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TMI-2 REACTOR VESSEL PLENUM FINAL LIFT

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ABSTRACT

Removal of the plenum assembly from the TMI-2 reactor vessel was necessary to gain access to the core region for defueling. The plenum was lifted from the reactor vessel by the polar crane using three specially designed pendant assemblies. It was then transferred in air to the flooded deep end of the refueling canal and lowered onto a storage stand where it will remain throughout the defueling effort. The lift and transfer were successfully accomplished on May 15, 1985 in just under three hours by a lift team located in a shielded area within the reactor building. The success of the program is attributed to extensive mockup and training activities plus thorough preparations to address potential problems.

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TMI-2 REACTOR VESSEL PLENUM FINAL LIFT REPORT

BACKGROUND

The plenum assembly was located within the reactor vessel directly above the reactor core. Removal of the plenum assembly was necessary to gain access to the core region for defueling. The plenum assembly consists of a plenum cover assembly, a grid rib section, control rod guide assemblies, and a flanged plenum cylinder connected to the plenum cover plate flange and the upper grid (see Figure 1). An important programmatic assumption was that the plenum assembly could be removed intact using the polar crane and the existing tripod. Plenum inspection, endfitting separation, and plenum initial lift (jacking) were performed to assess the condition of and prepare for the removal of the plenum assembly. A video system of cameras on long poles was used to inspect potential plenum removal interference points. Inspection results indicated that excessive binding due to thermal distortion or debris deposits did not exist. Damaged fuel assemblies known to be attached to the plenum were removed using long handled impact tools. This was necessary to prevent fuel or control materials from being lifted with the plenum during final lift and storage. The plenum was lifted to a height of 7.25 inches using hydraulic jacks as a means to have a controlled initial lift. The results of the initial lift indicated that there was no serious binding that would prevent the use of the polar crane for final lift and storage of the plenum assembly.

During normal operations, the plenum assembly is lifted from the reactor vessel by its lifting lugs and transferred to its storage stand in the dry (no water shielding) refueling canal. However, the March 28, 1979 accident may have caused damage to the plenum assembly and a different approach to the final lift and transfer of the plenum assembly was developed.

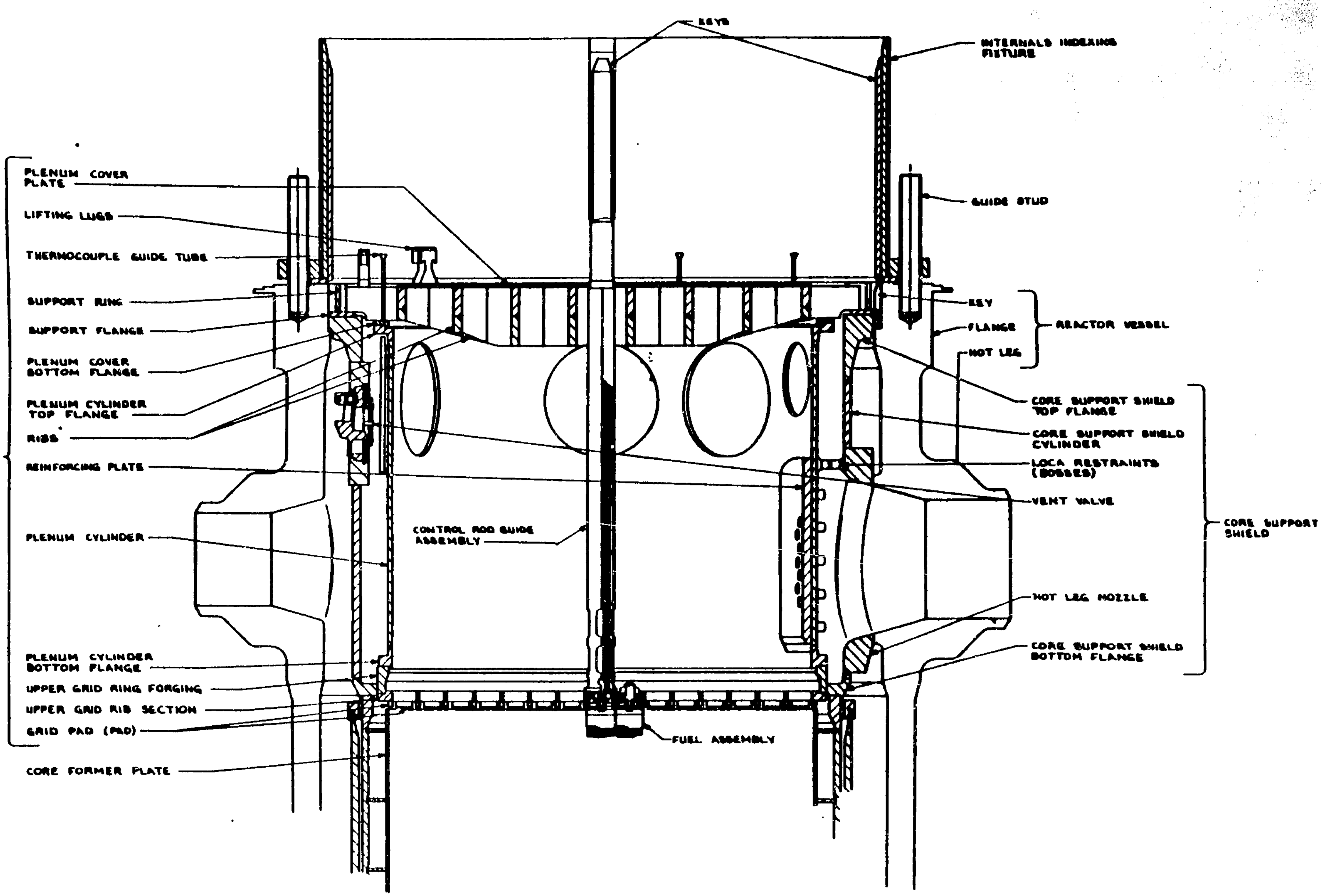


Figure 1 Upper Reactor Internals Nomenclature

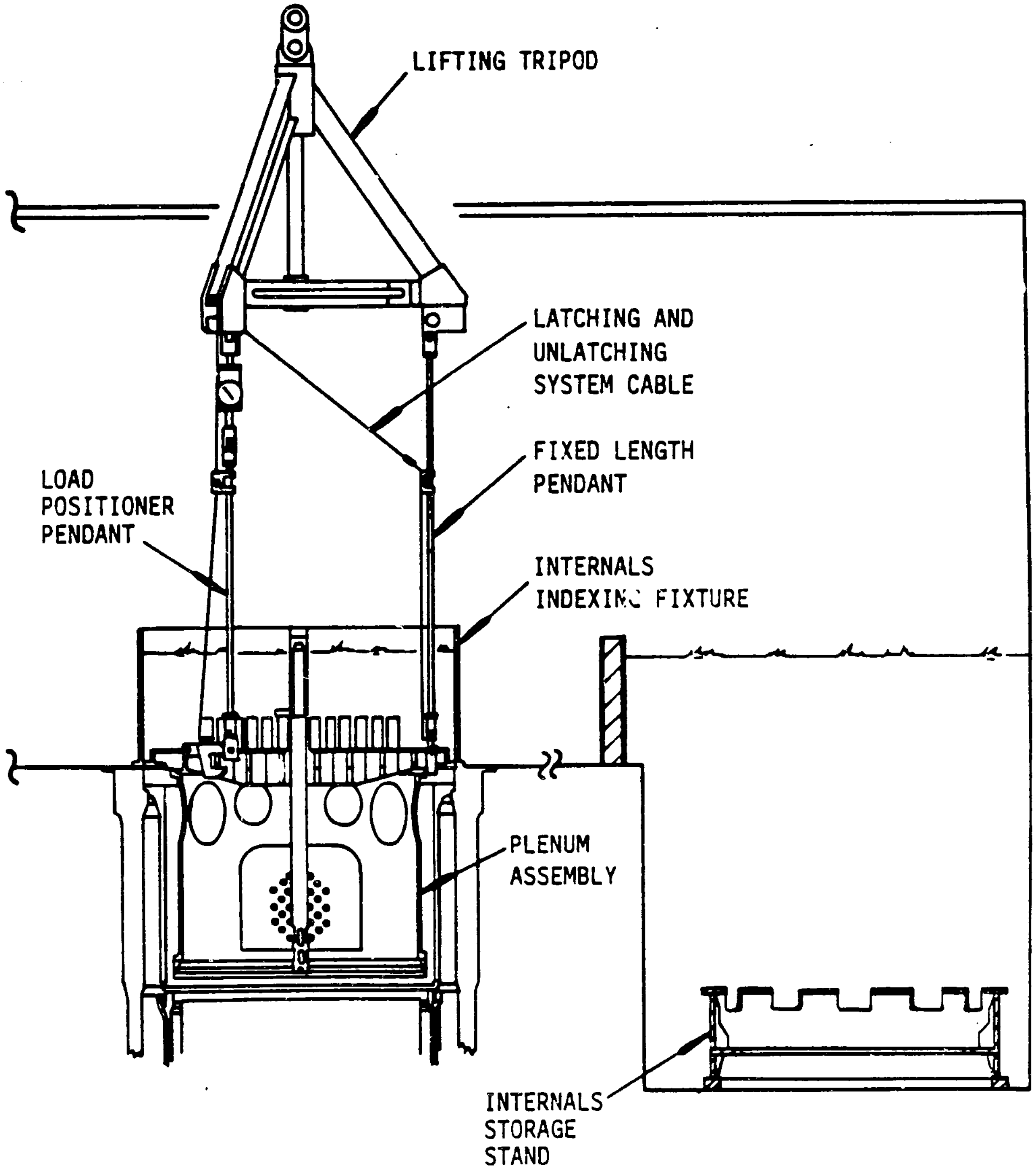


Figure 2 Plenum Lift General Arrangement

Three new pendant assemblies were designed and fabricated. Each pendant had a lift arm at the lower end of the assembly that engaged the plenum cover ribs and lifted the plenum from below these ribs. One pendant assembly was of fixed length and the other two were adjustable through the use of hydraulic devices (load positioners) that enabled load leveling while lifting.

A shielded lift station was established on top of the "A" D-ring from which a lift control supervisor controlled and monitored the lift. Also within the lift station were the two load positioner operators, the polar crane operator, and a radiation control technician. To provide underwater storage for the radioactive plenum assembly, a dam was designed and installed in the refueling canal between the reactor vessel and the deep end of the canal. The deep end could then be flooded to a level comparable to that existing in the internals indexing fixture (IIF). The plenum was lifted vertically until it was free of the reactor vessel, it was then transferred north to the deep end of the refueling canal and lowered onto its storage stand where it will remain throughout the defueling effort (see Figure 2).

Description of Equipment

The plenum assembly lift and transfer was accomplished using a mixture of specially designed and existing tools and equipment. The following is a brief description of the major equipment used for the lift and transfer operations.

Polar Crane

The reactor building polar crane was used to lift and transfer the plenum assembly. The polar crane was subjected to a post-accident refurbishment and load test program that certified the crane to a rated capacity of 170 tons (the load test was performed in March 1984). The 170 ton rating (well below the design rating of 500 tons) was chosen because it was sufficient to lift the reactor vessel head, which is assumed to be the heaviest lift of the recovery effort. The polar crane has been in continuous use since the refurbishment and is the subject of a rigorous maintenance program.

The hoist speed of the polar crane was approximately 4 inches per minute in slow speed and approximately 3.2 feet per minute in fast speed (the crane was used in slow speed throughout the lift). The crane trolley travel was approximately 6 inches per minute in slow speed and approximately 25 feet per minute in fast speed (the trolley was used in slow speed throughout the lift). The crane bridge function was only used for initial target alignment and was not used during the actual lift. The polar crane was operated via pendant controls by an operator located in the shielded lift control station on the "A" D-ring and taking direction from the lift control supervisor.

Dillon Load Cell

The weight of the plenum assembly was thought to be approximately 50 tons submerged and 57 tons in air. The specially designed plenum assembly lift rigging (three pendant assemblies, two with load positioners) had a total rated capacity of 75 tons and individual pendant assembly capacities of 25 tons. During the initial stages of the plenum lift there was a potential for binding between the plenum assembly and the reactor vessel internals. This binding could cause the loading of the plenum lift rigging to exceed the rated capacity. A 200 ton capacity Dillon load cell was used in the rigging between the polar crane main hook and the tripod to monitor the total load. The Dillon load cell was also used in conjunction with the load positioner readouts to monitor individual pendant assembly loads. The remote load readout for the Dillon load cell was located in the shielded lift control station and monitored by the lift control supervisor during lift and transfer operations.

Tripod

The head and internals handling fixture assembly (tripod) had been used successfully during headlift operations. For the plenum assembly lift, the tripod was attached to the Dillon load cell below the polar crane main hook. The tripod acted as a spreader, which provided three lifting points, for attaching the pendant assemblies. Adapter plates were used to position the three pendant assemblies on the appropriate radius for proper engagement with the plenum cover ribs.

Lift Pendants

The plenum assembly was lifted from the reactor vessel using a system of three specially designed and fabricated lift pendants (see Figure 3). The pendants had an overall length of approximately 17 feet. One pendant was of fixed length and the other two were adjustable (± 6 inches) by use of load positioners attached to the pendants. The pendant rods were made of 2-3/4 inch diameter stainless steel bars and had a load rating of 25 tons each. The three pendant assemblies engaged the plenum 120° apart at a radius of 71-1/2 inches from the centerline of the plenum assembly (see Figure 4).

The lower end of the pendants consisted of a transfer block and a lifting arm. These assemblies were connected together with 2-1/8 inch diameter pins. This pin arrangement precluded bending moments from being transferred to the pendant rods. The pendant lifting arms engaged and lifted the plenum assembly from below three of the plenum cover assembly ribs. Rotational twist of the lift rib due to the off-set lift arm arrangement was prevented by opposing the reaction forces of the lift arm with the adjacent rib. The lifting arms were held in position by the latching and unlatching system. After the lifting arms were in position, the pull rod for each pendant was pulled and the arm automatically locked under the ribs. When the pendant was slightly raised, the pull rod was repositioned preventing disengagement of the lifting arm assembly. After the transfer, the pull rod was repositioned again allowing the lifting arm to be disengaged from the plenum ribs (see Figure 5).

Hydra-Sets

Model ES Hydra-Sets were used as load-leveling positioners in two of the three pendant assemblies (see Figure 6). Hydra-Sets are pneumatically (nitrogen) operated self-contained hydraulic actuators (hydraulic fluid was Houghto-Safe 620). The Hydra-Sets (512 pounds each) were rigged between the lift pendants and the tripod, providing the ability for travel adjustment of up to 12 inches (± 6 inches) with an accuracy of 0.001 inch. Each Hydra-Set had a capacity of 25 tons (with a 5:1 safety factor) and had gauge accuracy of 1/2 of 1% of scale (± 10 pounds). The Hydra-Sets were remotely operated from the

