated in the rollover ring assemblies.

As a safety feature, the backup rigging end cap lifting eyes were blocked by the opened end cap clamp ring. This feature and the lifting grapple preset lug spacing provided passive safety protection, assuring that the fixture end caps were properly installed and tightened prior to horizontal lifting. For grapple installation, the lifting frame was lowered using the crane and electric auxiliary hoists until the frame was seated on the UF lifting lugs. A centrally located actuating drive on the lifting frame was rotated to engage all lifting pins in one operation. Secondary electric auxiliary hoists were used to maintain 0 to 5.0 inches of slack in the backup rigging as the main crane hook lifted the UF and module from the elevation of the horizontal upender (approximately 7 feet) to the elevation of the MDA table (23 feet).

For support and positioning on the MDA table, the UF contained external rollover rings which mated with roller assemblies on the holddown and rotation fixture. The horizontal grapple system was designed so that the grapple pins could not be disengaged from the fixture until the fixture weight was supported by the MDA table. After grapple removal, holddown clamps were installed above the rollover rings to secure the module to the table while permitting rotation of the UF.

All subsequent disassembly operations required removal of the UF end caps. The end caps were designed to be removed or installed when the UF was in the rotational orientation for module cutting. Therefore, as shown in Figure 24, depending upon the module type, the module was rotated either 30 degrees, 60 degrees, or 90 degrees prior to end cap removal.

After the end caps were removed, the module was ready for baseplate cutting or machining. A minimum module length of approximately 2.9 inches (as measured from the inboard edge of the baseplate) extended out of the UF when the end caps were removed.

After end cap removal, the module baseplate ends were severed using the COS or the upper half of the UF main body was separated to expose the module for MDA machining operations. For top half removal, the assembly was rotated back to position the parting surface horizontal.

A slide bar assembly was designed as an interlock feature to control the position of the side attachment nuts used to secure the UF halves. The slide bars used a combination of varying slot diameters and bar thickness to retain