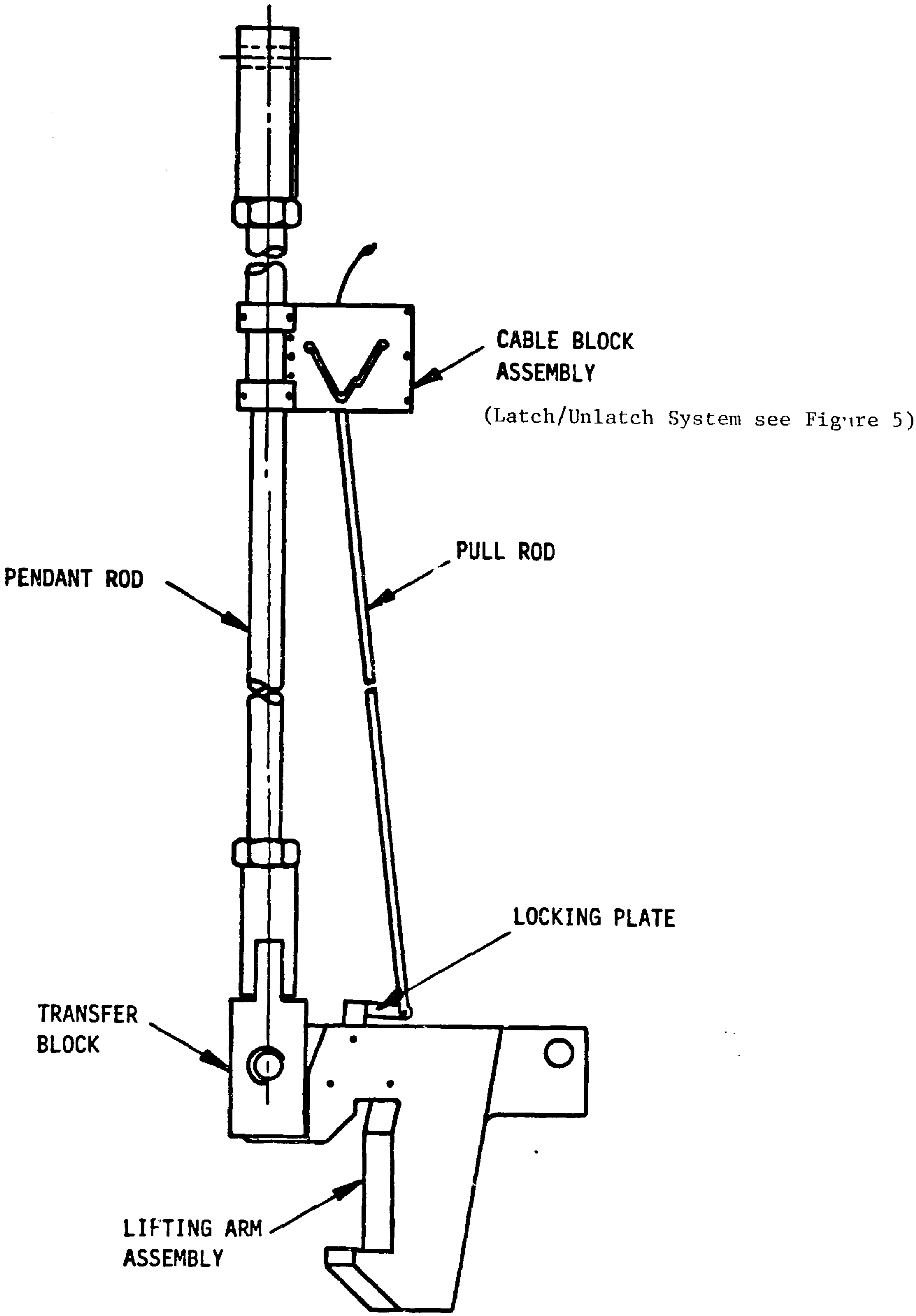


Figure 3 Pendant Assembly

PLENUM ASSEMBLY
ACCESS AREAS & CORE MAP

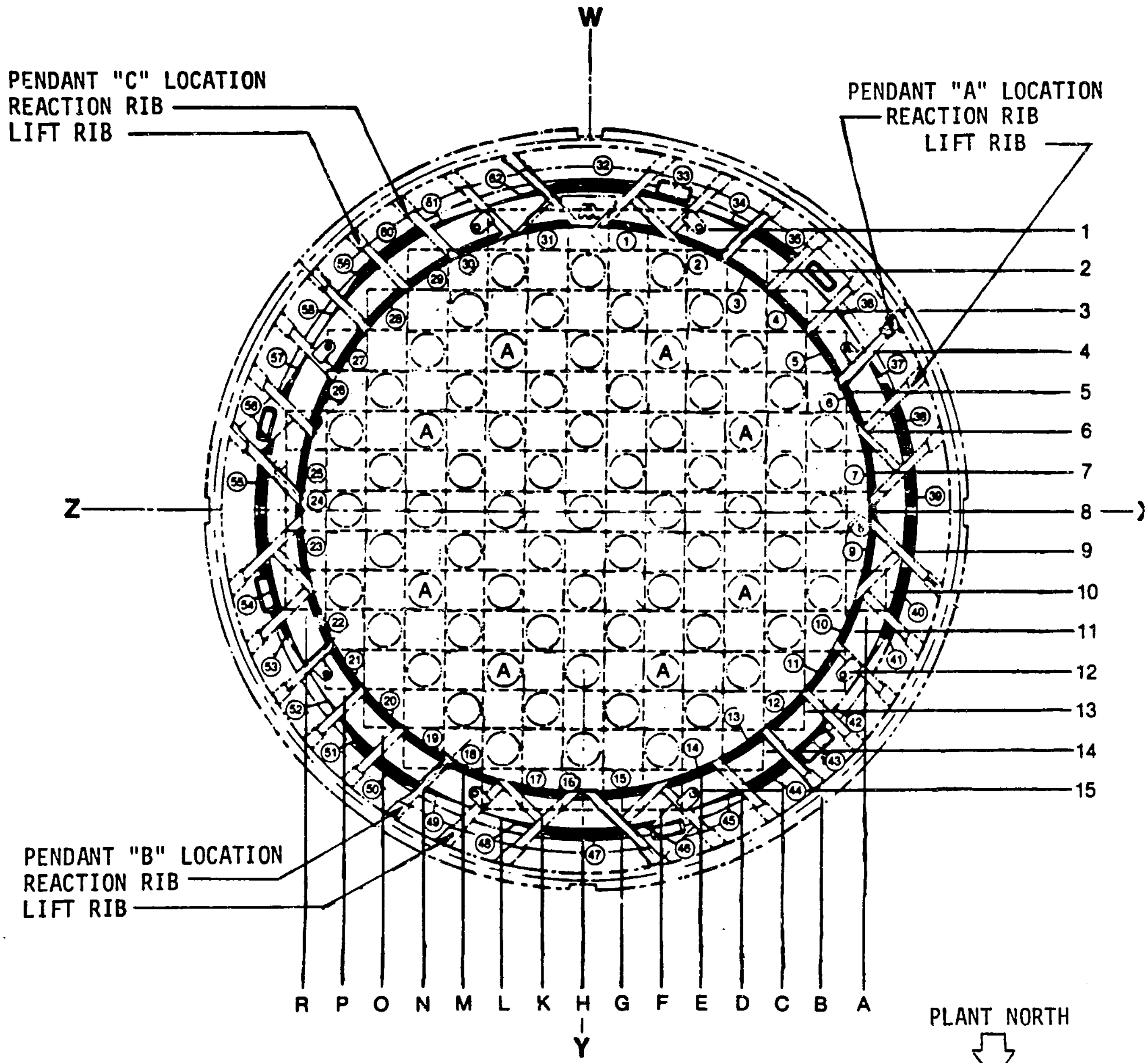


Figure 4 Pendant Locations

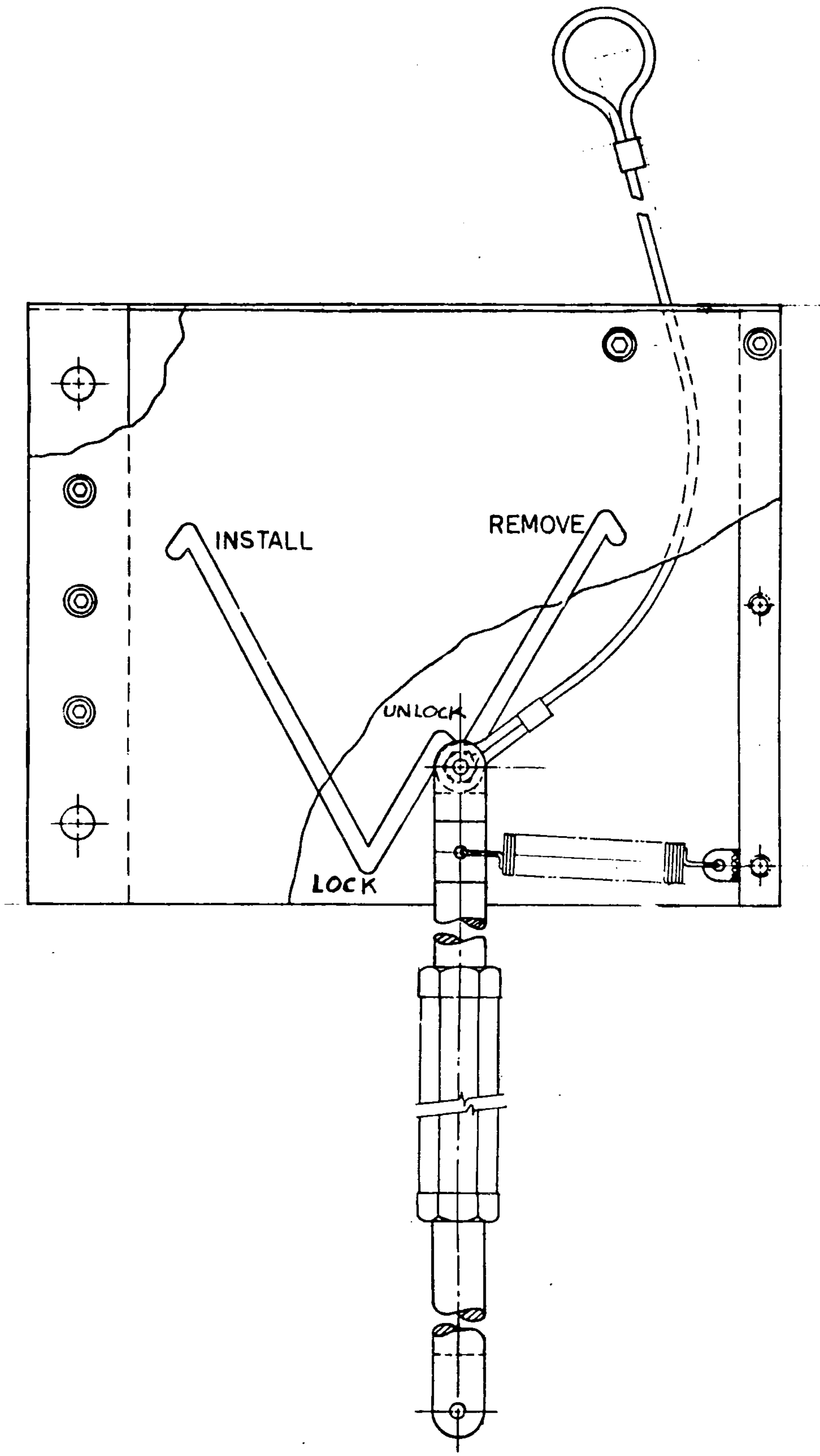


Figure 5 Pendant Latch/Unlatch System

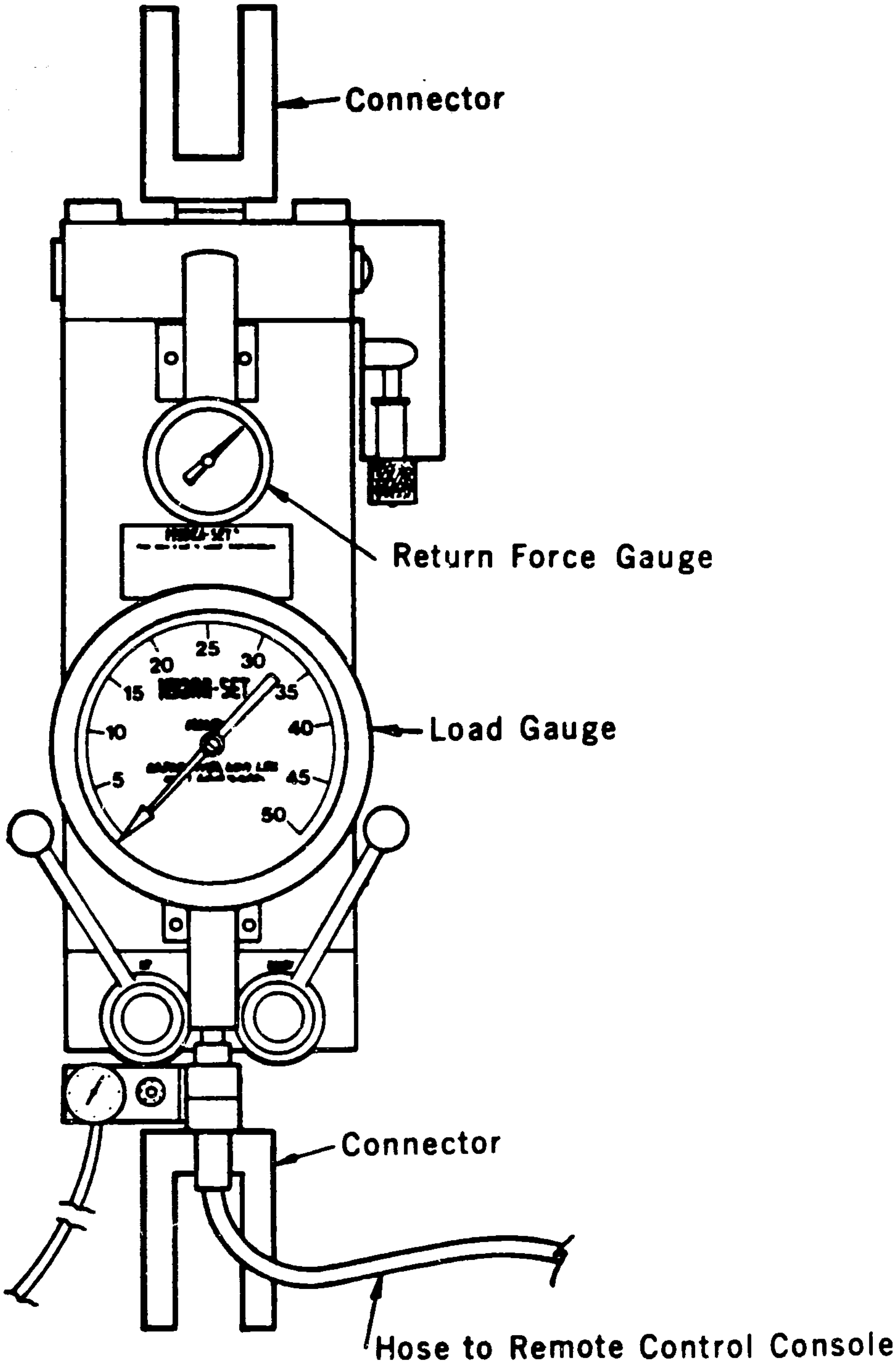


Figure 6 Model ES Hydra-Set

shielded lift control station located on the "A" D-ring. The Hydra-Set remote control consoles were self contained systems for storing, metering, and regulating the nitrogen gas used to control the Hydra-Sets (see Figure 7). Also available in the shielded lift control station were the remote digital displays for the Hydra-Set load and linear travel.

The primary use of the Hydra-Sets was to maintain the level position of the plenum assembly during the initial phase of the lift. The Hydra-Sets were used in conjunction with a bubble level (see Bubble Level Section). Precise level control was necessary due to potential binding in the interface between the plenum assembly keyways and the reactor vessel or IIF keys. A plenum tilt of 15 minutes could cause binding with the reactor vessel keys and a plenum tilt of 45 minutes could cause binding with the IIF keys. The Hydra-Sets were also used to assist in the latching and unlatching of the lift arms by extending or retracting the pendants as necessary. The remote load readouts of each Hydra-Set were also used to monitor individual pendant loads during the lift and transfer.

Video System

The video system used to monitor and control the lift and transfer of the plenum assembly consisted of cameras at nine positions with back-up cameras provided at two of the positions (see Figure 8).

Camera Number 1A & 1B (Plenum Elevation Cameras). There were two plenum elevation cameras (one primary and one back-up) located within the refueling canal, at each side, just south of the canal dam. The cameras were installed at elevation 329'-6", which is approximately 1 inch above the lowest clear transfer height for the bottom of the plenum assembly.

Plenum elevation cameras were used to:

- Monitor the plenum elevation gauges during the initial phase of the lift (see Elevation Gauges Section).

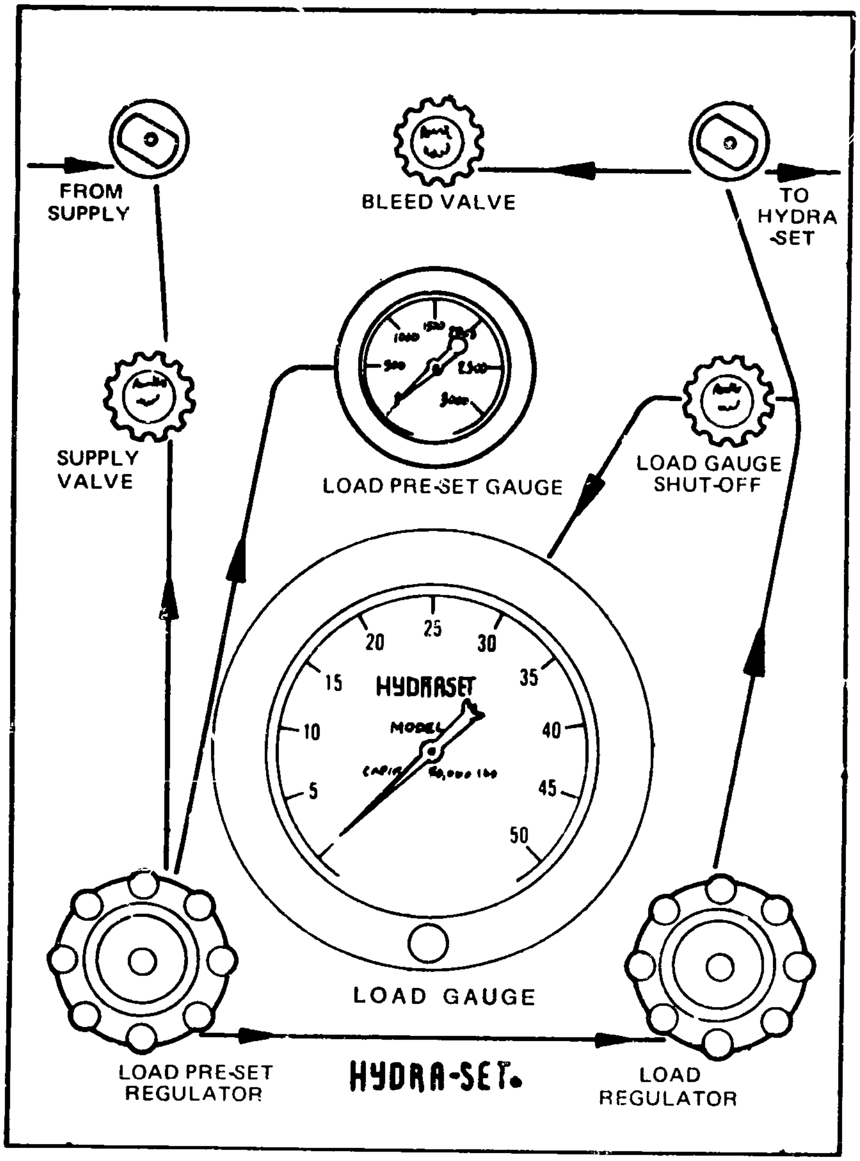
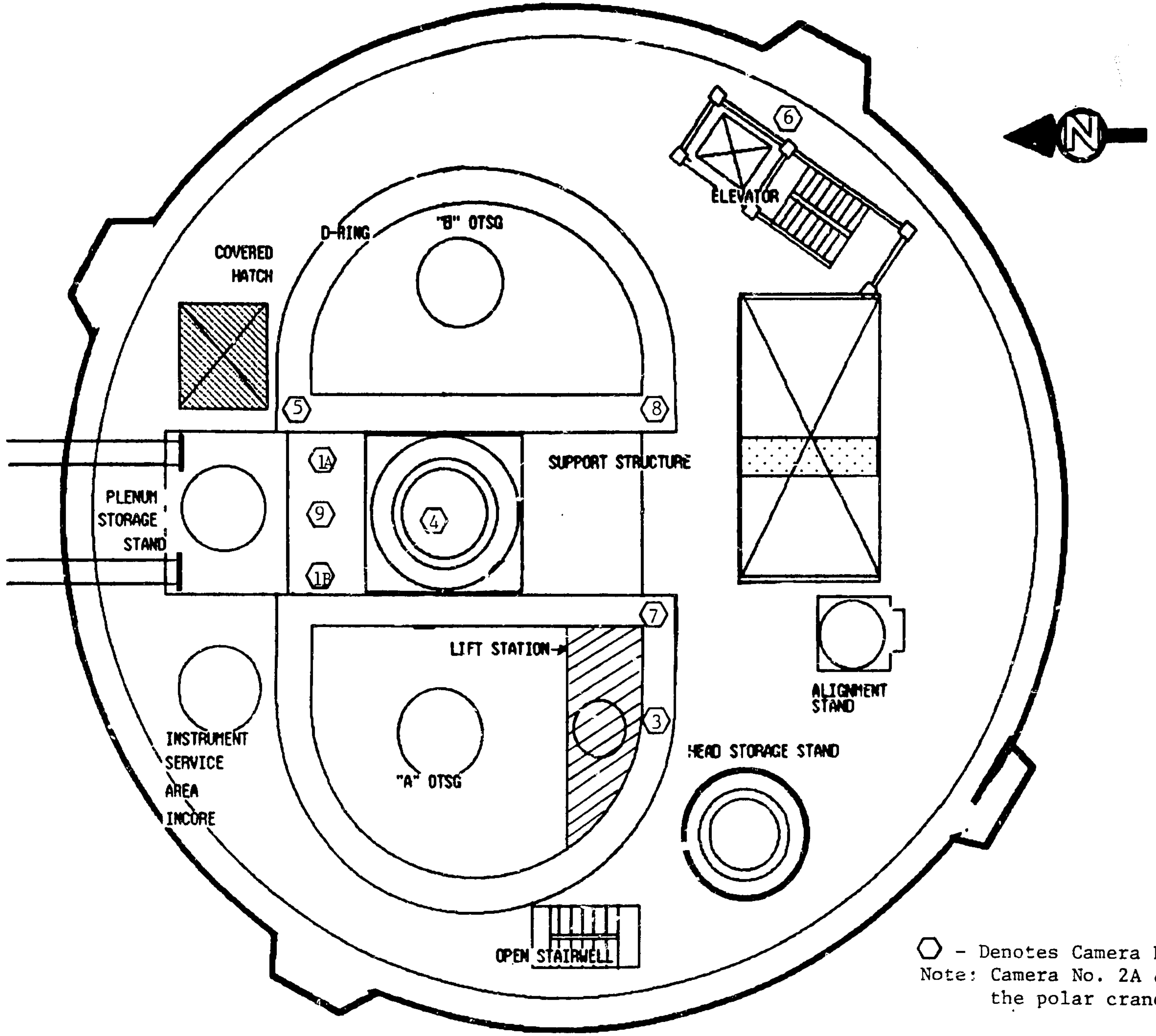


Figure 7 Hydra-Set Remote Control Console



⬡ - Denotes Camera Number & Location
Note: Camera No. 2A & 2B located on the polar crane trolley

Figure 8 Plenum Lift Video System

- Monitor the bottom of the plenum to determine that a clear transfer height had been reached.

- Monitor the maximum height gauges to assure that the maximum lift height had not been exceeded (see Maximum Height Gauges Section).

- Monitor the plenum elevation gauges during the final phase of the lift to determine the position of the plenum relative to the storage stand (based on the depth of the water covering the plenum).

The plenum elevation cameras were monitored and controlled by the lift control supervisor in the shielded lift control station. The cameras had remote pan, tilt, zoom, and focus controls.

The signals from these cameras were also sent to the coordination center.

Cameras 2A & 2B (Polar Crane Target Cameras). There were two polar crane target cameras (one primary and one back-up) located on the polar crane trolley.

The polar crane target cameras were used to monitor targets for polar crane alignments. The targets were used to position the polar crane trolley relative to the crane bridge, and the bridge relative to the reactor building wall. The targets were positioned such that the crane could be centered over the reactor vessel centerline at the start of the lift and over the storage stand centerline to complete the transfer.

The polar crane target cameras were monitored by the lift control supervisor in the shielded lift control station. Either camera could be monitored in the coordination center. The video output line had to be manually changed by the lift control supervisor to send the alternate camera signal to the coordination center. The cameras had remote pan, tilt, zoom, and focus controls and could be controlled from either the shielded lift control station or the coordination center at the discretion of the lift control supervisor (the coordination center control was chosen).

Camera 3 (Lift Station Monitor Camera). The lift station monitor camera was located in the shielded lift control station at elevation 377'.

The lift station monitor camera, which had remote zoom and focus controls was monitored only in the coordination center. The camera was intended to give the lift control supervisor the ability to request back-up support from the coordination center by manually positioning the camera to monitor instruments, equipment, gauges, or activities within the lift control station. The camera was set-up for monitoring radiation detection instruments at the start of the lift and was not used for back-up support by the lift control supervisor.

Camera 4 (Bubble Level Monitor Camera). The bubble level monitor camera was located underwater in the bubble level fixture installed in the plenum assembly control rod guide tube at position C-7 (see Figures 4 & 9).

The bubble level camera monitored the bubble level, which was used to detect plenum assembly tilting (see Bubble Level Section).

The bubble level camera was monitored and controlled in the shielded lift control station by the lift control supervisor. The video signal could also be sent to the coordination center. The camera had remote zoom, focus; light, and iris controls in the shielded lift control station.