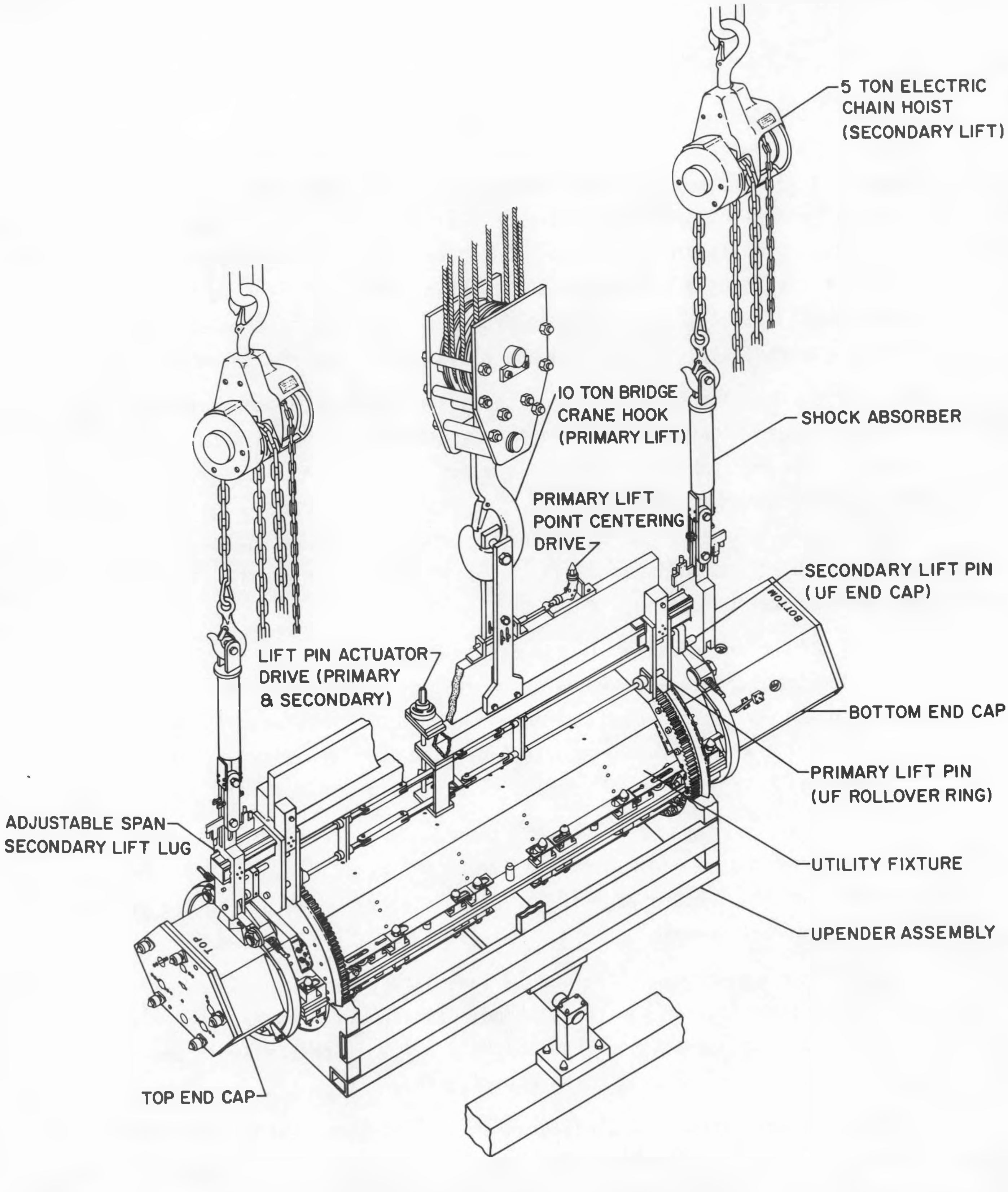

Figure A3-1 - LWBR Utility Fixture
Horizontal Grapple Double-Rigged Lifting

the attachment nuts unless certain physical safety conditions were met. With the slide bar in the closed position (attachment nuts tightened), a smaller diameter and thinner zone of the slide bar fit around a mating groove of the attachment nuts. When the slide bar was in the center position, the nut was free to rotate and be pushed axially upward by the nut captured spring after thread disengagement. When the nut was in the full up position, the slide bar could be moved to the full open position, thus rotating a lifting eye into an accessible location where the top half removal lifting cable could be attached. As the slide bar was moved to this position, it extended outward through the UF end cap flange. This provided a passive mechanical safety feature that prevented slide bar movement (and main body separation) while the UF end cap was installed. Each nut was captured in the full up position until the slide bar was returned to the center neutral position. The use of eight slide bars and eight lifting eyes provided interlocks for all of the side attachment nuts on both the top and bottom main body halves of the UF flanges. The attachment nuts had to be tightened in order to move the slide to the closed position. With the slide bars closed, the UF end cap could be reinstalled.

After UF top half removal, clamps were installed at selected grid levels to retain the module in the fixture. Partial rollover rings were installed at the two rollover ring locations to replace the ring sections removed with the UF top half.

The steps for returning the module to the vertical position with the UF in the upender were basically the reverse of the operations discussed above. If the ends of the module were cut off during end cap removal, the bottom blanket or reflector stabilization clamps were installed on the bottom end of the module to replace the cutoff length. For the seed module, the bottom stabilization clamp was loaded into the bottom UF end cap and installed as an assembly during end cap installation. After COS, the as-received insert in the top end cap of the UF was exchanged for an insert designed to restrain the cutoff end of the rods and provide support and alignment during installation of the stabilization clamp tie rods and sleeves.

With the module secured in the upender and rotated to the vertical position, the stabilization clamp tie rods and sleeves were installed. The UF top end cap cover plate contained holes which allowed installation of the tie rods and sleeves. Rectangular channels existed inside the UF to guide each tie rod and sleeve into the bottom stabilization clamp lugs. A keyway was provided at the top end of the UF to position the support pins of the tie rod sleeve for alignment during top stabilization clamp installation.

Once the tie rods and sleeves were installed, the top end plate of the UF was removed. The end cap was left in place to protect the cutoff module and provide guidance for the top stabilization clamp installation. The stabilization clamp was installed by lowering it into the UF over the aligned tie rods and sleeves. Installation of the stabilization clamp system was completed by installing the tie rod bolts into the tie rods, rotating the stabilization clamp gage plate to the closed position, and closing the tool guide and lock key. The UF was used to react the applied bolt torque. The module was vertically lifted out of the UF with the top end cap in place.

APPENDIX A4 - MODULE HOLDDOWN AND ROTATION FIXTURE

HOLDDOWN AND ROTATION SYSTEM DESCRIPTION AND OPERATION

A4.1 - BACKGROUND

The holddown and rotation system (HDRF) was designed to support and rotate the horizontal utility fixture (UF) during machining operations. The fixture design permitted removal of the top half of the UF to provide access for core examination component machining, removal, or inspections. The system also included movable stages to support, attach, remove, and reinstall the UF end caps and other auxiliary equipment required for disassembly.

A4.2 - DESCRIPTION AND OPERATIONAL USE

As shown in Figure 13 and Figure A4-1, the HDRF consisted of UF rotation support saddles and end cap removal stages mounted on a 2-inch thick baseplate. Clamps were provided to secure the UF in the HDRF and to attach the rotation drive and lock systems. Posts on the stages were used to provide attachment locations for the UF end cap lift fixture, the module remnant removal adapters, and other auxiliary equipment.

The holddown and rotation fixture and the stages were pre-assembled on the baseplate. The baseplate provided alignment and support of the system features through checkout and maintained component alignment during shipping and installation. It also provided a relatively simple means for remote attachment of the assembly to the MDA table "T" slots.

Prior to receiving a UF, the HDRF-UF clamp assemblies were removed. Both the top and bottom stages were moved to their positions farthest away from the rollover ring saddles. The MDA head was moved to its full stop position toward the bottom of the module (extreme west position) if the COS head was installed, or retracted from over the table (extreme south position) if the MDA milling head was installed.