Camera 5, 6, 7 & 8 (General Area Cameras). Four of the reactor building closed circuit television system cameras were used for monitoring the plenum assembly lift and transfer. All of these cameras were monitored and controlled from the coordination center only. All had remote pan, tilt, focus, and zoom control in the coordination center. The coordination center personnel used these cameras primarily to look for problems or potential problems with the rigging and the cable management system.

Camera five was located on the handrail at the north end of the control rod drive mechanism (CRDM) cable tray catwalk at approximately elevation 360'.

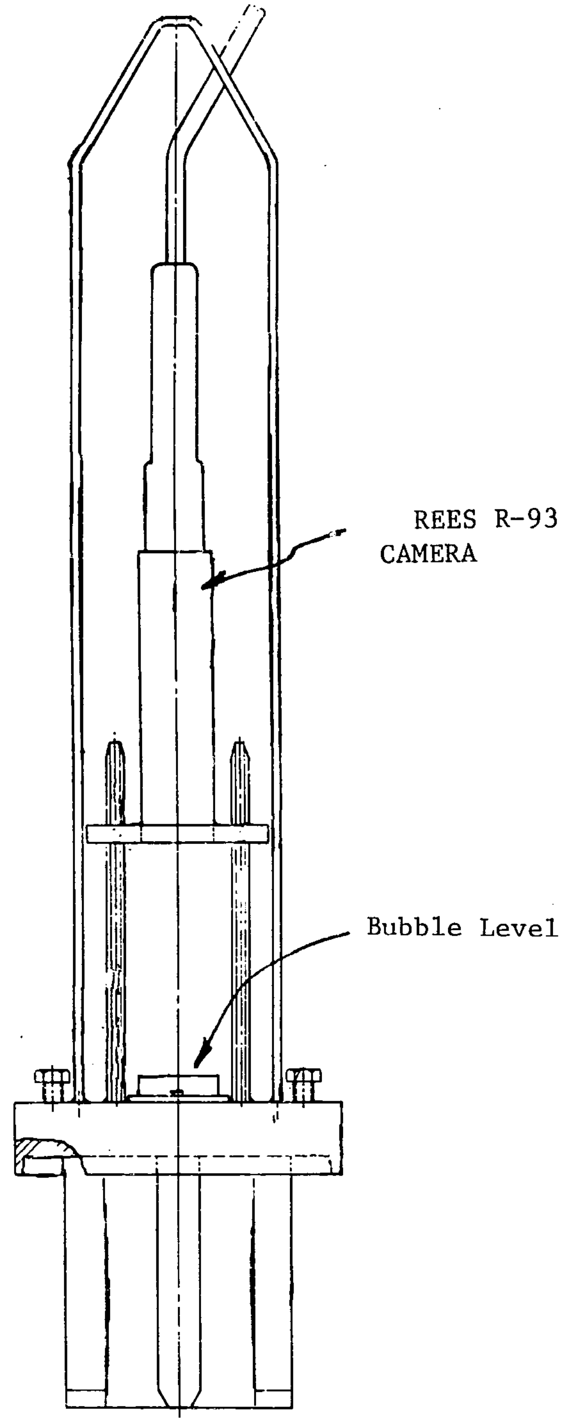


Figure 9 Bubble Level Fixture

Camera six was located on the polar crane access ladder above the elevator at approximately elevation 392'. This camera was also used to monitor the Dillon load cell readout in the lift control station.

Camera seven was located on the handrail of the "A" D-ring just outside the shielded lift control station at approximately elevation 371'.

Camera eight was located on the handrail at the south end of the CRDM cable tray catwalk at approximately elevation 360'.

Camera 9 (Bottom of Plenum Camera). The bottom of plenum camera was located on the refueling canal floor south of the canal dam on the north-south centerline of the reactor vessel at approximately elevation 323'.

The bottom of plenum camera was used to record the damage caused by the March 28, 1979 accident to the underside (upper grid ribs) of the plenum assembly (see Appendix A).

The bottom of plenum camera was monitored and controlled by the lift control supervisor in the shielded lift control station. The camera had remote pan, tilt, zoom, focus, and auxiliary light controls. The camera signal was sent to the coordination center for video recording.

Audio System

The audio communications between members of the lift team and and the coordination center was handled by the earmark duplex portable base repeater station. This system included head sets with throat microphones that transmitted clear and uninterrupted voice communications.

Elevation Gauges

Two elevation gauges (one primary and one back-up) were used to monitor plenum assembly height during lift and transfer operations (see Figure 10). The gauges were installed in control rod guide tubes on the plenum cover assembly at locations E-13 and P-8 (see Figure 4). The gauges traveled with the plenum assembly during the lift and transfer. A laser beam projected onto the elevation gauges gave a direct reading of the plenum assembly lift height during the initial phase of the lift (see Lasers Section). This was accomplished by indexing the beams to the gauges at the 7-1/4 inch mark of the gauge for the start of the lift. This corresponded to the amount the plenum had been lifted by the four plenum jacks. The projected beam was monitored by the lift control supervisor and the coordination center on the plenum elevation cameras.

As the plenum assembly was being lifted out of the reactor vessel, there were many points of potential interference between the plenum assembly and the core support assembly. A table of potential interference points and corresponding lift heights (as read on the elevation gauges) was available to the lift control supervisor to resolve interferences encountered during the initial phase of the lift (see Appendix B).

Another table of plenum assembly heights, relative to the storage stand in the deep end of the refueling canal, was available to the lift control supervisor for the final phase of the lift (see Appendix C). This table could be used in conjunction with the laser beam as read on the elevation gauges, or the water level in the deep end of the refueling canal as read on the elevation gauges.

Maximum Height Gauges

Two maximum height gauges (one primary and one backup) were used to assure that the maximum allowable lift height was not exceeded (see Figure 11). The maximum lift height as specified by the Safety Evaluation Report was elevation 333' 11-3/4". This was approximately 4 feet above the anticipated lift height. The maximum lift height gauges were installed on the defueling support structure and positioned on the east-west centerline of the reactor vessel. The lift control supervisor could compare the height of the bottom of the plenum with the maximum height gauge by using the plenum elevation cameras.

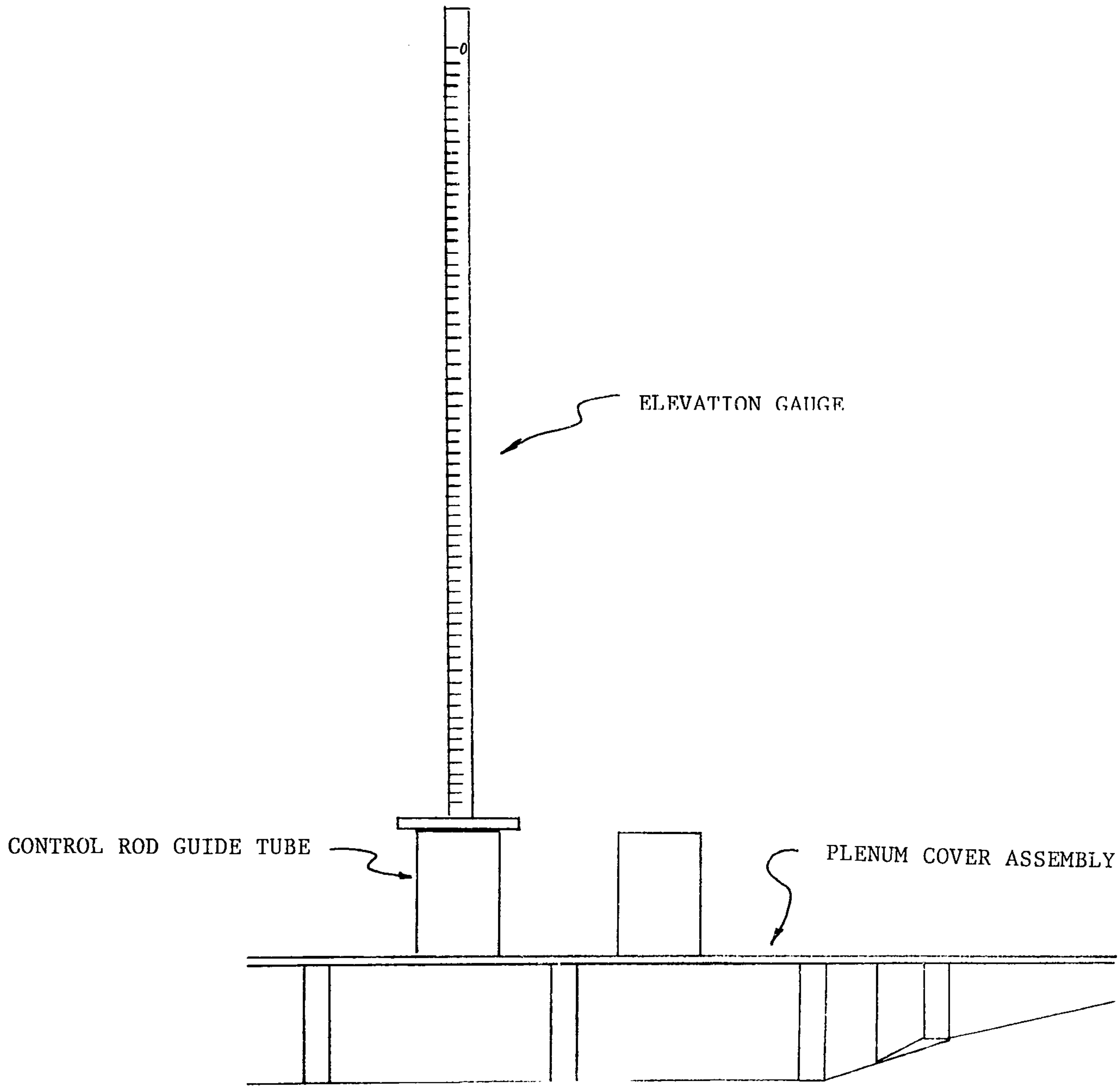


Figure 10 Elevation Gauge

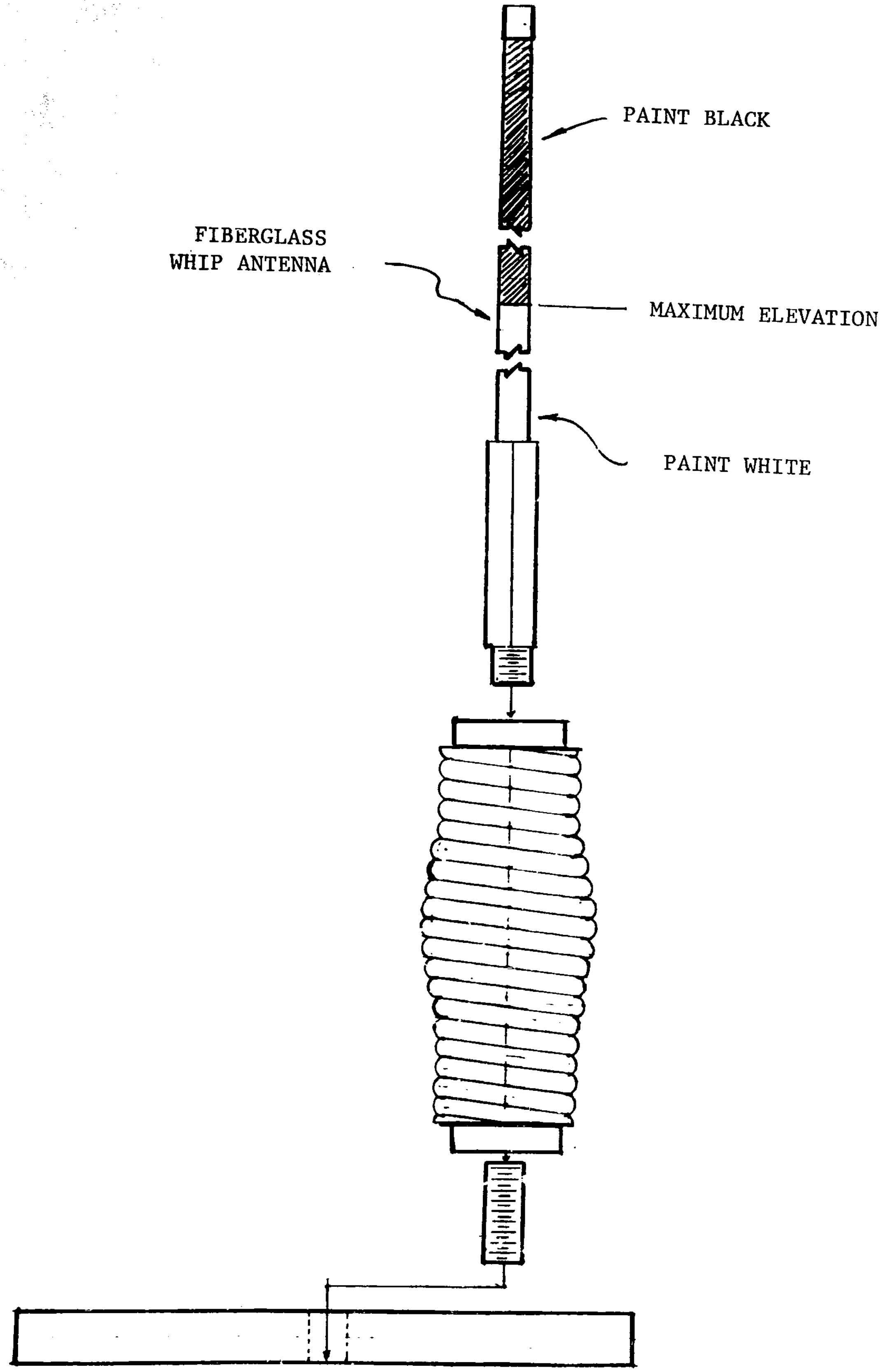


Figure 11 Maximum Height Gauge

Lasers

Two Spectron-Physics Model 910 Laser Levels were used in conjunction with the plenum elevation gauges to monitor the height of the plenum assembly during lift and transfer operations. The lasers were located within the refueling canal, at each side, just south of the canal dam. The lasers, utilizing a spinning optical penta prism, projected a 1/4 inch diameter laser beam onto the plenum elevation gauges. Prior to the start of the lift operation the lasers were adjusted vertically such that the laser beam was projected onto the elevation gauge at the 7-1/4 inch mark. This corresponded to the 7-1/4 inches that the plenum had been lifted by the four plenum jacks. The projected beam was monitored by plenum elevation cameras 1A and 1B. Only one laser at a time was used during the lift (the second laser served as a back-up). Both lasers were controlled by the lift control supervisor from within the shielded lift control station.

Bubble Level

Precise level control of the plenum assembly during the initial phase of the lift was necessary due to potential binding in interface between the plenum assembly keyways and the reactor vessel or IIF keys. A plenum tilt of 15 minutes could cause binding with the reactor vessel keys and a plenum tilt of 45 minutes could cause binding with the IIF keys.

Controlling and monitoring the plenum assembly levelness during the final phase of the transfer operation was necessary to assure that the plenum was properly positioned and seated within the storage stand located in the deep end of the refueling canal.

A bull's eye bubble level was used to provide direct measurement of plenum assembly levelness during lift and transfer operations (see Figure 9). The bubble level was used with the Hydra-Sets to maintain the level position of the plenum assembly. The bubble level sensitivity was such that a plenum assembly tilt of 5 minutes could be detected.

The bubble level was mounted in a fixture and installed underwater in the control rod guide tube at position C-7 of the plenum cover assembly (see Figure 4). The fixture also supported an underwater video camera that viewed the bubble level and was monitored by the lift control supervisor. The bubble level and video camera traveled with the plenum during the lift and transfer operations.

The bubble level indicated both direction and magnitude of any plenum assembly tilting during the lift and transfer operations. This in conjunction with the elevation gauges and/or Hydra-Set readouts, the listing of potential interferences (see Appendix B), the table of heights relative to the storage stand (see Appendix C), and other information, could be used by the lift control supervisor to make appropriate adjustments in the lift.

Pendant Installation Platforms

Special lightweight easily maneuverable platforms were used to assist in the installation of equipment associated with the plenum lift and transfer. The platforms were used on top of the defueling support structure and could be clamped in position to span across the open vessel providing direct access for the following activities:

- Latching the pendant assemblies to the plenum ribs.
- Video verification of pendant latching.
- Installation of plenum elevation gauges.
- Installation of the bubble level.

The pendant installation platforms could also be used by the lift team during the lift. The platforms were light enough to be positioned without the use of a crane and could therefore be used in the very early stages of the lift to gain access to the plenum assembly and the core support assembly to overcome binding (see Alignment Tool Section).

Cable Management System

Particular attention was required to prevent damage to cables that traveled with the plenum assembly during the lift and transfer operations. These were the cables routed from the shielded lift control station to the plenum assembly and its rigging. The cables involved were as follows:

- the Dillon load cell remote read out cable
- remote pneumatic control cables for each Hydra-Set
- remote load and position readout cables for each Hydra-Set
- the bubble level camera remote video cable.

The method chosen to manage these cables was to bundle them together and handle them as one cable. This cable bundle was then festooned with pulleys on a wire rope strung south to north along the upper east face of the "A" D-ring. This cable management system was operated by two control lines from within the shielded lift control station. The control lines could pull the cable bundle either north or south along the wire rope as required.

PREPARATIONS

Preparations for plenum lift and transfer essentially began with the removal of the reactor vessel head. Major preparatory activities included: in-vessel inspections of the plenum, separation of end fittings from the bottom of the plenum, and the initial lifting of the plenum by a system of four hydraulic jacks. These preparatory activities are discussed in other reports. Preparations covered by this report include those activities taking place after plenum jacking.

Preparations included many tasks categorized in the following general areas.

- Preparation of software - including procedures, technical evaluation reports (TERs), safety evaluation reports (SERs), and unit work instructions (UWIs). The bibliography of this report contains a listing of the major software items involved with plenum lift.

- Preparation of hardware - including plant modifications, new equipment installations, and functional checkouts of special lift equipment.

- Preparation of the plenum - including cleaning, securing the plenum jacks, and additional inspections related to the installation of lift and transfer equipment.

- Mock-ups and personnel training.

- Readiness reviews - conducted by an appointed readiness review committee. The committee met with TMI-2 staff on two occasions to review plenum lift plans and to assess the status of preparations.

The following sections provide brief discussions of the major hardware and training preparatory activities.

Equipment Checkouts

The plenum assembly lift system checkout program was developed to check the ability of the three pendant assemblies to operate as a coordinated system. The checkout was accomplished in three phases.

- Equipment load testing.
- Equipment functional tests.
- System functional checkout.

The Hydra-Sets and pendant assemblies were load tested by the manufacturer before being sent to TMI.

Each pendant assembly was tested functionally by the manufacturer prior to being sent to TMI. The test utilized a heavy steel weldment that simulated the three unique lifting pendant attachment points on the plenum assembly. The manufacturer used as-built data gathered during inspections on the plenum lift ribs for the test. The test resulted in the removal of spacer plates from the pendant assembly lift arms (see Inspect Plenum Lift Ribs Section).

The system functional checkout was conducted at the TMI site. This checkout was performed under conditions that closely simulated the actual interfacing conditions that the equipment would experience during lift and transfer operations. A three point lift frame, a mock-up tripod, and the Hydra-Sets were used to perform functional checks on the pendant assemblies as an integrated system.

Problems identified during the on-site checkout resulted in the following equipment modifications.

- Larger washers were installed in the latch/unlatch system.
- The reaction area thickness of the "A" pendant lifting arm was reduced.

- The pull cables on the latch/unlatch systems were lengthened.

- The "B" pendant latch assembly was modified to avoid interference with the thermocouple bracket weld on the plenum cover assembly.

- The upper lock nut on the fixed length pendant was loosened to provide some rotational freedom (variable length pendants have rotational freedom) to enhance latching and unlatching operations.

Mock-Ups

An extensive program of mock-ups was developed to provide training for plenum assembly lift and transfer operations. The mock-ups provided for the simulation of operations and interfaces important to the successful lift and transfer of the plenum assembly.

The following configurations were simulated during the mock-ups.

- The lift control station was simulated with relative physical orientations, remote video monitors, Hydra-Set controls, remote audio, and an enclosure blind.

- The defueling support structure and its elevation relative to the plenum cover ribs was simulated.

- The elevation difference between the plenum in the storage stand and elevation 347'-6" was simulated.

- The D-ring height and canal width were simulated.

The criteria used to establish mock-ups was as follows:

- Mock-ups used the actual lift and transfer equipment when possible.

- Mock-ups duplicated all important equipment interfaces.

- Mock-ups duplicated actual conditions and configurations as much as practical.

- Mock-ups provided the ability to simulate upset conditions.

- Mock-ups provided the ability to develop and test contingency plans.