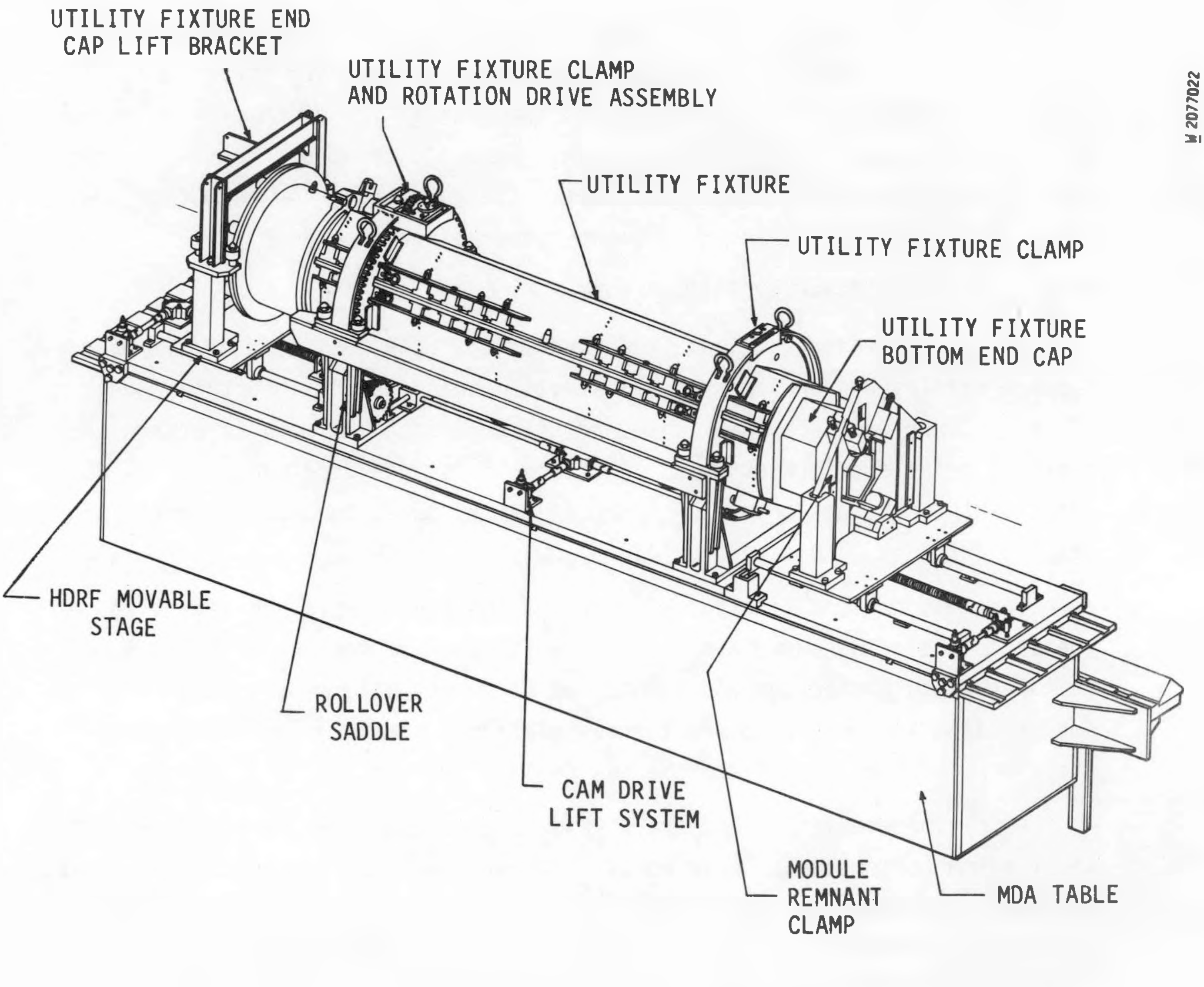

Figure A4-1 - LWBR Holddown and Rotation System Assembly Containing Utility Fixture, HDRF Clamps, and End Cap Lift Brackets

The sequence of operations for module disassembly on the HDRF consisted of receiving a horizontal UF containing a fuel module from the upender. The UF was handled using the horizontal lift grapple which was double rigged to the bridge crane. It was positioned beside the MDA table in an axial position that would clear the COS or MDA head. The UF was lifted to a height sufficient to clear the rollover system support saddles, translated, and lowered into the saddles.

The maximum radiation level at the water surface was required to be no greater than 0.2 mrem/hr, which positioned the top surface of the modules approximately eight feet below the water. After the UF was lowered on the support saddles, a rollover ring clamp was installed above each saddle. One clamp contained the gearbox system used to rotate the UF. This clamp could be installed at either saddle location. The second clamp contained a stainless steel clamping pad used to secure the fixture.

For rotation, the UF was lifted approximately 0.3 inch above the solid support saddles. The solid supports were designed to provide a high friction stable surface for machining operations. For rotation, two rollers were located under each UF rollover ring of each saddle. The rollers were installed on an eccentric cam-mounted shaft such that the rollers were lifted or lowered when the shaft was rotated. All rollers were interconnected with shafts and gearing which lifted the entire UF by rotation of a single gearbox shaft.

When in the raised position, the fixture was rotated to place the module in the desired orientation for machining or cutoff operations. Rotation was produced by a 40:1 ratio worm/worm gear drive assembly that was mounted to a UF clamp. The gearbox output shaft contained a spur gear which meshed with the large rollover ring drive gear. For seed and blanket module end cap removal and cutoff, a 30-degree rotation was required. For the Type IV reflector module, a 60-degree rotation was required, and for the Type V reflector module, 90-degree rotation was required.

After the UF was rotated, it was lowered back onto the solid saddle supports and the clamping pad was tightened to secure the module in position. For UF end cap removal, the stage was straddled around the UF end cap lift lugs and the end cap lift fixture (shown in Figure A4-1) was lowered into the posts and attached to the UF end cap lifting lugs. The UF end cap ring clamp was loosened and the end cap was removed by retracting the stage manually using the ball screw stage drive. The end cap was lifted out of the posts and moved to a temporary storage location. The lift fixture remained attached to the end cap for re-installation when machining was completed.

The stage assemblies consisted of a flat plate approximately 48 inches by 20 inches by 0.75 inch thick which contained two vertical posts. Each post contained a hole and keyway cutout which enabled remote attachment of fixturing by simply lowering the assemblies into the keyways. The stages were mounted on two 2.0-inch diameter hardened stainless steel rails. Stainless steel ball bushings were used to provide low-friction sliding movement. The assemblies were driven using a 1.5-inch diameter stainless steel ball screw and nut. The nut was fixed to the bottom of the stage and driven by screw rotation. Each stage had a design capacity of approximately 3500 pounds and had an axial travel of approximately 26 inches and 35 inches for the top and bottom ends, respectively.

Prior to module cutoff, a remnant support clamp was mounted into the posts of the stage assembly. This clamp was used to support the remnant during cutting and also as a lifting device for removal of the cutoff section of the module. The installed remnant clamp is shown in Figure A4-1.