The mock-ups were located in the turbine building and provided a means to train personnel on individual equipment and as members of a lift team in simulated lift and transfer operations. The following sections describe the mock-up equipment used for training.

Three Point Lift Frame

The plenum cover assembly was simulated by a structural frame loaded with approximately 10,000 pounds of weight (see Figure 12). This mock-up was used to checkout equipment and to train personnel involved in the plenum assembly lift and transfer.

Plenum assembly interfaces that were important to equipment checkouts or personnel training were simulated on the structural frame as follows:

o Keyways were simulated at four axes positions to interface with keys on the IIF mock-up (see IIF Mock-Up Section).

o Lift and reaction ribs were simulated at three locations 120° apart to interface with the pendant assembly lift arms.

o Control rod guide tubes were simulated to interface with the bubble level and the two plenum elevation gauges.

IIF Mock-Up

A metal cylinder approximately 14 feet in diameter and 6 feet high was used to simulate the IIF installed in the reactor building. Keys were installed on the cylinder to simulate the IIF keys. The IIF mock-up was used for the training of personnel and interfaced with the three point lift frame.

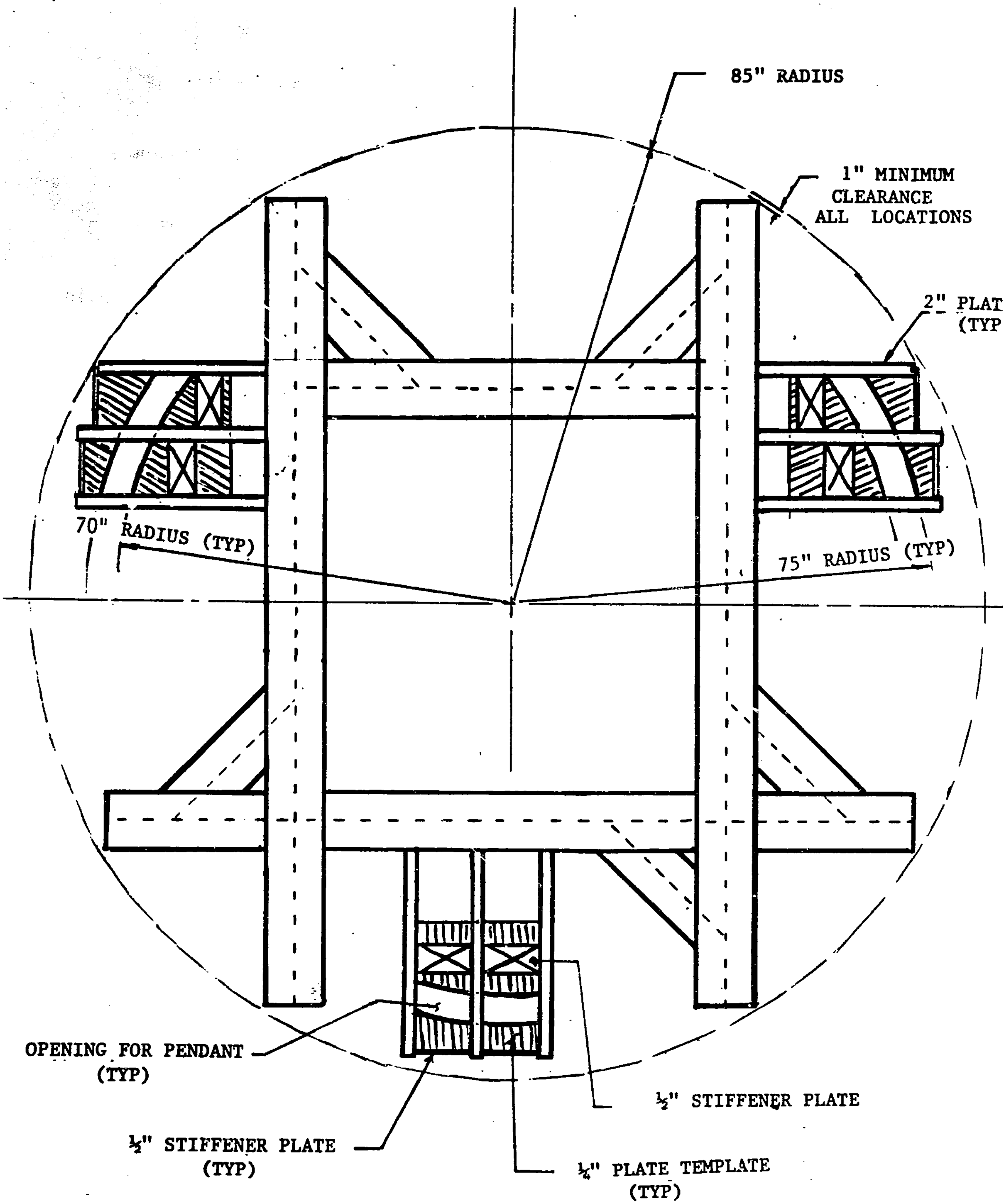


Figure 12 **Three Point Lift Frame**

Tripod Mock-Up

A triangular structural frame was used to simulate the tripod in the reactor building. The interface between the tripod and the pendant assemblies was simulated. The frame was suspended from the turbine building crane with three wire ropes. The actual pendant assemblies and Hydra-Sets were suspended from the tripod mock-up. The mock-up was used in both the checkout of equipment and training of personnel.

Bubble Level Mock-Up

A mock-up was fabricated to simulate the bubble level that remained in the reactor building after its use in plenum jacking (see Figure 9). The mock-up interfaced with a camera and a simulated control rod guide tube on the three point lift frame. The bubble level mock-up was used in the training of personnel.

Actual Lift Equipment

Some equipment used in the actual lift and transfer of the plenum assembly was first used as mock-up equipment for the training of personnel. Essentially, if actual equipment was available, it was used in training mock-ups. The following is a list of actual lift equipment used in mock-ups. (For detailed descriptions of equipment see Description of Equipment Section).

- Hydra-Sets
- Pendant assemblies
- Elevation gauges
- Maximum height gauges
- Lasers
- Pendant installation platforms and defueling work platform support structure

- Cameras 1A, 1B, 4 and 9

- Audio system.

Training

A total of six lift control supervisors and lift teams were trained for plenum assembly lift and transfer operations. This provided the ability for continuous around the clock operations, if necessary. The training program consisted of the following elements:

- Training for the installation of equipment.

- Training in the operation and use of equipment.

- Training in the conduct of lift operations.

- Training for upset conditions.

- Training for contingency operations.

The training program developed for the plenum assembly lift and transfer operations was conducted in three phases as follows:

- The first phase was classroom training. The training consisted of lectures, discussions, and handout literature that provided personnel with the basic theory of the equipment, instructions in the use and operation of the equipment, and appropriate limits and precautions.

- The second phase was a hands-on individual training on each piece of equipment. This training developed individual skills and proficiencies in equipment installation and operation.

- The third phase integrated the first and second phases of training into an operations training. This training was conducted with personnel performing as teams. The training consisted of full scale mock-ups and trial runs simulating actual lift and transfer operations. These training exercises were conducted by the lift control supervisors and included training for upset conditions and contingencies.

The following sections briefly describe the training program for the various equipment and how the equipment was integrated into the full scale training and trial runs.

Pendant Latching Training

The actual pendant assemblies were used in conjunction with the Hydra-Sets, the three point lift frame, video cameras, and long handled tools to train personnel in pendant assembly latching. The training progressed from single pendant latching to latching with all three pendants suspended from the tripod mock-up. During training, personnel worked from the pendant installation platforms on top of the defueling work platform support structure and latched the pendants to the three point lift frame located within the IIF mock-up.

Three important techniques were developed during the training period that contributed to the success of the actual pendant latching in the reactor building. The first technique was utilizing the Hydra-Sets to adjust the length of the variable pendants such that latching could progress one pendant at a time. The second technique was perfecting the use of remote video cameras to verify that the pendants were latched in the proper position. The third technique utilized long handle hook tools and pry bars to assist in the latching operation.

Hydra-Set Operation Training

The operation and control of the Hydra-Sets were crucial to plenum assembly lift and transfer operations. Operators were first trained in the use of a single Hydra-Set and then paired as two man teams to operate both Hydra-Sets in the three pendant lift configuration.

Lift and Level Training

The three point lift frame with the bubble level installed was used to train crews in lifting and leveling techniques. The three pendant assemblies were latched to the three point lift frame installed in the IIF mock-up. The lift team, composed of a crane operator, two Hydra-Set operators and a lift control supervisor, trained and worked as a team to lift and level the three point lift frame. By monitoring the bubble level and the remote level and position readouts of the two Hydra-Sets the crew was able to use the Hydra-Sets and the crane to lift and level the three point lift frame. Exercises were set up with eccentric loading on the frame or with the frame clamped to the IIF mock-up. The training was conducted blind (crews were not allowed to view the lift frame during the training exercises).

Bubble Level Installation Training

Training in the installation of the bubble level utilized the three point lift frame installed in the IIF mock-up. Personnel trained from the pendant installation platforms on top of the defueling work platform support structure. Installation techniques learned included the use of long handled hook tools and the proper orientation of the fixture within the simulated control rod guide tube to assure that the bubble level camera produced a picture with a known orientation.

Laser Installation Training

Laser levels were used in conjunction with elevation gauges and video cameras to monitor plenum assembly elevation during lift and transfer operations. Training for the installation of the lasers consisted of learning two main techniques. First, the laser was installed on a tripod and leveled. Second, the laser was adjusted vertically (while remaining level) to project the beam on the proper index mark of the plenum elevation gauges. This training was accomplished using the lasers in conjunction with elevation gauges installed on the three point lift frame.

Elevation Gauge Installation Training

The elevation gauges were used in conjunction with the laser levels and video cameras. Training in the installation of the elevation gauges used the three point lift frame installed in the IIF mock-up. Personnel trained from the pendant installation platforms on top of the defueling work platform support structure. Installation orientation was important because the laser beam must be visible to the plenum elevation cameras (i.e. gauge must reflect the beam toward the camera).

Maximum Height Gauge Installation Training

The maximum height gauges were used in conjunction with the plenum elevation cameras by the lift control supervisor to assure that the maximum allowable lift height was not exceeded. Personnel trained for the installation of the gauges using the actual gauges and the defueling work platform support structure on which the gauges were mounted.

Cable Management Training

The cable management system controlled the cables that traveled with the plenum assembly during lift and transfer operations. This system was developed and perfected during mock-up training. A full mock-up of the cable management system was installed on scaffolding simulating the D-ring. Personnel were trained from within a simulated lift control station during training exercises involving transfer of the three point lift frame (including a bubble level camera) by using the mock-up tripod, Hydra-Sets, and pendant assemblies.

Unlatching Training

The actual pendant assemblies were used in conjunction with the Hydra-Sets, the three point lift frame, and long handle tools to train personnel in unlatching the pendant assemblies. Training was done with the three point lift frame level and then tilted to simulate the plenum tilted in the storage stand. The elevation differences between the plenum in the storage stand and the 347'-6" elevation where unlatching would take place was duplicated. Unlatching proved to be much more difficult to accomplish than latching. This was primarily due to the increased working distances that personnel had to overcome and also because the latch/unlatch system did not function as reliably for unlatching as it did for latching. It was also evident during training that long handle tools were essential to assist the unlatching and additional tools were needed so that pendants could be unlatched simultaneously if necessary (the additional tools were fabricated on-site).

Contingency Plans

Contingency plans were formulated to address credible events that could impede the timely completion of the plenum assembly lift and transfer operations. Many of the contingency plans were a direct result of lessons learned during reactor vessel head lift operations. The following are major contingency plans or activities for the plenum lift operations.

Direct Polar Crane Access

Direct access to the polar crane during plenum lift and transfer operations was provided by an electrically operated scaffold (spider) that operated on wire ropes suspended from the south end of the polar crane bridge. This provided access from the 347' elevation for repairs. The spider had a capacity of 1100 pounds and a speed of about 27 feet per minute (about 3 minutes to access the crane from the 347' elevation).

Back-Up Equipment

Equipment essential to the plenum lift operations was provided with back-ups. The following is a list of the equipment with back-ups.

- Plenum elevation camera.

- Polar crane target camera.

- Plenum elevation gauge.

- Maximum height gauge.

- Laser level.

Additionally, the Hydra-Set position readouts could be used as a back-up to the bubble level and bubble level camera after the initial lifting and leveling of the plenum assembly was completed.

Alternate Unlatching

Because there was a possibility for unlatching difficulties, a contingency means for releasing the plenum from the polar crane was developed during mock-up training. The plan was to access the tripod via the auxiliary bridge or long pick boards and then use a boatswain's chair to reach and remove the pin on each pendant. The pendants would than be left (temporarily) with the plenum. The plan assumed that the water in the deep end of the refueling canal would provide adequate shielding from the plenum on its storage stand.

Alignment Tool

The potential for binding between the plenum assembly and reactor vessel internals existed in the early stages of the lift. Therefore, a hydraulic tool was developed that could be used between the core support shield and the plenum cylinder to overcome the binding or interference (see Figure 13). The tool was designed to be used from the pendant installation platforms that could be positioned as necessary on top of the defueling work platform support structure. Underwater video cameras and drop lights were also available to help identify and resolve interference problems. It was assumed that the water shielding above the plenum assembly would be sufficient to allow personnel access.

Stand-by Repair Crews

Sufficient equipment repair personnel were trained and available to support around the clock operations if necessary.

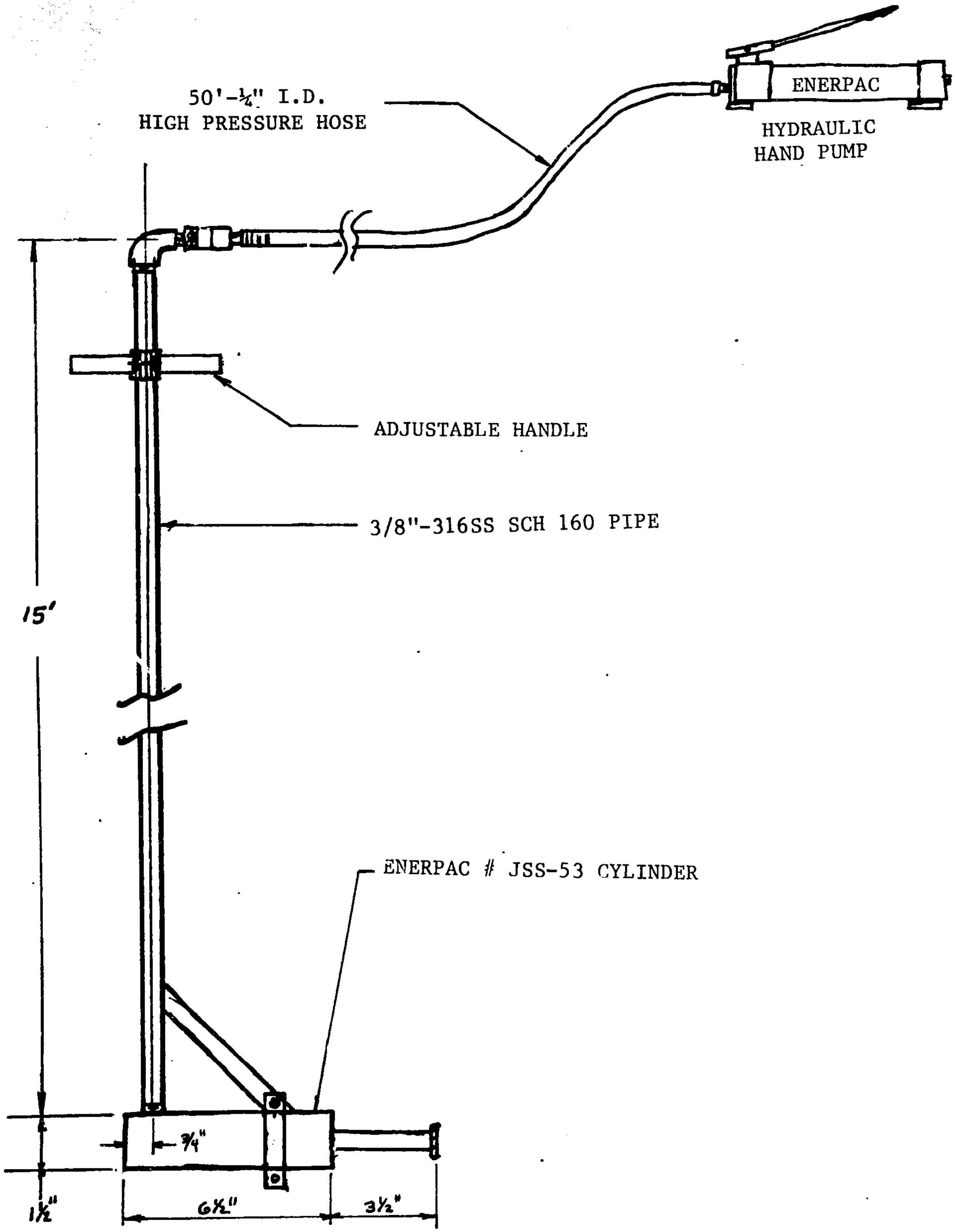


Figure 13 Alignment Tool

Polar Crane Maintenance

As a result of the lessons learned from head lift, the polar crane yearly preventative maintenance was scheduled to be completed just prior to the beginning of the plenum lift evolution.

Canal Flood

The plant had the ability to flood the refueling canal with borated water to provide shielding protection if necessary. Although no credible upset condition could be envisioned that would require canal flooding, it was available as the bottom line contingency plan.

Prerequisites

Following are the major inspection and installation activities that were prerequisites to the initiation of plenum assembly lift and transfer operations.

Confirm Free Lift Path

Extreme temperatures during the March 1979 accident could have caused damage and distortion to the plenum assembly and core support shield. This damage could have interfered with the planned removal of the plenum assembly using the polar crane.

During December 1984, the plenum assembly was lifted 7.25 inches using a system of four specially designed hydraulic jacks. This precisely controlled initial lift raised the plenum assembly to a height sufficient to eliminate any binding between the core support shield and the plenum grid ring forging.

An inspection to confirm a free lift path was performed in February 1985. This inspection used a plumb bob to plumb down from the eight vent valves and from vertical sets of LOCA bosses to the plenum assembly grid ring forging. The inspection determined that there was a free lift path for the removal of the plenum assembly.

Inspect Plenum Lift Ribs

The removal of the plenum assembly used a three pendant assembly lift configuration. The three pendants were positioned 120° apart on the plenum cover. At the lower end of each pendant was a lift arm (see Figure 3) that engaged and lifted the plenum assembly cover ribs. Reaction forces due to the off set lift arrangement were opposed by ribs adjacent to the lift ribs.

A plan for the inspection of these three pairs of lift and reaction ribs was formulated to assure that the lifting equipment would interface properly.

The inspections consisted of underwater video examinations and measurements of the various physical aspects of both the lift and reaction ribs. The inspections were intended to determine the following:

- The condition (cleanliness) of the upper surfaces of the lift and reaction ribs.
- Verify that both the lift and reaction ribs were at the same elevation for each pair.
- The plumbness of the lift and reactor ribs.
- The spacing between the lift and reaction ribs.
- The width, length, and height of the bearing surface on the lift rib.
- The distance from the bottom of the lift rib to the top of the core support shield.
- The spacing between the plenum cover bottom flange and the plenum support flange.
- Verify that there were no interferences preventing installation of the lift arms (thermocouple brackets, etc.).

The results of the inspections indicated that conditions were acceptable with the exception of the spacing between the plenum cover bottom flange and the plenum support flange. At each of the three lift points, the spacing was considerably less than the designed spacing.

There were no indications of distortion that could be linked to the accident. It was therefore concluded to be an as-built dimensional problem. The spacings were too narrow and would have obstructed the lift arm installations. The spacer plates on the lower end of the lift arms were removed to accommodate this space restriction.

Verify IIF/Vessel Key Alignment

There are four keys (one key at each axis) on both the reactor vessel and the IIF. The plenum assembly support flange has four keyways that engage these keys. The key-to-keyway interface has a nominal clearance. There is a transition between the reactor vessel keys and the IIF keys (see Figure 14). It is relatively important for a successful lift that the keys are aligned vertically. The keys index the plenum assembly within the reactor vessel and also prevent the rotation of the plenum assembly during installation and removal operations.

During February 1985 the vertical alignments between the reactor vessel keys and the IIF keys were inspected. Inspections were performed with a specially designed key alignment tool and underwater video cameras. These inspections confirmed that the vertical alignment of the keys was within acceptable limits.

Clean Plenum

Plenum inspection activities performed in October and November 1984 revealed that some debris had accumulated on the horizontal surfaces of the lower regions of the plenum assembly. The debris ranged in size from very fine particles to nearly fuel pellet size. To minimize the transporting of loose debris with the plenum, a method of cleaning the plenum was devised. The method chosen utilized a water lance to access all available areas of the lower regions of the plenum assembly. The water lance was inserted into all

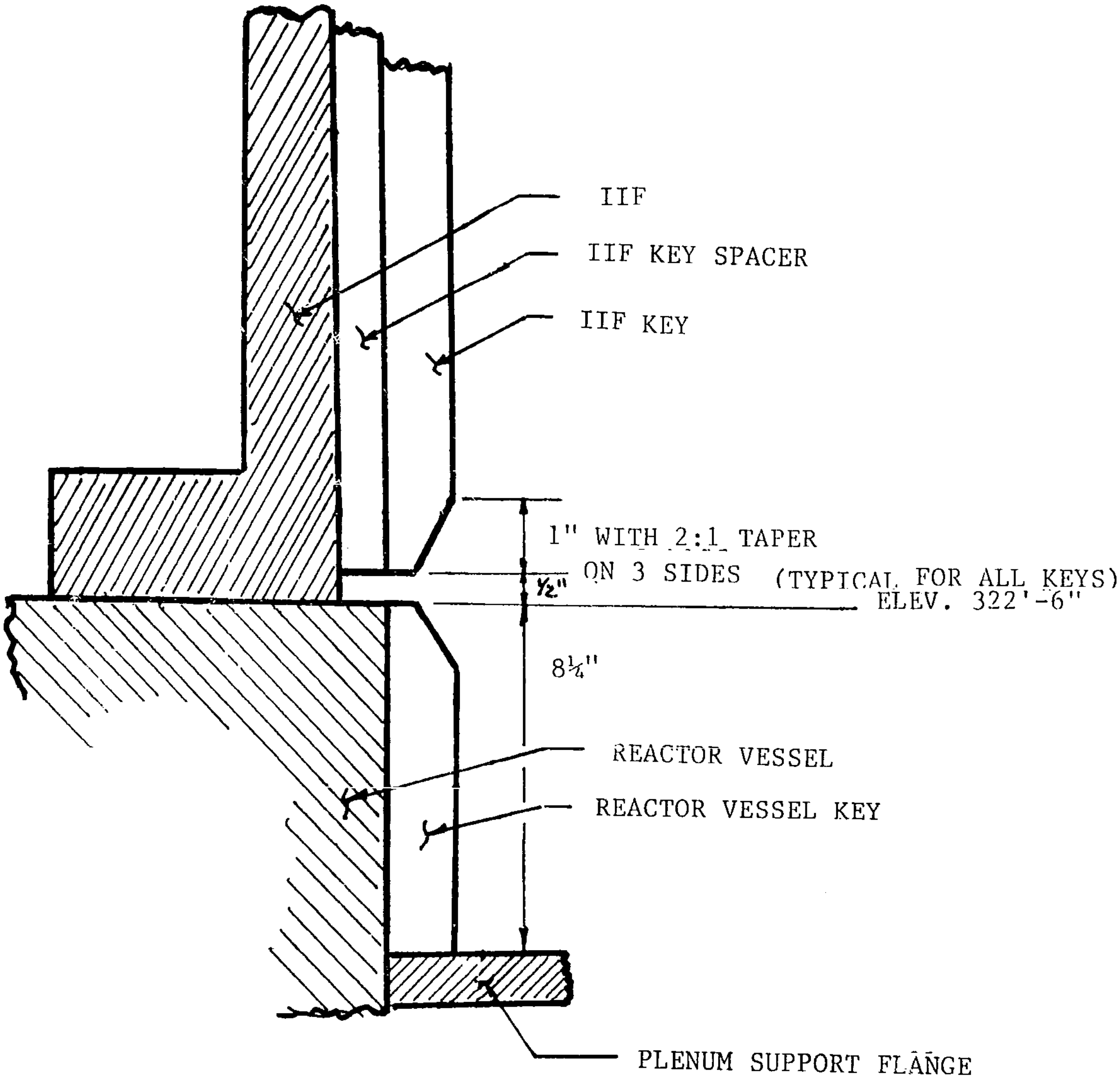


Figure 14 Reactor Vessel/IIF Key Transition

annulus openings in the plenum cover and down through all control rod guide assemblies (see Figure 4). Borated water was supplied by a high pressure pump at a rate of 16 to 18 gpm and 3500 to 4000 psig through a 16 jet nozzle at the end of the lance. Testing outside the reactor building had shown that this arrangement was very effective in removing loose debris. During the cleaning of the plenum several underwater inspections at various locations were performed to assess the effectiveness of the cleaning. These inspections indicated that the loose debris was effectively removed. It should also be noted that some of the debris actually adhered to the plenum and could not be removed.

Secure Plenum Jacks

In December 1984 a specially designed hydraulic jack system lifted the plenum assembly 7.25 inches. The plenum remained in this position, resting on 2-inch diameter Acme threaded mechanical followers in each of the four depressurized jacks, until the final lift and transfer. The plenum assembly jacks are located at each major axis and engage the plenum cover ribs by clamping them between the lifting lug and the take-up stud (see Figure 15). The jacks remained clamped to the plenum assembly during the lift and transfer of the plenum.

During the preparations for the installation of the jacks, it was noted that the ribs were spaced further apart than the jack design had anticipated. Shims were added under the take-up studs to provide additional bearing area to clamp the jacks to the ribs. Because of the addition of the shims for clamping and the fact that the center of gravity of the jacks was outboard of the clamped ribs, it was necessary to provide additional means to secure the jacks to the plenum. This would assure that the jacks would not fall off the plenum assembly as a result of any unanticipated upset condition during the lift and transfer.

Each jack was secured to the plenum independently. A 2-1/2 inch schedule 40 pipe was inserted into the control rod guide assembly immediately inboard of the jack. The jack was then secured with a 1/4 inch wire rope running from its hoist ring to the pipe.

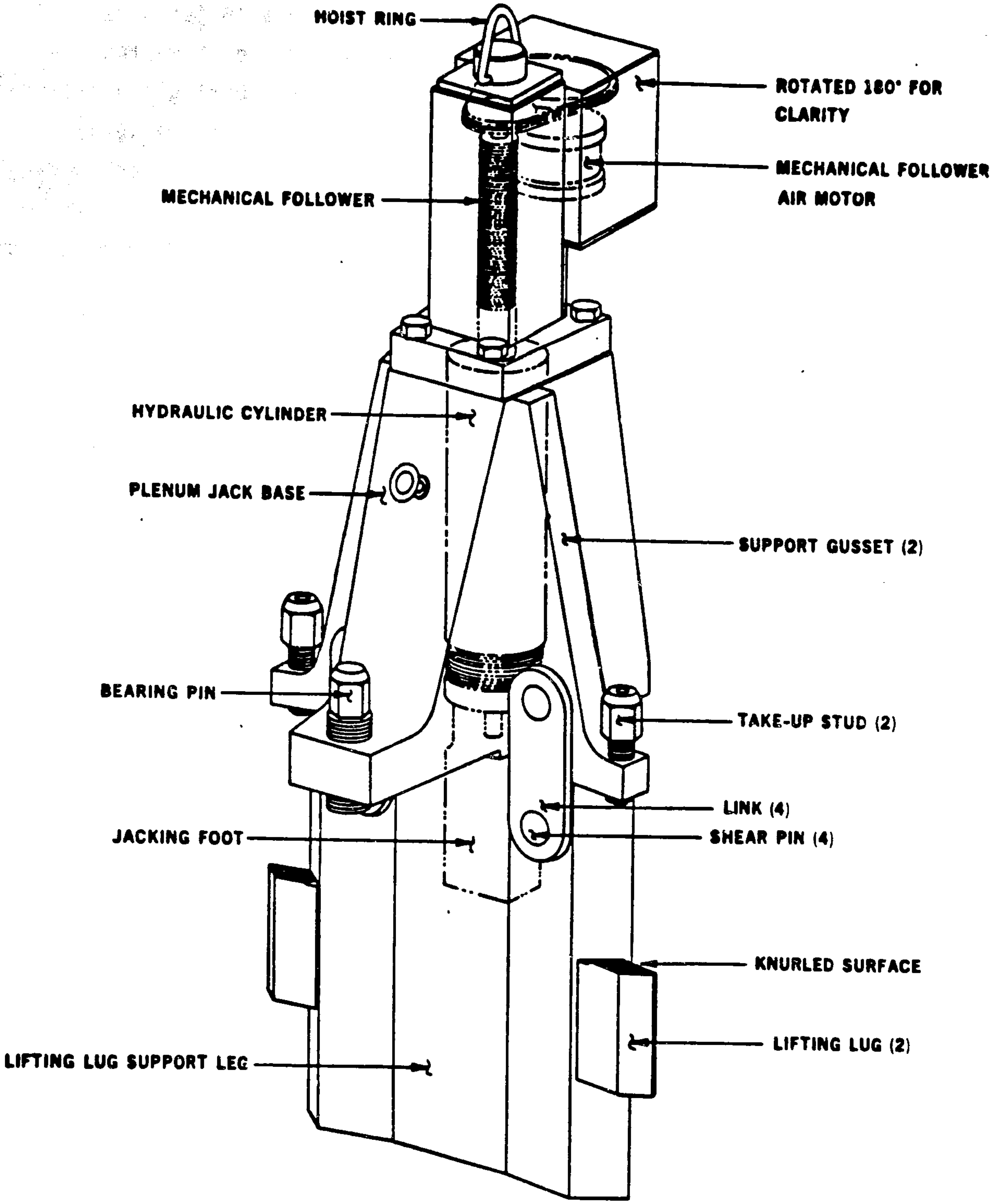


Figure 15 Plenum Jacks

Prepare Refueling Canal

The plenum lift and transfer plan called for a dry transfer of the plenum assembly from the reactor vessel into the flooded deep end of the refueling canal. The following preparatory activities were required before flooding the deep end.

- The plenum storage stand was properly positioned in the refueling canal deep end to receive the plenum.

- A dam was installed in existing keyways in the refueling canal to separate the flooded area from the dry area. The canal dam was metal with redundant inflatable seals.

- Canister racks that will be used to store defueling canisters were installed in the deep end.

- The canister transfer system modifications were completed.

- A level indication system was installed in the deep end.

- Certain defueling water cleanup system installations were completed in the deep end.

Work Platform Support Structure

The defueling work platform support structure was installed in the refueling canal around the IIF (see Figure 16). This structure served two functions.

- Provided the support for the pendant installation platforms.

- Provided protection for the canal seal plate from a dropped plenum accident and thereby retained the ability to flood the canal.

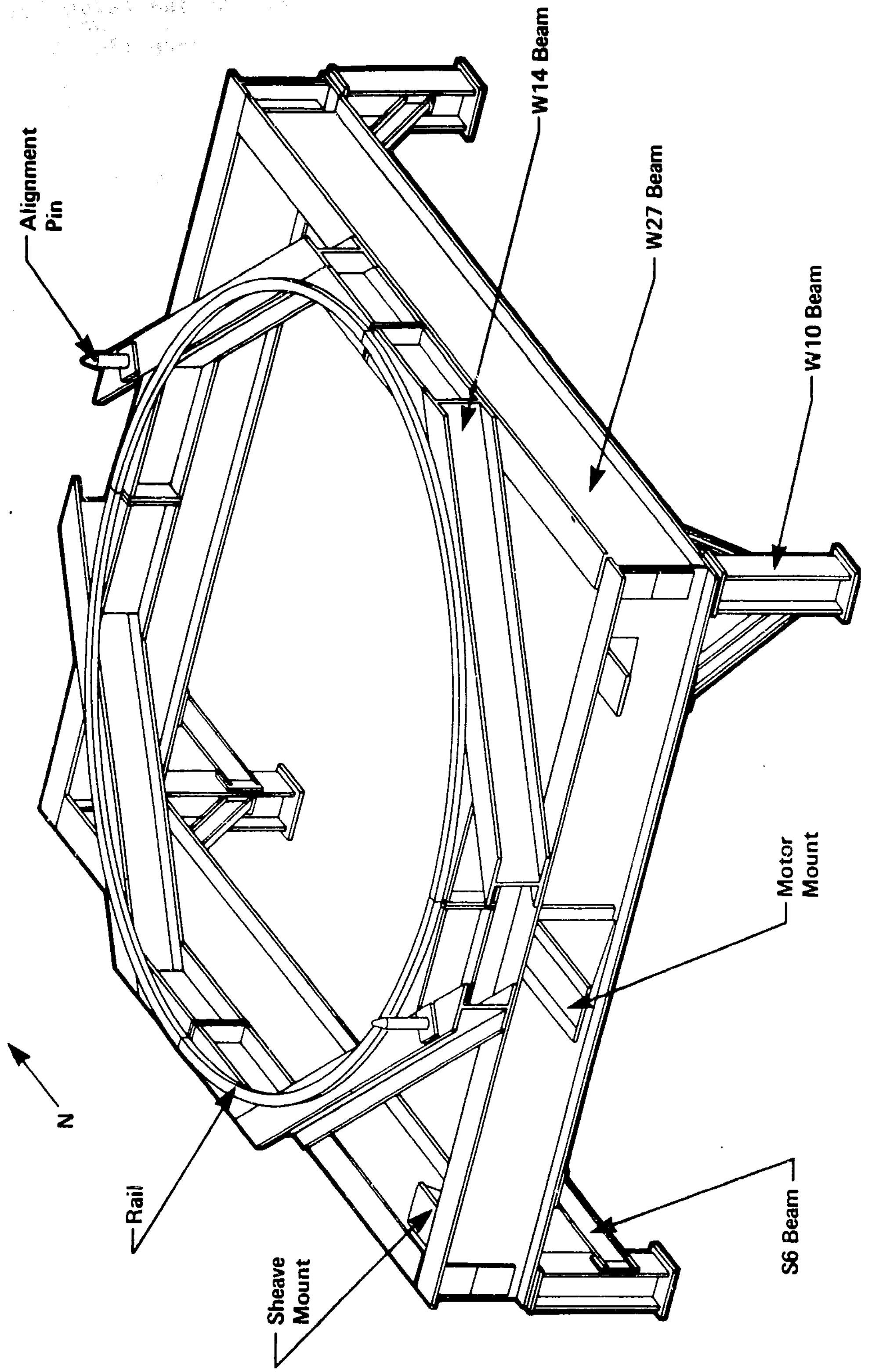


Figure 16 Defueling Work Platform Support Structure

Prepare Polar Crane

The polar crane was prepared for the plenum lift as follows:

- The yearly preventative maintenance was completed just prior to the plenum lift.
- Targets were installed to properly align the crane with the plenum and the storage stand.
- The polar crane spider was relocated to the south end of the bridge to provide direct access to the crane during lift activities.

Install Lift Equipment

The following equipment was installed as a prerequisite to the lift.

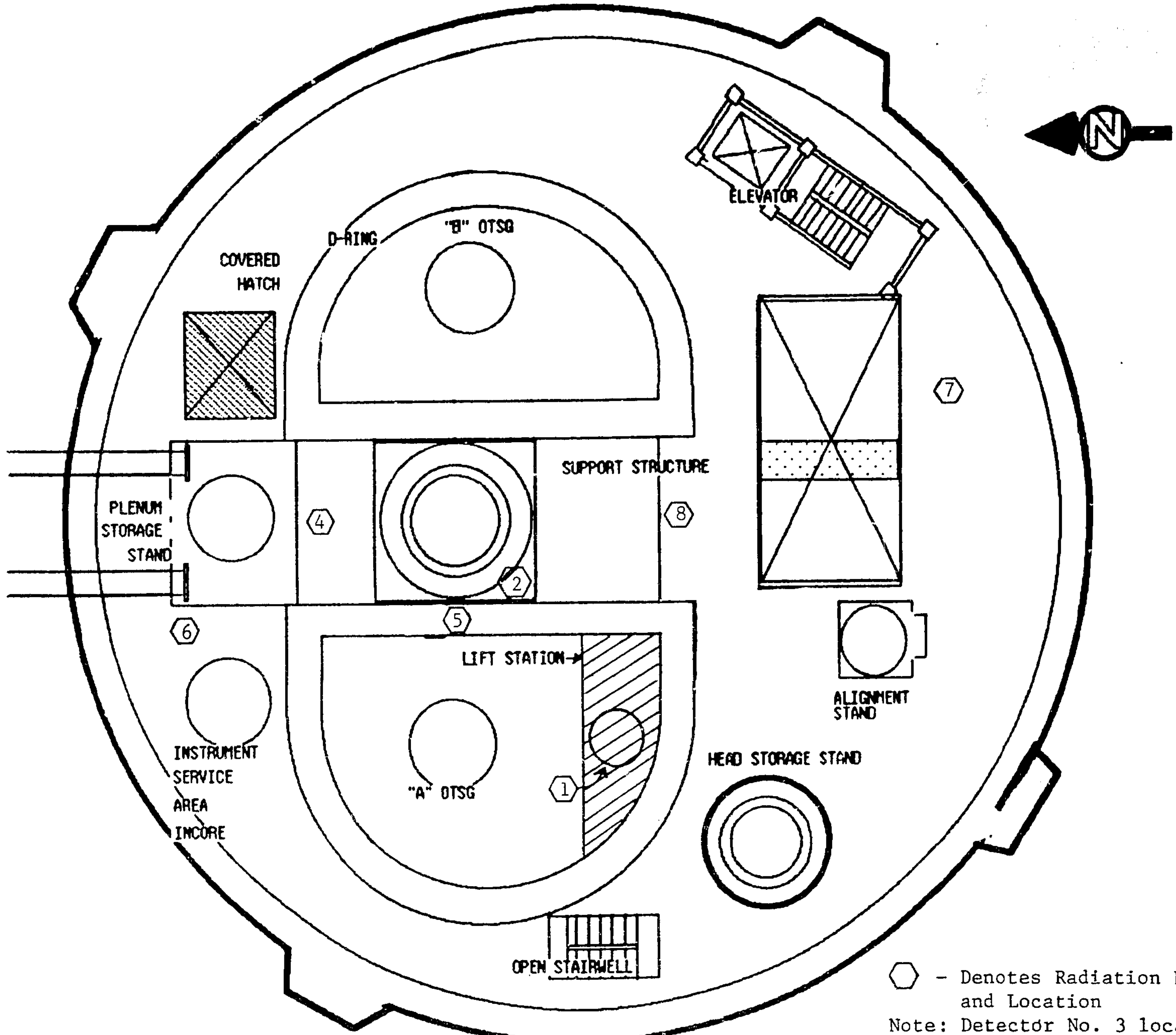
- Elevation gauges
- Lasers
- Maximum height gauges
- Lift monitor cameras
- Bubble level
- Lift rigging.

Install Radiation Monitors

Radiation monitors were set-up in the following locations (see Figure 17) to provide measurements and to monitor dose rates in possible worker location:

- In the lift control station (Detector Number 1).

Figure 17 Location of Radiation Detection Instruments



⬡ - Denotes Radiation Detector Number and Location

Note: Detector No. 3 located on middle of polar crane

- On the defueling work platform support structure (Detector Number 2).

- On the polar crane walkway, half way across the bridge (Detector Number 3).

- On the canal dam in the center of the refueling canal (Detector Number 4).

- On the "A" D-ring handrail at the reactor centerline (Detector Number 5).

- The northwest corner of the refueling canal at elevation 347' (Detector Number 6).

- On elevation 347' near the polar crane spider (Detector Number 7).

- On elevation 347' at the south end of the refueling canal (Detector Number 8).

The radiation monitors had remote readouts in the shielded lift control station. See Appendix D for the readings taken during the lift and transfer operations.

Shielded Lift Control Station

The shielded lift control station was established on top of the "A" D-ring at the south end (see Figure 18). During the lift the following five personnel were in the lift control station.

- The radiation control technician

- The polar crane operator

- Two Hydra-Set operators

- The lift control supervisor.