When the module and UF were being positioned for machining operations on the MDA, rotation of the UF was required after end cap removal. Since the UF was designed to be separated with its bolted flanges in the horizontal position, the UF and module were lifted and rotated so the bolt flanges were in the horizontal position with the side of the module to be machined in the upper half of the UF. The top half of the UF was removed and reinstalled as discussed in Appendix A3.

APPENDIX A5 - MODULE STABILIZATION CLAMPS

A5.1 - PURPOSE

The LWBR core contained six geometrically different cross sectional module shapes which included the seed, Types I, II, and III blanket modules, and the Types IV and V reflector modules. Illustrations of the as-received modules at Expended Core Facility (ECF) are shown in Figures 5, 6, and 7. After cutoff of the baseplate ends, the fuel rods were still laterally supported within the module by the grid, post, and shell structures, but axially the rods were relatively unsupported and free to slide out of the module ends. Also, during the cutoff operation, the top end vertical lifting attachment and the module serial numbers were removed with the cutoff remnant.

The purpose of the stabilization clamps was to provide support of the cutoff module fuel rods within the structural remnants of the disassembled module, and to provide a means for vertical handling of the module after baseplate cutoff. The stabilization clamps were also designed to provide lateral spacing sufficient to assure nuclear decoupling of all modules by lugs which extended radially outward beyond the module, precluding lateral contact between modules. The seed module stabilization clamp system is illustrated in Figure 27. The clamp system was installed on the module after the ends were cut off. The stabilization clamps provided the means for vertically handling the cutoff modules through subsequent disassembly operations and remained installed on the modules during final storage.

A5.2 - DESIGN

Six different stabilization clamp types were built to correspond with the six cross-sectional module shapes. Illustrations of the Type I, II, III, IV, and V stabilization clamp assemblies are shown in Figures A5-1, A5-2, A5-3, A5-4, and A5-5, respectively.