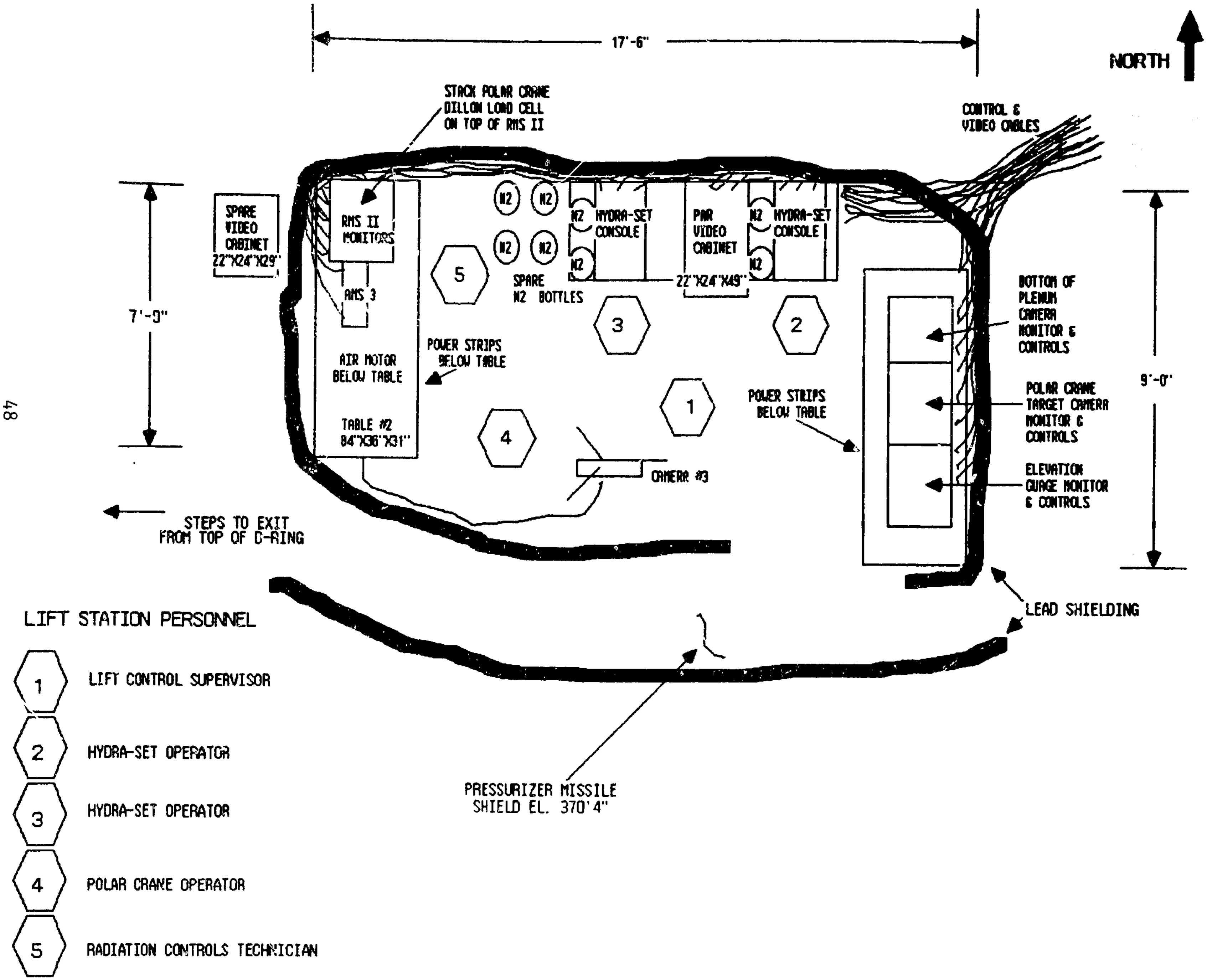


Figure 18. Shielded Lift Control Station

The following equipment was located in the lift control station:

- Audio and video equipment and monitors
- The polar crane pendant controls
- The radiation monitors
- The Dillon load cell remote readout
- Two Hydra-Set control stations and remote readout monitors
- The lift station monitor camera.

LIFT AND TRANSFER OPERATIONS

Operations for plenum assembly lift and transfer were conducted in two stages. The first stage was a carefully planned "dry run" or technical rehearsal. The second stage was the actual lift and transfer of the plenum assembly.

Plenum Lift Dry Run

The dry run was incorporated into the plan for lift and transfer operations at the recommendation of the Plenum Removal Readiness Review Committee. The dry run was conducted on May 14, 1985 the day before the actual lift and transfer. The personnel conducting the dry run were the same team that would conduct the actual lift and transfer the following day. The major activities included in the dry run were as follows:

Pre-dry Run Checklist

The lift control supervisor completed a pre-dry run checklist to assure that all activities and equipment were in the proper condition/configuration to conduct the dry run (see Appendix E, Exhibit 1).

Final Lift Rigging Inspection

A standard pre-lift rigging inspection was performed by the lift control supervisor to determine structural damage or defects, broken wire strands, kinks, broken sheaves, unsecured pins, pinched cables, loose electrical connections, or any other defects that could affect the capability or operability of the equipment.

Polar Crane Positioned Over the Plenum

Personnel were stationed on the polar crane during the dry run to reposition polar crane targets if necessary and to lower the polar crane access spider for contingency access during the actual lift and transfer. The polar crane with all final lift rigging installed was positioned directly over the plenum assembly. The cable management system and the latch/unlatch system of the pendant assemblies were verified operational. Polar crane targets were verified to be correctly located.

Polar Crane Positioned Over the Storage Stand

The polar crane was trolleyed north (with the final lift rigging and cable management system installed) until it was positioned over the plenum storage stand. The polar crane targets were found to be 8 to 12 inches out of position. They were repositioned visually by lowering the pendants until nearly in contact with the storage stand and then positioning the crane such that the pendants were properly aligned and oriented. The targets were then adjusted to this position. The rigging was then raised and the crane trolleyed back to the reactor vessel centerline. The crane was trolleyed back and forth several times to confirm target alignments and cable management function. Personnel on the polar crane lowered the spider to provide contingency access to the crane during the lift and transfer. During the dry run, an interference was discovered between the lift rigging (tripod) and a piping manifold overhanging the north end of the refueling canal. The lift plan was revised to stop the plenum travel about 9 inches south of the intended target and then lowered until the tripod was below the interference. The plenum was then trolleyed the last 9 inches north to the storage stand target and lowered to complete the lift.

Latch Pendants to the Plenum Ribs

After various pre-lift weights were recorded (i.e. Dillon load cell reading and Hydra-Set weight readings) the pendants were latched to the plenum ribs. The latching was verified by underwater video inspections. The polar crane was then slightly raised to increase the net load on the Dillon load cell by about 15,000 lbs. The polar crane breaker was opened and the crane left in this configuration until the lift and transfer the next day.

Completion of Lift Set-Up

At the completion of latching, the following activities were completed in preparation for the final lift the next day.

- The bubble level and bubble level camera were installed on the plenum cover assembly at position C-7.

- The elevation gauges were installed on the plenum cover assembly at positions E-13 and P-8.

- The lasers were verified operational and adjusted to index with the elevation gauges at the 7-1/4 inch mark.

- Elevation gauge cameras were adjusted to view the lasers projected on the elevation gauges.

- The maximum height gauges were installed on the support structure.

- All cameras and camera functions were verified operational (see Appendix E, Exhibit 2).

- The Hydra-Set manual control levers were locked in position for remote operation and Hydra-Sets and control consoles were verified operational (see Appendix E, Exhibit 3).

- The Dillon load cell was verified operational.

- Radiation detection equipment was verified operational.

- Audio communications equipment was verified operational.

The equipment (with the exception of the polar crane) remained energized over night to eliminate equipment warm-up time the next day.

Plenum Lift and Transfer

On May 15, 1985 the plenum assembly was lifted from the TMI-2 reactor vessel and transferred to a storage stand located in the flooded deep end of the refueling canal. The lift team was composed of the same personnel that had conducted the dry run on the previous day. The lift was monitored and controlled by the lift control supervisor located in the shielded lift control station within the reactor building. The lift team in the reactor building consisted of the lift control supervisor, two Hydra-Set operators, the polar crane operator, and a radiation control technician. This team was supported by a team within the coordination center in the turbine building consisting of a senior reactor operator (SRO), a task supervisor, a reactor building entry supervisor, a representative from the safety department, and a representative from the radiation control department. Additional support personnel from on-site departments were standing by and available. During the lift and transfer, the lift control supervisor had a reporting relationship with either one of the two organizations (See Figure 19). Under normal or expected conditions, the lift control supervisor reported through the task supervisor to the Manager of Recovery Operations. Under emergency or upset conditions, the lift control supervisor reported through the SRO to the Manager of Plant Operations (the lift and transfer was conducted without encountering any emergency or upset conditions). The following is a brief discussion of the lift and transfer activities.

Pre-Plenum Lift Checklist

Prior to starting actual lift operations, the lift control supervisor completed a pre-lift checklist to ensure that all activities and equipment were in the proper condition/configuration to conduct the lift operations (see Appendix E, Exhibit 4). Certain equipment was designated as essential for the start of the lift (i.e. the lift could not start without the essential equipment installed and operational). The following is a list of the equipment designated as essential. (For detailed descriptions of equipment see Description of Equipment Section).

- The polar crane Dillon load cell

- The two-Hydra-Sets, control consoles and remote load and position readouts

- The two plenum elevation cameras, (Cameras 1A and 1B)

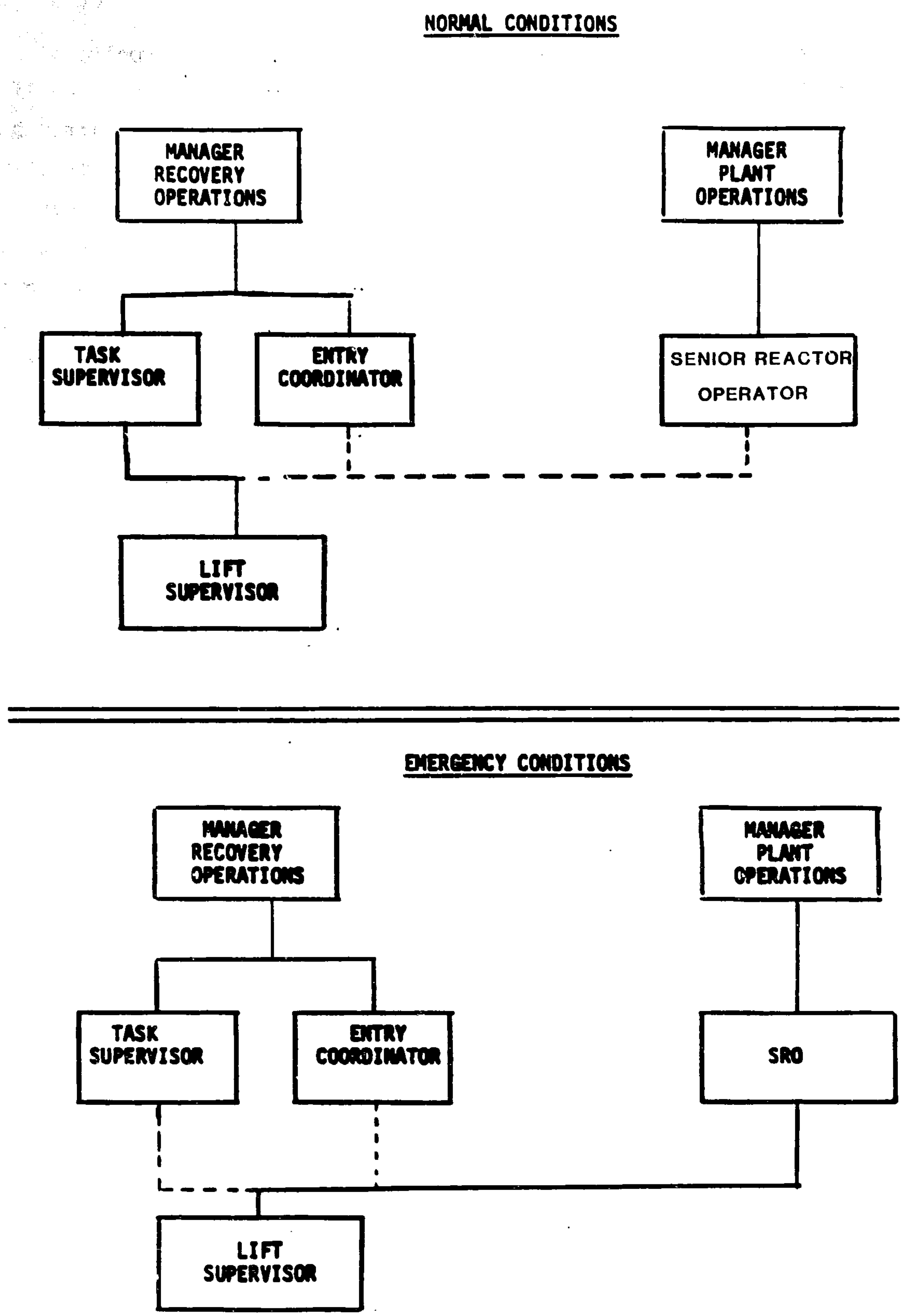


Figure 19 Organizational Reporting Relationship

- The two polar crane target cameras
- The bubble level and bubble level camera (Camera 4)
- The audio equipment
- The two elevation gauges
- The two maximum height gauges
- The two lasers.

Lift and Level

After the pre-lift activities on the checklist were completed, the lift operation was initiated by transferring the plenum load from the plenum jacks onto the final lift rigging and the polar crane. The plenum was then leveled utilizing the bubble level, Hydra-Sets, and remote level, load, and position readouts. This initial leveling was necessary to assure that the plenum could be lifted out of the reactor vessel without encountering interferences or hang-ups. Precise level control during removal from the reactor vessel was necessary due to potential binding in the key to keyway interface between the plenum assembly and the reactor vessel and IIF. A plenum tilt of 15 minutes could cause binding with the reactor vessel keys and a tilt of 45 minutes could cause binding with the IIF keys.

The lifting and leveling was accomplished in approximately 15 minutes (it was anticipated that it could take up to one hour). With the plenum leveled and the total weight on the lift equipment and polar crane, the following loads were observed:

- 29,040 lbs net load on pendant "A"
- 26,130 lbs net load on pendant "B"

- 28,330 lbs net load on pendant "C"
- 83,500 lbs net load on the polar crane.

The designed weight of the plenum assembly (with plenum jacks installed) was approximately 114,500 lbs. The corresponding underwater weight was expected to be 99,500 lbs. During the final stages of the initial lift (or jacking) approximately 103,000 lbs of force was required to lift the plenum. It was thought that this indicated a friction or binding force of approximately 3,500 lbs. (103,000 lbs - 99,500 lbs). The loads observed during plenum lift indicate that the friction or binding force encountered during jacking was much larger (103,000 lbs - 83,500 lbs = 19,500 lbs), because the plenum was approximately 16,000 lbs lighter underwater than expected.

Lift and Transfer

After leveling, the plenum was lifted vertically approximately 19 feet (while maintaining level) until a clear transfer height was achieved and verified by video inspection. The target lift height would put the bottom of the plenum at elevation 329'11", or approximately 7'5" above the canal floor and 6 inches above the defueling work platform support structure. The actual lift height achieved prior to starting the transfer was about 6 inches to 1 foot above the target height. The vertical lift took less than one hour and no interferences were encountered. During most of the vertical lift (until the plenum was clear of the reactor vessel) the tilting limits described in the previous section continued to apply. Equipment load limits also applied (i.e. a maximum load of 50,000 lbs on any pendant and a maximum total load of 150,000 lbs for the entire system).

At the start of the lift the water level in the IIF was at approximately 327'6" and it dropped approximately 17 inches with the plenum removed.

The transfer of the plenum north to the deep end of the refueling canal took approximately one hour. It was during this transfer that the damage to the underside of the plenum was observed and recorded using camera number 9 (see Appendix A).

According to design data from the plenum manufacturer, the load (plenum and jacks) should have weighed 14,500 lbs, however, the actual weight in air was 96,500 lbs. Based on the underside plenum damage (Appendix A), it appears that the mass of material missing from the plenum is no more than 2,000 to 3,000 lbs. Therefore, the load discrepancy may be attributable to differences in the as-built and designed weight.

Lower to Storage Stand

The polar crane was aligned over the storage stand in the flooded deep end of the defueling canal by using targets monitored by cameras. The plenum was lowered (approximately 21 feet) to the storage stand in approximately one hour. No problems were encountered during this part of the operation. The water level in the deep end of the refueling canal was at approximately elevation 327'2" and raised approximately 6 inches when the plenum was submerged.

The entire lift and transfer operation was completed in just under 3 hours. Unlatching was completed by additional teams later during the same day.

IN-CONTAINMENT MAN-HOURS AND MAN-REM

The man-hours and man-rem for plenum lift were estimated in the Safety Evaluation Report for Plenum Lift and Transfer. The collective dose was estimated to be 36 man-rem based on 600 in-containment man-hours.

Due to the uncertainty in the man-hour estimate and the radiological conditions during plenum lift and transfer activities, it was estimated that the total exposure could vary by ± 30 percent. Therefore 25 to 50 man-rem was selected as the estimate for total exposure, which included radiological support.

The actual man-hours and man-rem for plenum lift activities are shown in Table 1. These values were obtained from the self reading dosimeters and the Reactor Building Entry Log. These values include health physics technicians who provided direct job coverage during operations.

Table 1

Man-Hours and Man-Rem for Plenum Lift Activities

In-containment Activity	Man-hours	Man-rem
Modify, relocate, install, remove video equipment	206	7.612
Modify polar crane, relocate storage stand, inspect and level tripod	194	7.308
Install canal dam, preps for canal flood	95	2.896
Modify IIF processing and RCS sampling systems	71	1.926
Clean and inspect plenum, secure plenum jacks	343	9.559
Remove and dispose of IIF platform	131	3.438
Install defueling work platform support structure	86	3.236
Plenum Lift		
Preps & staging	140	6.032
Dry Run	35	1.274
Latching	33	1.095
Lift and Transfer	20	.710
Unlatching	52	1.228
TOTAL for Plenum Lift Activities	1406	46.314

LESSONS LEARNED

Plenum lift and transfer operations provided valuable lessons learned that are directly applicable to future TMI-2 cleanup activities. The major lessons learned can be categorized into the four areas described below.

Integrated System Checkouts

Vendors typically subject equipment to some form of functional checkout prior to delivery. The vendor's functional checkout is not designed to check the equipment under the conditions in which it will be operated at TMI, but instead the checkout is designed to assure that it functionally meets design and/or procurement requirements. It is critical that special equipment be operationally and functionally checked out as part of an integrated system prior to use in the reactor building. The on-site checkout should be performed under conditions that closely simulate the actual interfacing conditions the equipment will be subjected to during use in the reactor building. This type of checkout program was used for the plenum lift equipment and resulted in the identification of several needed modifications. This type of integrated checkout program should be continued for future recovery activities.

As-Built Dimensions

Inspections have revealed that the as-built dimensions of reactor vessel internals are not consistent with the designed dimensions. Thus, it is imperative that inspections for as-built dimensions be made at critical interface locations between reactor intervals (and perhaps all NSSS equipment) and specially designed recovery equipment well in advance of final manufacture to avoid reworks or unusable equipment.

Training

The training program for plenum lift and transfer operations provided workers with the instructions and hands on practice necessary to familiarize them with tasks to be performed under conditions closely simulating the actual conditions to be expected. The program provided the training and experience necessary for the workers to perform their tasks safely and efficiently. This type of training program should continue to be a major part of future recovery activities.

Dry Run

The dry run conducted prior to plenum lift proved to be invaluable in that a potential interference with the transfer of the plenum was discovered and corrected quite easily prior to the actual lift. Without the dry run, the interference would have been discovered with the plenum suspended from the polar crane and corrections would have been more time consuming and costly due to the more severe radiological conditions. The dry run concept should be used in future recovery activities that deal with the potential for upsets in severe radiological conditions.

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APPENDIX A

APPENDIX A

Plenum Underside Damage

During plenum assembly lift and transfer a camera was used to record the damage caused by the march 1979 accident to the underside of the plenum. The camera was located on the refueling canal floor just south of the dam on the north-south centerline of the reactor vessel. The plenum assembly passed directly over this camera (approximately 8 feet above) as it was transferred to its storage stand in the deep end of the canal. The camera had remote pan, tilt, zoom, focus, and auxiliary light controls and was monitored and controlled by the lift control supervisor. This camera provided the first comprehensive view of the underside of the plenum assembly. The damage appeared to be localized in specific areas. The exhibit attached shows the areas that suffered the most significant damage, i.e., where the grid pads and portions of the grid ribs are completely or mostly melted away.

APPENDIX B

APPENDIX B

Potential Interference Points
Plenum Assembly/RV-IIF

The March, 1979 accident may have caused damage or distortion to the plenum assembly and reactor vessel internals. Therefore, the potential existed for interferences that would hinder plenum removal. Inspections indicated that a free, clear lift path existed for the removal of the plenum from the reactor vessel. However, the close tolerances between the plenum and vessel internals could still cause binding or interferences if the plenum were tilted during the lift.

The system designed to remove the plenum assembly included a three point lift arrangement with load positioners and precise level monitoring capability. The plenum elevation was monitored during the lift by using a laser level projecting a beam onto an elevation gauge mounted in a control rod guide tube assembly on the plenum cover.