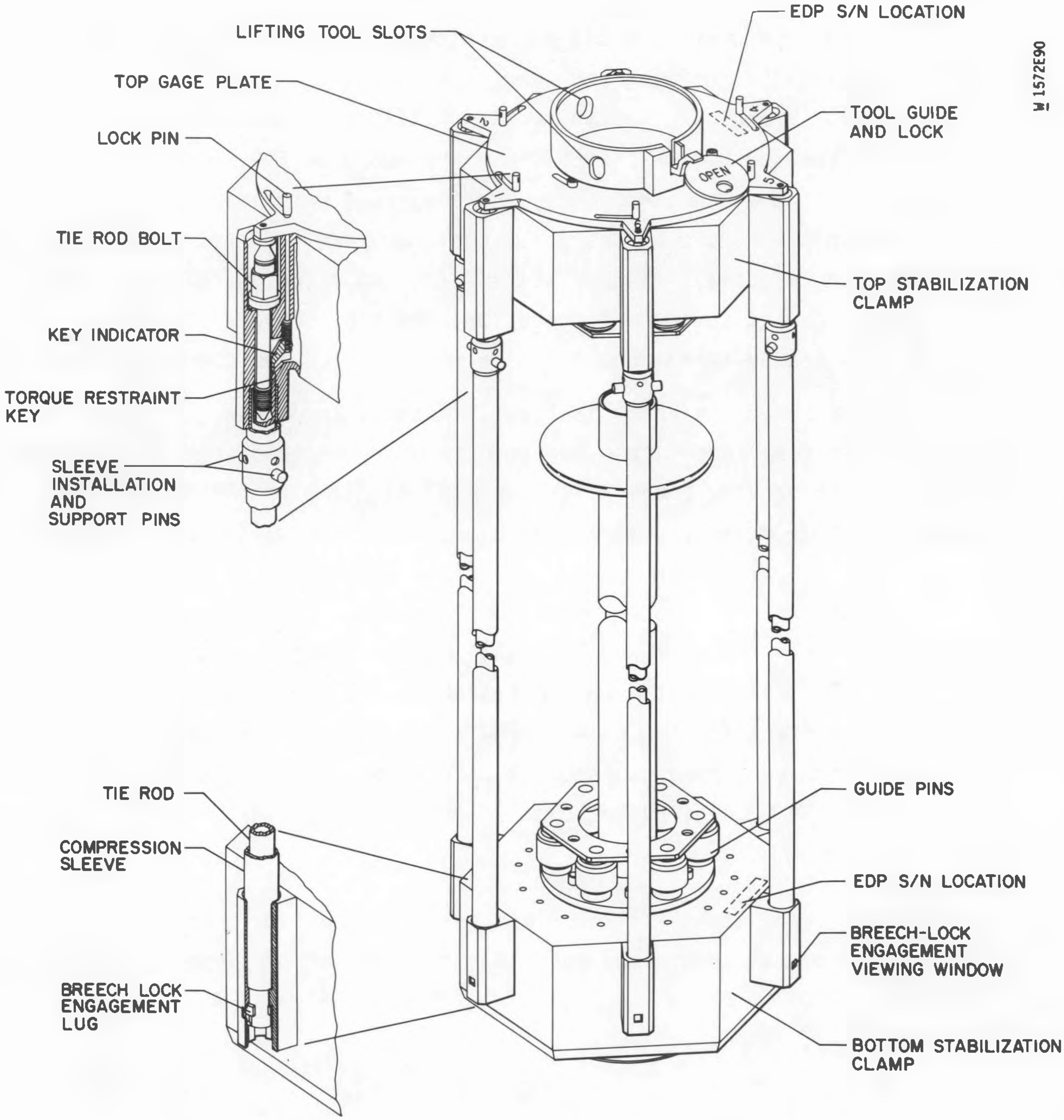

Figure A5-1 - LWBR Type I Blanket Stabilization Clamp

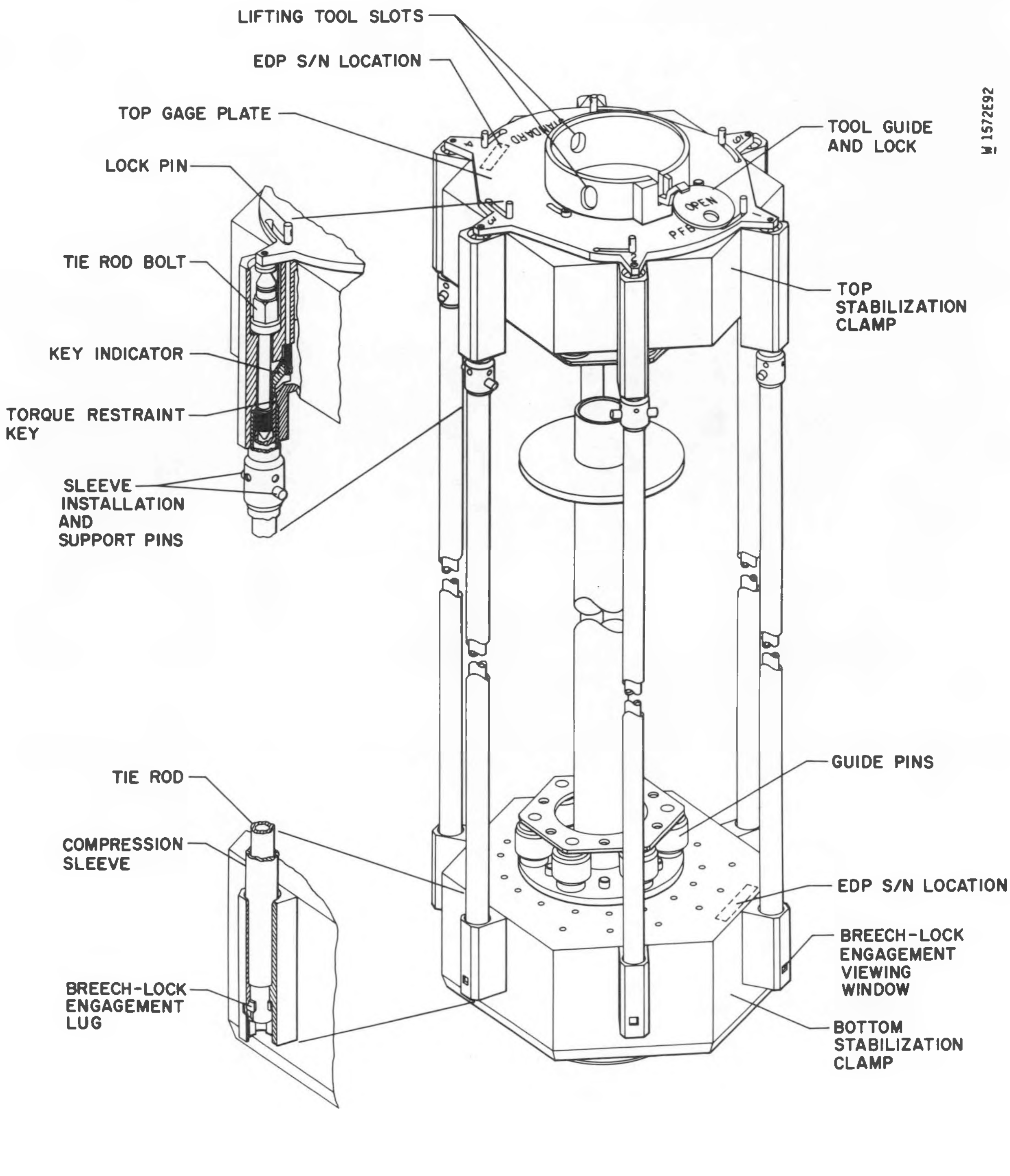

Figure A5-2 - LWBR Type II Blanket Stabilization Clamp

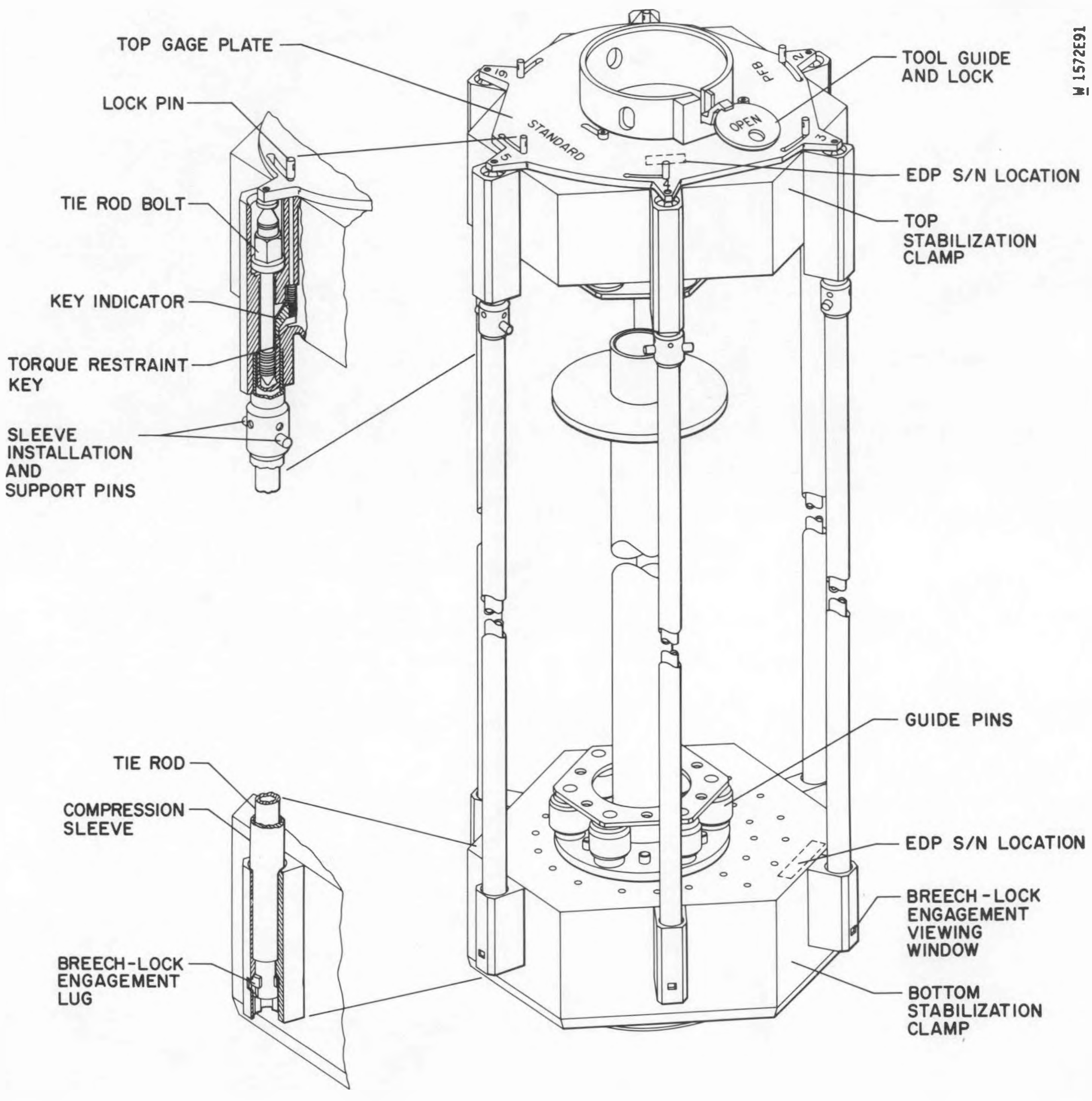

Figure A5-3 - LWBR Type III Blanket Stabilization Clamp

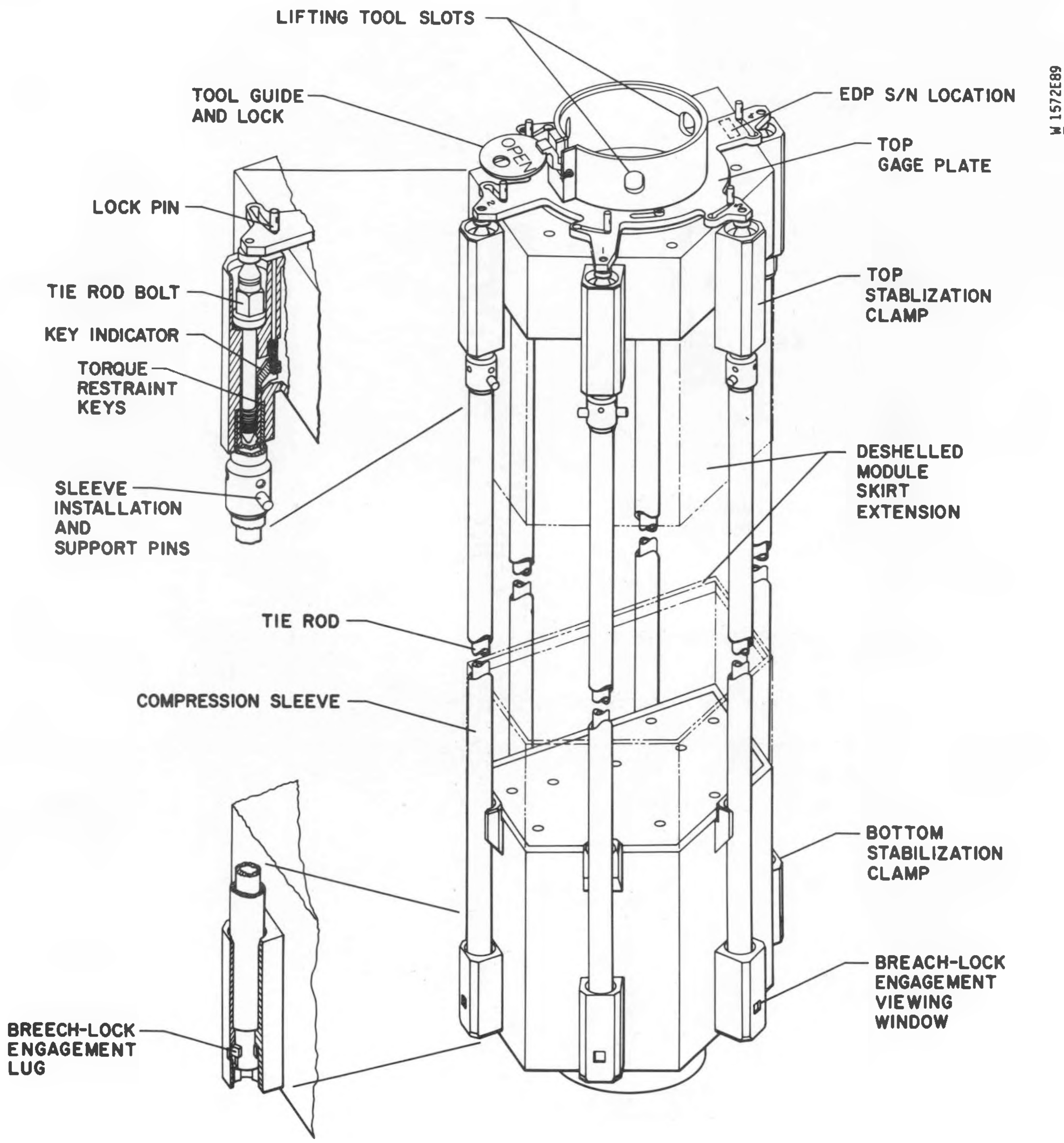

Figure A5-4 - LWBR Type IV Reflector Stabilization Clamp

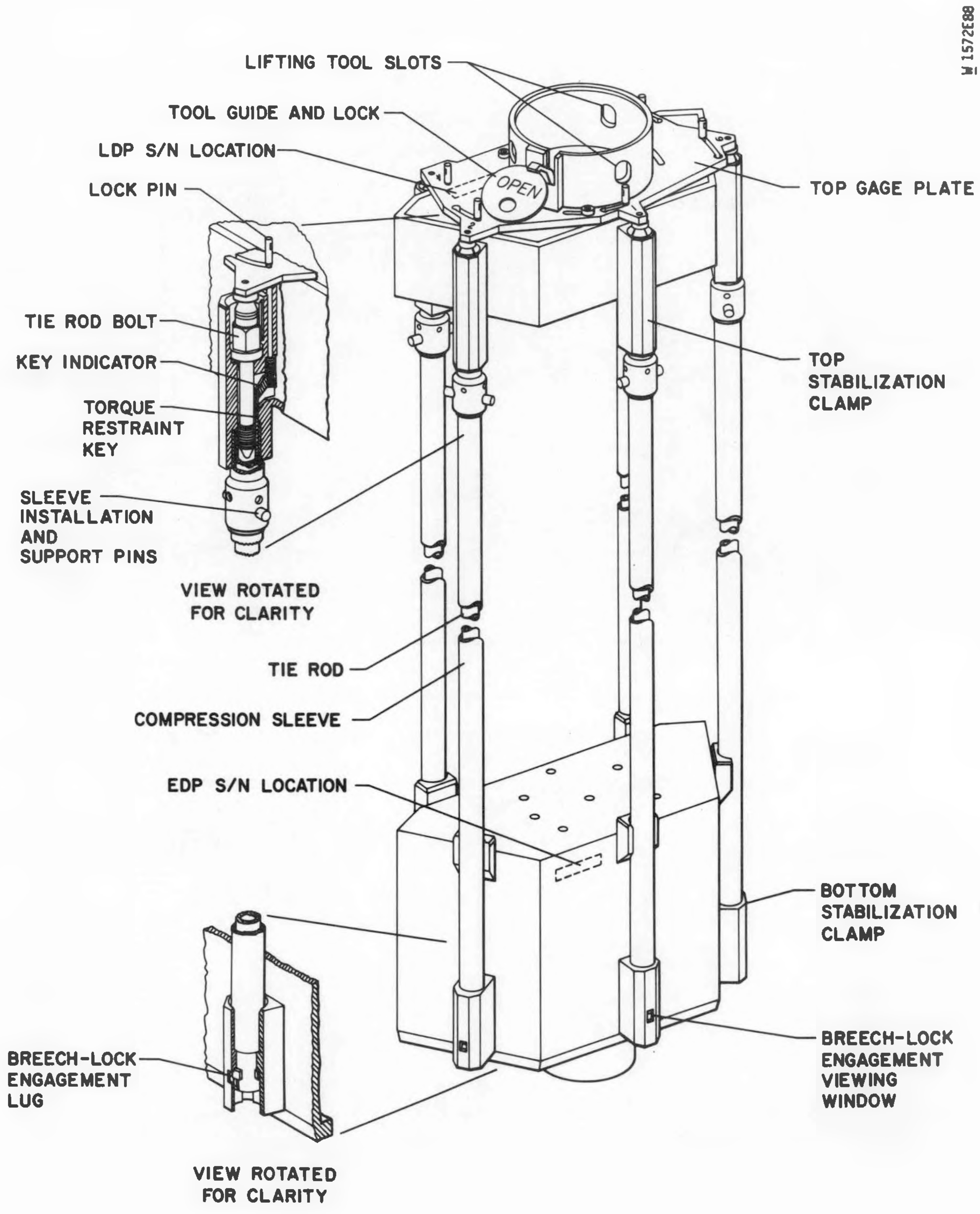

Figure A5-5 - LWBR Type V Reflector Stabilization Clamp

The stabilization clamps consisted of top and bottom clamps fabricated from stainless steel weldments which were slightly larger in cross-sectional shape than the modules (approximately 0.050-inch radially) and approximately the same length as the cutoff remnant that was removed. The top and bottom clamps were attached using tie rod and sleeve hardware assemblies that provided approximately 0.5-inch of end clearance between the top of the cutoff module and the top clamp.

Integral rectangular lugs on the outside of the clamps were used for attachment of the tie rods and sleeves and also to provide nuclear decoupling of adjacent modules. The bottom clamp lugs contained a breechlock configuration that mated with the tie rod ends. This connection was used for remote assembly and produced an attachment for tensile loading of the tie rod. The sleeve assemblies which fit over the tie rods were used as a compression member and seated in counterbores in the top and bottom clamp lugs.

The top clamp lugs contained captured bolts which were threaded into the tie rod ends to produce the tensile loading which was reacted by the compression sleeves. To provide uniformly preloaded joints, the sleeves were fabricated in closely matched lengths for each stabilization clamp set (0.003-inch tolerance per set). The top clamp lugs also contained three equally spaced keyways. These mated with three tie rod keys that were used to provide torque restraint during bolt tightening.