This appendix provides a table of the elevations (as read on the gauge) at which interferences could occur during the removal of the plenum from the reactor vessel. The table could be used by the lift control supervisor to help identify the cause of an interference and determine the actions necessary to resolve the interference.

Table B

Potential Interference Points
Plenum Assembly/RV-IIF

Elevation As Read on Gauge (inches)	Description	Nominal Radial Clearance (inches)
0.00	Begin plenum assembly (PA) removal operation with lifting jacks	
2.75	Disengagment of loss of coolant accident (LOCA) bosses	
6.75	Engagement of leading edge of PA bottom flange with 1st row of LOCA bosses	0.8125
7.25	Engagement of LOCA bosses. Hold for inspection and transfer to final lift equipment. End jacking. Start final lift and transfer operations.	0.1875
9.75	Engagement of leading edge of upper grid (UG) ring forging with 1st row of LOCA bosses.	0.6875
12.75	Disengagement of LOCA bosses. Also, disengagement of trailing edge of PA bottom flange from the 1st row of LOCA bosses.	
16.75	Engagement of PA bottom flange with 2nd row of LOCA bosses	0.8125
17.25	Engagement of LOCA bosses	0.1875
18.00	Engagement of leading edge of UG rib section with 1st row of LOCA bosses	0.6875

Table B

Potential Interference Points
Plenum Assembly/RV-IIF (continued)

Elevation As Read on Gauge (inches)	Description	Nominal Radial Clearance (inches)
19.75	Engagement of leading edge of UG ring forging with 2nd row of LOCA bosses	0.6875
	Also, engagement of LOCA bosses in the 5th row with the 2nd protrusion on the vent valve assembly (VA)	0.486
21.00	Disengagement of trailing edge of UG ring forging from 1st row of LOCA bosses	
21.75	Disengagement of trailing edge of UG rib section from the 1st row of LOCA bosses	
22.75	Disengagement of the trailing edge of the PA bottom flange from the 2nd row of LOCA bosses	
	Also, disengagement of LOCA bosses	
24.25	Disengagement of LOCA bosses in in the 5th row from the 2nd protrusion of the VAs	
26.25	Engagement of the leading edge of the PA bottom flange with the 3rd row of LOCA bosses	0.8125
27.25	Engagement of LOCA bosses	0.1875
28.00	Engagement of the leading edge of the UG rib section with the 2nd row of LOCA bosses	0.6875

Table B

Potential Interference Points
Plenum Assembly/RV-IIF (continued)

Elevation As Read on Gauge (inches)	Description	Nominal Radial Clearance (inches)
29.75	Engagement of LOCA bosses in the 4th row with the 2nd protrusion on the VAs	0.486
	Also, engagement of the leading edge of the UG ring forging with the 3rd row of LOCA bosses	0.6875
31.00	Disengagement of trailing edge of UG ring forging from the 2nd row of LOCA bosses	
31.75	Disengagement of the trailing edge of the UG rib section from the 2nd row of LOCA bosses	
32.75	Disengagement of the LOCA bosses	
	Also, disengagement of the trailing edge of the PA bottom flange from the 3rd row of LOCA bosses	
34.25	Disengagement of LOCA bosses in the 4th row from the 2nd protrusion on the VAs	
36.75	Engagement of the leading edge of the PA bottom flange with the 4th row of LOCA bosses	0.8125
37.25	Engagement of the LOCA bosses	0.1875
38.00	Engagement of the leading edge of the UG rib section with the third row of LOCA bosses	0.6875

Table B

Potential Interference Points
Plenum Assembly/RV-IIF (continued)

Elevation As Read on Gauge (inches)	Description	Nominal Radial Clearance (inches)
39.75	Engagement of the leading edge of UG ring forging with the 4th row of LOCA bosses	0.6875
	Also, engagement of LOCA bosses in the 3rd row with the 2nd protrusion on the VAs	0.486
41.00	Disengagement of the trailing edge of the UG ring forging from the 3rd row of LOCA bosses	
41.75	Disengagement of the trailing edge of the UG rib section from the 3rd row of LOCA bosses	
42.75	Disengagement of the trailing edge of the PA bottom flange from the 4th row of LOCA bosses	
	Also, disengagement of LOCA bosses	
44.25	Disengagement of LOCA bosses in the 3rd row from the 2nd protrusion on the VAs	
46.75	Engagement of leading edge of PA bottom flange with the 5th row of LOCA bosses	0.8125
48.00	Engagement of the leading edge of the UG rib section with the 4th row of LOCA bosses	0.6875

Table B

Potential Interference Points
Plenum Assembly/RV-IIF (continued)

Elevation As Read on Gauge (inches)	Description	Nominal Radial Clearance (inches)
49.75	Engagement of LOCA bosses in the 2nd row with the 2nd protrusion on the VAs	0.486
	Also, engagement of the leading edge of th UG ring forging with the 5th row of LOCA bosses	0.6875
51.00	Disengagement of the trailing edge of the UG ring forging from the 4th row LOCA bosses	
51.75	Disengagement of the trailing edge of the UG rib section from the 4th row of LOCA bosses	
52.75	Disengagement of the trailing edge of the PA bottom flange from the 5th row of LOCA bosses	
54.25	Disengagement of LOCA bosses in the 2nd row from the 2nd protrusion on the VAs	
55.75	Engagement of the leading edge of the PA bottom flange with the 6th row of LOCA bosses	0.8125
58.00	Engagement of the leading edge of the UG rib section with the 5th row of LOCA bosses	0.6875
58.75	Engagement of the leading edge of the UG ring forging with the 6th row of LOCA bosses	0.6875
59.75	Engagement of LOCA bosses in the 1st row with the 2nd protrusion on the VAs	0.486

Table B

Potential Interference Points
Plenum Assembly/RV-IIF (continued)

Elevation As Read on Gauge (inches)	Description	Nominal Radial Clearance (inches)
61.00	Disengagement of the trailing edge of the UG ring forging from the 5th row of LOCA bosses	
61.75	Disengagement of the trailing edge of the PA bottom flange from the 6th row of LOCA bosses Also, disengagement of the trailing edge of the UG rib section from the 5th row of LOCA bosses	
64.25	Disengagement of LOCA bosses in the 1st row from the 2nd protrusion on the VAs	
65.375	Engagement of the leading edge of the PA bottom flange with the 1st protrusion on the VAs	1.028
67.00	Engagement of the leading edge of the UG rib section with the 6th row of LOCA bosses	0.6875
68.375	Engagement of the leading edge of the UG ring forging with 1st protrusion on the VAs	0.903
69.25	Engagement of the leading edge of the PA bottom flange with the 2nd protrusion on the VAs	0.672
69.625	Disengagement of the trailing edge of the PA bottom flange from the 1st protrusion on the VAs	

Table B

Potential Interference Points
Plenum Assembly/RV-IIF (continued)

Elevation As Read on Gauge (inches)	Description	Nominal Radial Clearance (inches)
70.00	Disengagement of the trailing edge of the UG ring forging from the 6th row of LOCA bosses	
70.75	Disengagement of the trailing edge of the UG rib section from the 6th row of LOCA bosses	
72.25	Engagement of the leading edge of the UG ring forging with the 2nd protrusion on the VAs	0.547
73.75	Disengagement of the PA keyway from the keys on the internals indexing fixture (IIF)	
73.875	Engagement of the leading edge of the PA bottom flange with the 3rd protrusion on the VAs	1.028
74.25	Disengagement of the trailing edge of the PA bottom flange from the 2nd protrusion on the VAs	
76.625	Engagement of the leading edge of the UG rib section with the 1st protrusion on the VAs	0.903
76.875	Engagement of the leading edge of the UG ring forging with the 3rd protrusion on the VAs	0.903
77.875	Disengagement of the trailing edge of the UG ring forging from the 1st protrusion on the VAs	

Table B

Potential Interference Points
Plenum Assembly/RV-IIF (continued)

Elevation As Read on Gauge (inches)	Description	Nominal Radial Clearance (inches)
78.625	Disengagement of the trailing edge of the UG rib section from the 1st protrusion on the VAs	
79.625	Disengagement of the trailing edge of the PA bottom flange with the 3rd protrusion on the VAs	
80.50	Engagement of the leading edge of the UG rib section with the 2nd protrusion on the VAs	0.547
82.50	Disengagement of the trailing edge of the UG ring forging from the 2nd protrusion on the VAs	
83.25	Disengagement of the trailing edge of the UG rib section from the 2nd protrusion on the VA	
85.125	Engagement of the leading edge of the UG rib section with the 3rd protrusion of the VAs	0.903
87.875	Disengagement of the trailing edge of the UG ring forging from the 3rd protrusion on the VAs	
88.625	Disengagement of the trailing edge of the UG rib section from the 3rd protrusion on the VAs	

APPENDIX C

APPENDIX C

Potential Interference Points
Plenum Assembly/Storage Stand

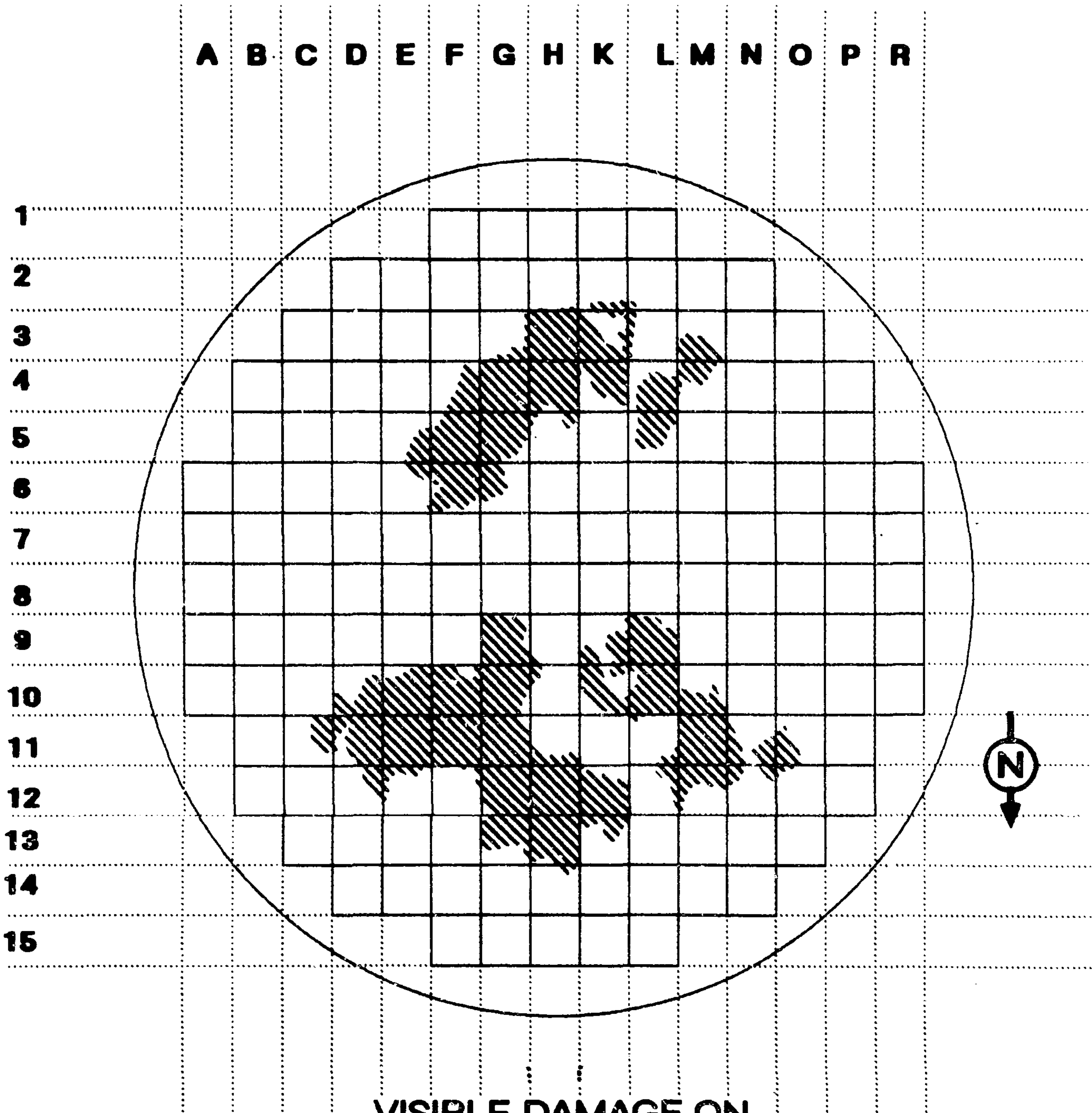
After the plenum was lifted free and clear of the reactor vessel, it was transferred north to the deep end of the refueling canal and lowered onto its storage stand. Previously installed targets were used to align the polar crane and plenum assembly over the storage stand. The deep end of the refueling canal was flooded with water up to elevation 327'2" ± 3" to provide shielding for the stored plenum. Since water turbidity precluded underwater monitoring of the lowering of the plenum, the following table was developed to monitor the elevation of the plenum as it was lowered onto the storage stand. The elevation of the plenum could be determined by either reading the laser beam or the water level on the elevation gauge mounted in the control rod guide tube assembly on the plenum cover. The table provided information to the lift control supervisor to resolve interferences due to plenum misalignment with the storage stand.

Table C

Potential Interference Points

Elevation Gauge Reading (inches)		Elevation of Top of Plenum Cover	Description	Water Shielding Above Top of Plenum CRGT	Nominal Radial Clearance (inches)
Laser Beam	Water Level				
		337'10"	Plenum enters water		
29	118	324'11"	Grid pads at the top of the storage stand	1'0"	6
26	115	324'8"	Plenum enters the first lead-in of the storage stand	1'3"	3-1/2
Top of Gauge	86	322'3"	Plenum enters the second lead-in of the storage stand	3'8"	1/2
--	68	320'9"	Plenum lands on the bottom of the storage stand	5'2"	

NOTE: Water level gauge readings are based on canal water level starting at elevation 327'2" and rising 6 inches during the submerging of the plenum assembly. Adjustments must be made for differences in actual water levels.



VISIBLE DAMAGE ON
PLENUM UNDERSIDE GRID
(LOOKING UP)

APPENDIX D

APPENDIX D

Plenum Lift Radiological Data

On May 15, 1985 the TMI-2 plenum assembly was lifted out of the reactor vessel and transferred to a storage stand located in the flooded deep end of the refueling canal. During the lift and transfer operations radiation levels were monitored in several locations within the reactor building. The detectors had remote readouts located in the shielded lift control station located on top of the "A" D-ring within the reactor building. A radiation controls technician in the lift control station continuously monitored the readings during the lift. Readings were recorded at about five minute intervals. The highest dose rate recorded at the lift control station was 30 mrem/hr and the highest dose rate recorded at any location during the lift was 80 rem/hr on detector 4 near the canal dam. Airborne radioactivity inside the reactor building was monitored during the lift. The monitor (an AMS-3) was located inside the shielded lift control station. After completion of the lift, the sample filter was analyzed and it indicated a gross beta gamma activity of 1.8×10^{-10} μCi/cc. All personnel in the reactor building during the lift wore BZA samplers and these indicated activities ranging from 1.6×10^{-10} μCi/cc to 3.2×10^{-10} μCi/cc. These levels are about the same as those experienced during other routine activities within the reactor building. The personnel in the reactor building during the plenum lift received an average of 146 mrem. The total man-rem for the plenum lift operation was 3.033 man-rem (latching was 1.095 man-rem, the lift and transfer was 0.710 man-rem, and unlatching was 1.228 man-rem). These values were lower than had been estimated. Attached are tables and exhibits that detail the radiological data recorded during plenum lift.

Table D-1

Plenum Lift Radiological Data

Detector Number	Detector Location	Detector Range	Estimated Peak Dose Rate	Actual Peak Dose Rate
1	In the shielded lift control station mounted on the side of the RMS-II readout panel	0.1 mrem/hr to 10 rem/hr (5 decades)	142 mrem/hr	30 mrem/hr
2	At the southwest corner of the defueling support structure 76" from the IIF and 42" above to support structure	0.1 rem/hr to 1000 rem/hr (4 decades)	24 rem/hr	20 rem/hhr
3	On the polar crane. 66' from the reactor building wall measured from the cab end and 5" above the walk-way	0.1 mrem/hr to 10 rem/hr (5 decades)	182 mrem/hr	300 mrem/hr
4	In the refueling canal just south of the dam on the RV centerline, 63" above the floor	0.1 rem/hr to 1000 rem/hr (4 decades)	--	80 rem/hr
5	On a handrail on top of the "A" D-ring east face near the centerline of the reactor vessel.	0.01 rem/hr to 100 rem/hr (4 decades)	--	500 mrem/hr
6	37" above the 347' elevation floor at the northwest corner of the refueling canal	0.01 rem/hr to 100 rem/hr (4 decades)	2.2 rem/hr*	15 rem/hr**
7	37" above the 347' elevation floor at the south end of the refueling canal near the access area to the polar crane spider	0.1 mrem/hr to 10 rem/hr (5 decades)	429 mrem/hr	200 mrem/hr

Table D-1 (continued)

Plenum Lift Radiological Data

Detector Number	Detector Location	Detector Range	Estimated Peak Dose Rate	Actual Peak Dose Rate
8	63" above the 347' elevation floor at the south end of the refueling canal on the centerline of the reactor vessel	0.01 rem/hr to 100 rem/hr (4 decades)	--	2 rem/hr

NOTE: An AMS-3 was also located within the shielded lift control station.

* Dose rate calculated with the plenum submerged in the deep end. The actual peak dose rate with the plenum submerged was between 250 and 3000 mrem/hr.

** Plenum was above the water.

Table D-2

Detector Readings During Lift Operations

Time	Detector Number								
	1	2	3	4	5	6	7	8	AMS-3
Initial 1205	10	100	80	Off Scale Low	100	30	60	50	500
1215	15	150	80	Off Scale Low	100	30	60	50	1000
1220	15	2 rem	100	100	150	300	80	400	1000
1225	20	15 rem	200	800	200	900	80	1 rem	1200
1230	25	15 rem	250	1.5 rem	200	1 rem	100	1.5 rem	1200
1235	30	20 rem	300	2 rem	200	1.5 rem	100	2 rem	1500
1240	30	20 rem	300	3 rem	200	1.5 rem	100	2 rem	1500
1245	30	20 rem	300	5 rem	250	1.5 rem	150	2 rem	1500

Notes:

1. All readings on detectors 1 through 8 are in mrem/hr unless otherwise noted.
2. Readings for AMS-3 are in counts per minute (cpm).
3. Detector 4 peaked at 80 rem at approximately 1328.
4. All times were taken from plenum lift video monitors in the coordination center.