The top clamp contained several mechanical interlock features that were used to assure that proper remote stabilization clamp assembly was completed prior to lifting the fuel module. These features included a key indicator device that was located above each tie rod. The indicator was lifted as the tie rod-sleeve joint was preloaded. The top of each key contained a stepped diameter lock pin which had to be in the raised position prior to permitting rotation of a gage plate assembly. With all lock pins in the up position, the gage plate was free to rotate, which exposed a grapple ring keyway permitting insertion of the fuel grapple. The grapple ring design was compatible with the vertical fuel grapple.

Each top clamp contained machine engraved module serial numbers and module side location numbers to retain module identity after cutoff. The tool guide and lock assembly located on the gage plate also contained the module type and in-core location.

A5.2.1 - Unique Design Features

Special requirements for module disassembly and safety reasons necessitated special design features unique to specific stabilization clamp assemblies. Some of these features are discussed below.

For the one seed and one reflector module that were deshelled prior to baseplate cutoff, special stabilization clamps were provided. These clamps contained side wall skirts which extended up from the stabilization clamp to approximately the first grid level of the module. The skirt extensions were fabricated to approximately the same internal dimensions as the removed module shell. Externally, the side walls were the same size as other stabilization clamps.

The blanket module bottom stabilization clamp contained a center post to preclude the insertion of a seed module into the guide tube when the top clamp was removed. The post contained an upper guide plate which centered the cantilevered end as it was being inserted in the guide tube. For radial alignment of the blanket stabilization clamp with the module, alignment pins which fit into the corners of the module guide tube were used. The 2.50-inch diameter pins were chrome-plated and contained a connecting plate to minimize misalignment during installation. Radial alignment of other stabilization clamps was provided using exterior guides that contacted the shell or (in the case of the deshelled modules) the skirt extensions supported the baseplate remnant and perimeter fuel rods.

A5.3 - OPERATION AND ASSEMBLY

Assembly of the stabilization clamps began on the MDA-COS with the module in the horizontal position after cutoff. For the seed module, the bottom stabilization clamp was loaded into the utility fixture (UF) end cap and installed on the module during end cap assembly. Due to their large size and weight, the blanket and reflector stabilization clamps were independently installed on the module and the UF end caps were assembled over them. Various fixturing was mounted on the holddown and rotation fixture bottom stage to install and support the bottom stabilization clamps during end cap assembly. After bottom clamp and end cap installation, the UF and installed module were transferred horizontally to the upender and upended to the vertical position. When vertical, the tie rods and sleeves and the top stabilization clamp were installed.

The tie rod and sleeve pair were installed one at a time by lowering the assembly through holes in the UF top plate and into rectangular channels provided in the UF. As the assemblies were lowered, the bottom of the tie rod was guided into the stabilization clamp lug by a tapered lead-in. After initially entering the lugs, the rods were rotated so that the breechlock keys on the rod passed between the mating keyways in the bottom stabilization clamp lug. When this occurred, the tie rod lowered into the stabilization clamp lug and rested on the top surface of a lower set of cutouts within the clamp lug. A rotation of about 60 degrees in either direction permitted the lower keys on the tie rod to drop and enter cutouts. When this occurred, the breechlock keys on the tie rod were aligned under the breechlock clamp lugs, and the rod was restrained from rotation. Because of the 120-degree symmetry for the keys, any of the three possible rotational positions was acceptable. The tie rod lower keys remained engaged and provided initial rotational alignment for the tie rod top end keys as the top bolts were being tightened. During bolt tightening, as the tie rod was lifted (prior to contacting the breechlock pads) the top keys engaged keyways in the top stabilization clamp before the bottom keys were lifted out of the bottom clamp lower keyways. This complex keyway alignment was required to provide torque restraint and breechlock pad alignment during tie bolt tightening operations.

The design of the tie rods and sleeves permitted installation of the sleeve and the tie rod as an assembly. The weight in water was approximately 30 pounds for the tie rod and about 16 pounds for the sleeve.

When installed, the lower end of the sleeve fit into a counterbore in the stabilization clamp lug. The top end of the sleeve was retained in position by pins welded to a ring on the top portion of the sleeve. The sleeve pins were fixed in UF keyways that maintained the proper spacing for top clamp installation.

The top stabilization clamp was lowered onto the tie rods and sleeves using a rigid probe pole containing a "T" handle for positioning. The probe pole was attached to lifting holes in the clamp grapple ring.

After the top stabilization clamp was seated on the sleeves, the tie rod bolts were tightened. Initially, each captured tie rod bolt was tightened to a seating torque of 15 lb-ft. A final preload of about 2,500 pounds for each bolt was applied by rotating the bolt through an angle of 185 degrees in two tightening increments. The 2,500-pound preload resulted in an elastic strain of approximately 0.015 inch in the tie rod and 0.020 inch in the sleeve. After tightening all of the bolts, the tie rod top key lifted the key indicator, permitting gage plate interlock disengagement. In addition, the elevation of the bolt head was then low enough to permit positioning of the gage pin (located on the top clamp gage plate) over the bolt head. Engagement of the tie rod key in the keyway and rotation of the gage pin over the bolt head were both required to permit full rotation of the gage plate. This allowed alignment of the grappling keyways and permitted installation of the lifting grapple. These interlocks, in conjunction with visual aids, prevented lifting of the module unless the top stabilization clamp was properly installed. After the gage plate was rotated through a 15-degree angle to align the grapple keyways, the tool guide and lock plate which contained a 3-inch diameter disk was rotated from the open position and inserted into the center of the grappling cavity. This retained the gage plate in the locked position during handling operations.

After installation of the stabilization clamps, the module was transferred to the rod pull station using the vertical fuel lifting grapple. The bottom of the module was aligned in the rod pull station by a 2.980-inch diameter pin which fit into a 3.000-inch diameter hole in the bottom of the stabilization clamp. The top of the module and the tie rods and sleeves were supported using clamping arms in the rod pull station. The top stabilization clamp was removed for rod pull and later reinstalled after rod removal was completed.

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