Table D-2 (continued)

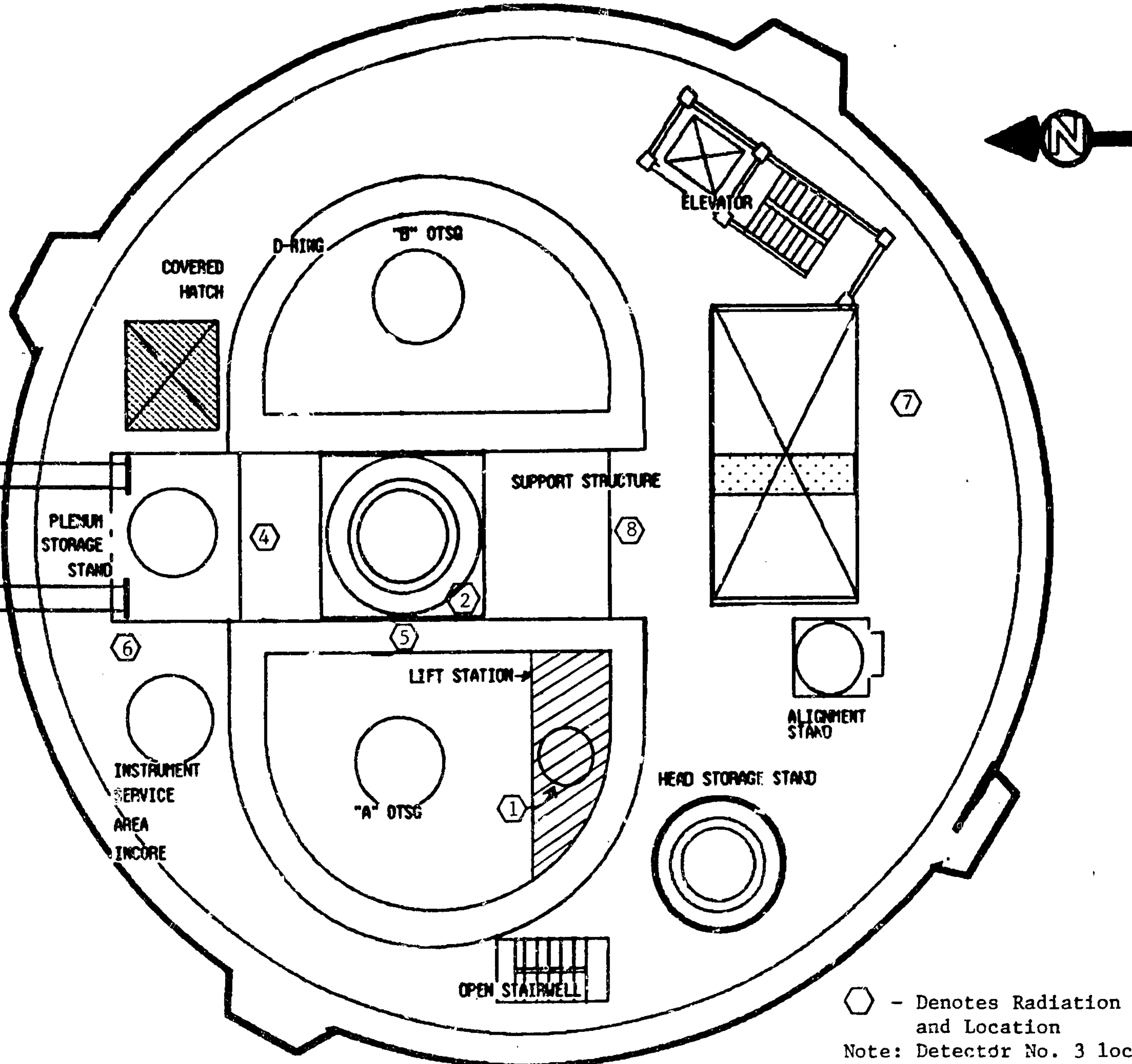
Detector Readings During Lift Operations

Time	Detector Number 1	2	3	4	5	6	7	8	AMS-3
1250	30	20 rem	300	5 rem	300	2 rem	150	2 rem	1500
1255	30	15 rem	300	5 rem	300	2 rem	150	2 rem	1500
1300	30	15 rem	300	5 rem	300	2 rem	150	1.5 rem	2000
1305	30	10 rem	300	5 rem	500	2 rem	150	1.5 rem	2000
1310	30	8 rem	300	7 rem	500	2 rem	150	1 rem	2000
1315	30	5 rem	300	10 rem	400	3 rem	200	700	2000
1320	30	4 rem	300	20 rem	500	4 rem	200	500	2000
1325	30	3 rem	300	60 rem	500	5 rem	200	400	2000
1330	30	3 rem	300	70 rem	400	7 rem	200	400	2000
1335	30	2.5 rem	300	40 rem	400	9 rem	200	300	2000
1340	30	2 rem	300	10 rem	300	10 rem	200	300	2000
1345	30	2 rem	300	5 rem	250	15 rem	200	250	2000
1350	30	1.5 rem	300	5 rem	250	15 rem	200	250	2000
1355	30	1.5 rem	300	4 rem	200	10 rem	150	250	2000
1400	30	1.5 rem	300	3 rem	200	10 rem	100	250	2000

Table D-2 (continued)

Detector Readings During Lift Operations

	Detector Number								
Time	1	2	3	4	5	6	7	8	AMS-3
1405	25	1.5 rem	300	4 rem	200	9 rem	100	300	2000
1410	25	2 rem	300	6 rem	200	8 rem	80	300	2000
1415	25	1.5 rem	300	5 rem	200	6 rem	80	300	2000
1420	25	1.5 rem	300	3 rem	200	5 rem	80	200	2000
1425	20	1 rem	300	2.5 rem	150	4 rem	80	200	2000
1430	20	900	200	2.5 rem	150	3 rem	70	200	2000
1435	15	100	100	Off Scale Low	100	250	60	60	2000
1440	15	100	80	Off Scale Low	100	40	50	50	2000
1445	15	100	70	Off Scale Low	90	35	50	50	2000
1450	15	100	70	Off Scale Low	90	35	50	50	2000



⬡ - Denotes Radiation Detector Number and Location

Note: Detector No. 3 located on middle of polar crane

Exhibit D-1 Location of Detectors

Exhibit D-2

MEASURED DOSE RATES - DETECTORS 1, 3, 5, 7

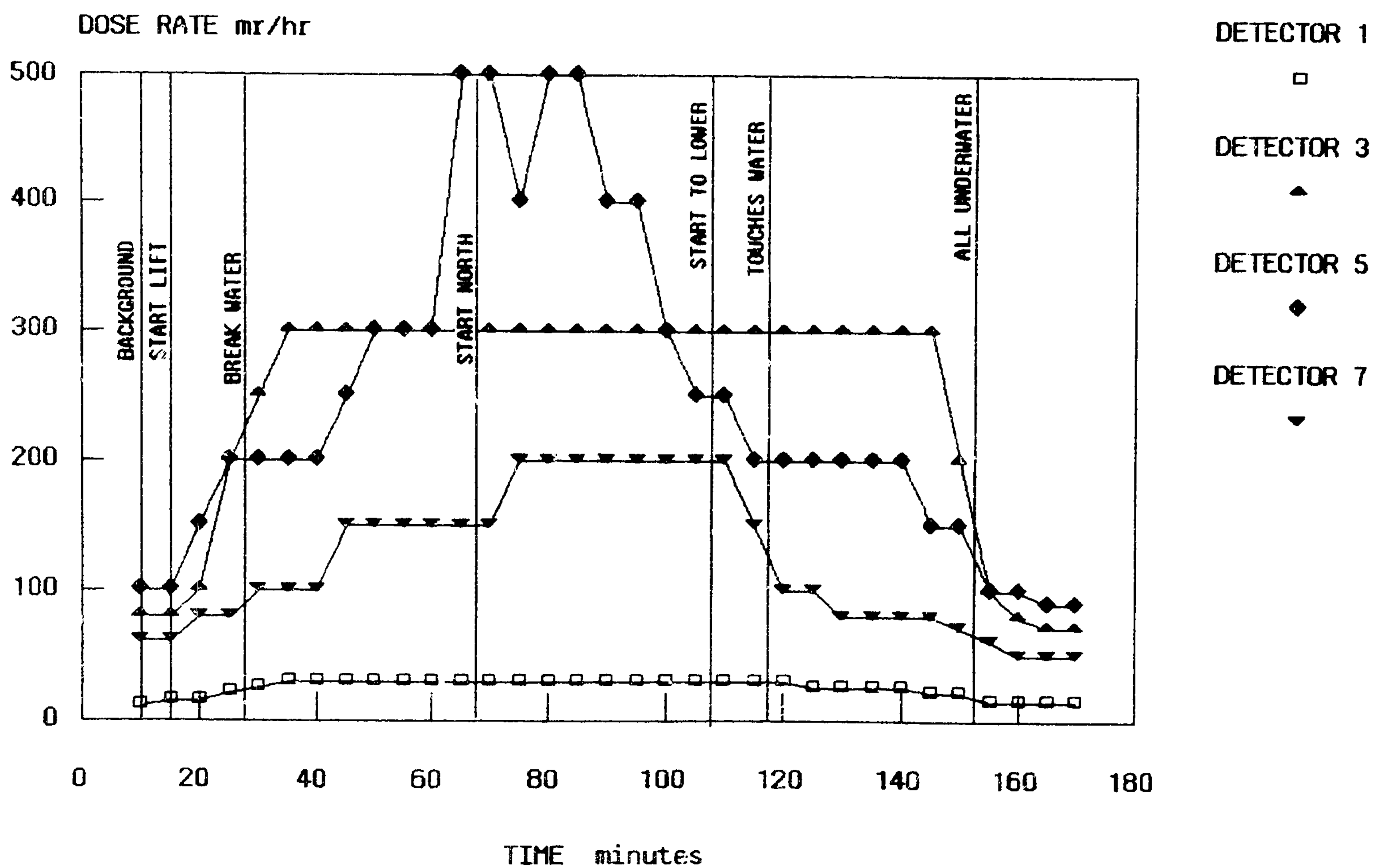
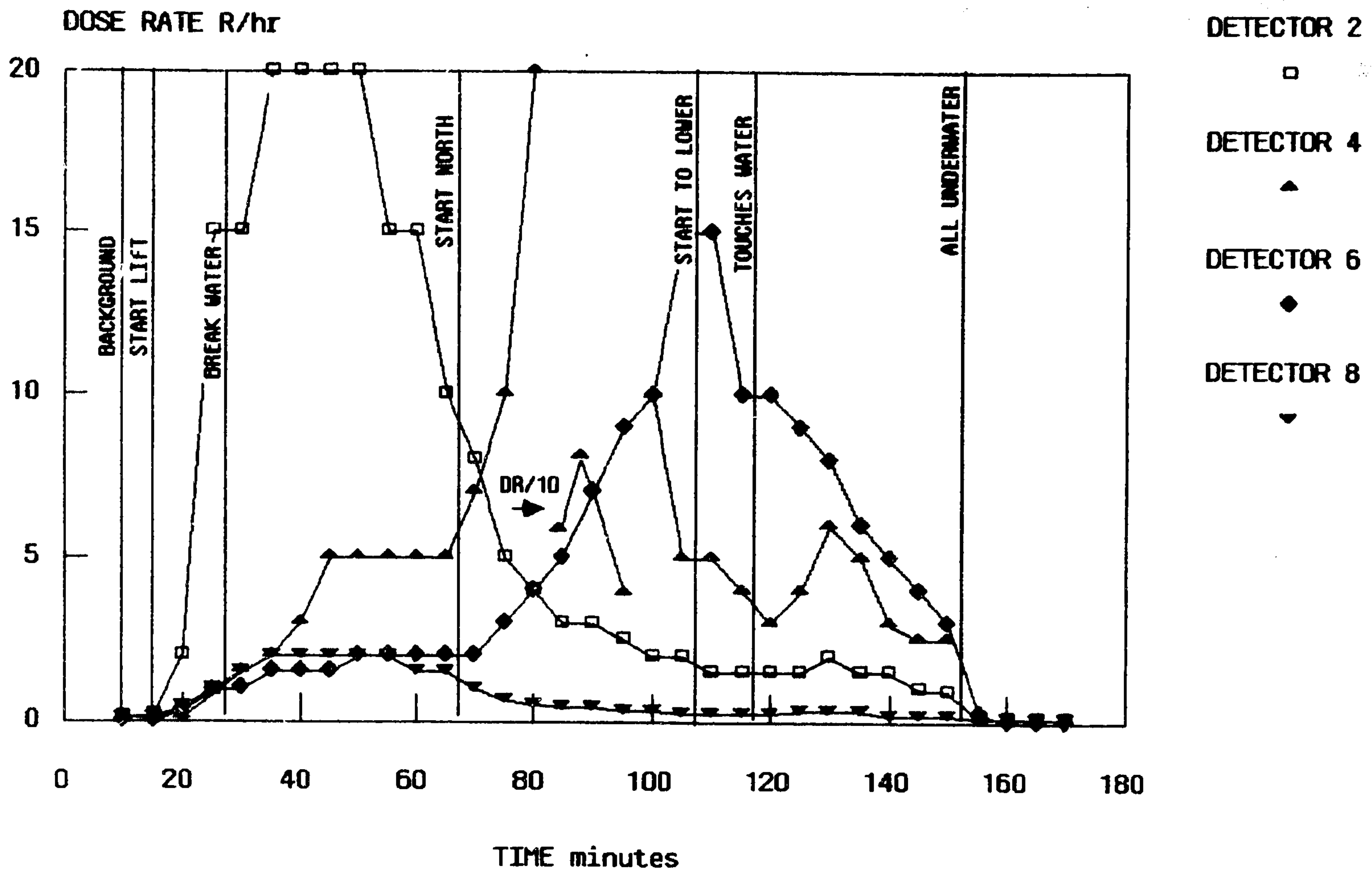


Exhibit D-3

MEASURED DOSE RATES - DETECTORS 2, 4, 6, 8



APPENDIX E

APPENDIX E

Lift Control Supervisor's Checklists

Checklists were developed to assist the lift control supervisor in assessing equipment, activities, and conditions to assure that prerequisites and preparations were completed and that a defined level of readiness was achieved prior to starting operations. Four of the key checklists are included as follows:

- Exhibit E-1 Pre-Dry Run Checklist
- Exhibit E-2 Video System Checklist
- Exhibit E-3 Hydra-Set Checklist
- Exhibit E-4 Pre Plenum Lift Checklist

Some items or activities are repeated on more than one checklist. This was done deliberately so that the dry run and the lift and transfer could be accomplished as independent operations.

Exhibit E-1

Pre-Dry Run Checklist

- [ ] The plenum final lift rigging is installed.

- [ ] The polar crane daily checks are completed.

- [ ] Personnel in the team have been trained to lower the polar crane spider.

- [ ] Both laser levels with stands are staged in the refueling canal.

- [ ] The bubble level and bubble level camera are staged in the refueling canal.

- [ ] Both hydra set control consoles are staged in the shielded lift control station.

- [ ] The dillon load cell is installed and serial number and calibration due date recorded.

- [ ] The defueling work platform support structure is installed.

- [ ] The cable management system is installed.

- [ ] Both pendant installation platforms are staged in the refueling canal.

- [ ] Both elevation gauges are staged in the refueling canal.

- [ ] Both maximum height gauges and clamps are staged in the refueling canal.

- [ ] Both pendant latch assist tools are staged in the refueling canal.

Exhibit E-1 (continued)

Pre-Dry Run Checklist

- [ ] Three unlatching assistance tools are staged.
- [ ] Spare pins for the latch/unlatch system are staged.
- [ ] Plenum alignment tool is staged in the refueling canal.
- [ ] Plenum latch verification camera and camera tool are stagec in the refueling canal.
- [ ] The support structure access ladder is staged in the refueling canal.
- [ ] The work platform alignment pin has been removed from the north side of the support structure.
- [ ] PAR video/audio is staged in the shielded lift control station.
- [ ] The bottom of plenum camera is staged in the refuleing canal.
- [ ] Six spare N_2 bottles and a wrench are staged on the D-ring near the shielded lift control station.
- [ ] A step ladder for laser leveling is staged in the refueling canal.
- [ ] The refueling canal access ladder is installed.
- [ ] Indexing targets for positioning the polar crane over the RV and plenum storage stand are installed.
- [ ] The catwalks between the D-ring's are removed.
- [ ] The IIF work platform is removed.

Exhibit E-1 (continued)

Pre-Dry Run Checklist

- [ ] The auxiliary bridge is parked at the south end of the refueling canal.

- [ ] The polar crane access "Spider" is located at the south end of the polar crane.

- [ ] An SRO is in the coordination center and communications have been established.

- [ ] Radiation detection equipment has been installed.

- [ ] Audio communications equipment has been installed.

Exhibit E-2 Video System Checklist

	PAN	TILT	ZOOM	FOCUS	LIGHT	IRIS	LIFT STATION MONITOR	COORDINATION CENTER MONITOR	Adequate Light/ Field of View	ACCEPTED
Camera Number 1A (Plenum Elevation Camera-East)					N/A			N/A		
Camera Number 1B (Plenum Elevation Camera-West)					N/A			N/A		
Camera Number 2A (P/C Target Camera-Primary)					N/A					
Camera Number 2B (P/C Target Camera-Backup)					N/A					
Camera Number 3 (Lift Station Monitor Camera)	N/A	N/A	N/A		N/A		N/A			
Camera Number 4 (Bubble Level Monitor Camera)	N/A	N/A	N/A							
Camera Number 5 (General Area Camera)					N/A		N/A			
Camera Number 6 (General Area Camera)					N/A		N/A			
Camera Number 7 (General Area Camera)					N/A		N/A			
Camera Number 8 (General Area Camera)					N/A		N/A			
Camera Number 9 (Bottom of Plenum Camera)										
Camera Tool Camera (Pendant Latch Verification)	N/A	N/A	N/A							

Exhibit E-3

Hydra-Set Checklist

REMOTE CONSOLE CHECKLIST		HYDRA SET "A"	HYDRA SET "B"
POSITION INDICATOR	ON		
	FUNCTIONAL (Set + and -)		
LOAD INDICATOR	ON		
	FUNCTIONAL		
N_2 SUPPLY BOTTLES	BOTTLE PRESSURE 2200 lbs		
	SPARE BOTTLE PRES 2200 lbs		
VALVES	BLEED VALVE CLOSED		
	LOAD GAUGE VALVE OPEN		
	SUPPLY VALVE OPEN		
REGULATORS INDICATOR	PRESET (Set to 1900 lbs)		
	LOAD REGULATOR CLOSED		
PRESET PRESSURE	SET AT 1900 lbs		
GAUGES	N2 SUPPLY FUNCTIONAL		
	PRESET FUNCTIONAL		
	LOAD FUNCTIONAL		

HYDRA-SET CHECKLIST		HYDRA SET "A"	HYDRA SET "C"
GAUGES	PRE LOAD OPERATIONAL		
	LOAD GAUGE OPERATIONAL		
LINES	POSITION INDICATOR ELEC.		
	LOAD INDICATOR ELEC.		
	GAS SUPPLY		
CABLE MANAGEMENT NO INTERFERENCES			
REMOTE HANDLES LOCKED INTO REMOTE OPERATION			
COTTER PINS INSTALLED			
PLUMBOB LINES WITHDRAWN (INTERFERENCE)			

Exhibit E-4

Pre-Plenum Lift Checklist

- [ ] Plenum lift rib inspections completed.
- [ ] A free lift path has been confirmed for the removal of the plenum assembly.
- [ ] IIF to Reactor Vessel key alignment has been verified.
- [ ] Loose debris has been flushed from the plenum assembly.
- [ ] Plenum jacks have been secured to the plenum cover assembly.
- [ ] The storage stand is installed in the deep end of the refueling canal.
- [ ] All polar crane functions are operational.
- [ ] The refueling canal dam is installed.
- [ ] Fuel transfer system modifications have been completed.
- [ ] DWCS installations in the deep end of the refueling canal have been completed.
- [ ] Fuel transfer canal drain pump modifications have been completed.
- [ ] Flanges on the reactor building side of the fuel transfer tubes have been removed.
- [ ] Blind flanges have been installed on the fuel pool "A" side of the fuel transfer tube gate valves.

Exhibit E-4 (continued)

Pre-Plenum Lift Checklist

- [ ] The polar crane pendant is located in the shielded lift control station.
- [ ] Pendant installation platforms have been staged in the refueling canal.
- [ ] The polar crane access spider has been lowered to elevation 347'.
- [ ] Both elevation gauges are installed.
- [ ] Both lasers are installed, indexed, and operational.
- [ ] Both plenum elevation cameras are operational and laser beams are visible on the elevation gauges.
- [ ] Hydra-Set control levers are locked into the remote operation position.
- [ ] The RCS sample line has been removed.
- [ ] The pendants have been latched to the plenum and verified by video inspection.
- [ ] Pendant installation platforms are moved east and west out of the load path.
- [ ] Both maximum height gauges have been installed.
- [ ] The refueling canal deep end is flooded to elevation 327'2" $\pm$ 3".
- [ ] Plenum final lift rigging has been inspected for structural damage or defects, broken wire strands, kinks, broken sheaves, unsecured pins, pinched cables, loose electrical connections, and any other defect that could affect the capability or operability of the equipment.

Exhibit E-4 (continued)

Pre-Plenum Lift Checklist

- |__| The auxiliary bridge has been moved to the south end of the refueling canal.

- |__| The auxiliary bridge is operational.

- |__| The auxiliary bridge rail is clear of all interferences.

- |__| The bubble level and camera is installed with the top of the picture on the video monitor pointing toward the "Y" axis of the plenum.

- |__| The bubble level monitor is marked with reference locations for pendants A, B, and C.

- |__| The Dillon load cell is operational.

- |__| Complete the video system checklist. (See Appendix E, Exhibit E-2).

- |__| Complete the Hydra-Set checklists. (See Appendix E, Exhibit E-3).

- |__| The dry run was completed successfully.

- |__| Water inventory is available to flood the refueling canal if necessary.

- |__| The refueling canal (deep end) water level is monitored by a remote indicating (in the control room) and alarming instrument.

- |__| At least one door on each personnel airlock is closed and secured.

- |__| The radiation monitors are operational.

- |__| Polar crane power is on.

Exhibit E-4 (continued)

Pre-Plenum Lift Checklist

- [ ] Polar crane index targets are installed and aligned properly.
- [ ] The catwalks between the D-rings have been removed.
- [ ] The IIF work platform has been moved.
- [ ] The defueling support structure has been installed.
- [ ] The lift control supervisor has acknowledged his responsibility.
- [ ] Communications have been established between the control room (SRO) and the lift team in the reactor building.