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## **TMI-2 DEFUELING TOOLS ENGINEERING REPORT**

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## **ABSTRACT**

This report describes the design and integration of the TMI-2 defueling system. It covers the technical and functional requirements, integration of the design of the equipment, and planned methods of implementation. The scope of the defueling system described is restricted to that which relates to accessing core debris within the reactor vessel and loading it into defueling canisters. The Appendix summarizes specific in-vessel tools to be used in defueling operations.

The prime contractor for supply of these equipment items was Westinghouse Electric Corporation. These activities were directed by GPU Nuclear Corporation (GPUN) Design Engineering, under the overall management of GPUN Recovery Programs Department.

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TMI-2 Defueling System Design Description

# TMI-2 DEFUELING TOOLS ENGINEERING REPORT

## 1.0 INTRODUCTION

### 1.1 Background

A major milestone in the TMI-2 Reactor Building Disassembly and Defueling Program is the removal of most of the accessible fuel from the reactor vessel. Accessible fuel is the fuel that is found within the core support assembly and any fines/debris below the lower grid that may be accessible.

The preliminary planning efforts for defueling were presented in June 1982, as part of the TMI-2 Plenum/Fuel Removal Preliminary Design Study (PDS) and the Technical Plan on Reactor Disassembly and Defueling (Reference 1). Since that time, new information has been gained as the result of various ongoing activities, including extensive core video and ultrasonic surveillance, and debris bed sampling. Conceptual designs and cost estimates were also prepared based on remote/manual and robotic techniques.

To that end, a task group was formed in December 1983 to review various defueling system approaches based on known core conditions and available or proposed tool designs. This group provided input in the form of cost and defueling assumptions, operational sequences, tool lists, and ALARA reviews. For each tooling option proposed by the tooling vendor, the group developed scoping for the support required to prepare for and perform the defueling. Based on this input, Recovery Programs performed an overall systems cost and schedule/operations comparative analysis of the remote/manual versus robotic defueling method.

At the same time, a Feasibility Review Group (FRG) was formed to review the scope and assumptions of the task group. The FRG evaluated the technical feasibility of each option presented, and identified open technical and licensing issues together with their assessment of the comparative programmatic risk between options. The FRG discussed its findings with the GPU Nuclear (GPUN) General Office Review Board (GORB), Safety Advisory Board (SAB), Technical Advisory and Assistance Group (TAAG), and the Nuclear Regulatory Commission (NRC).

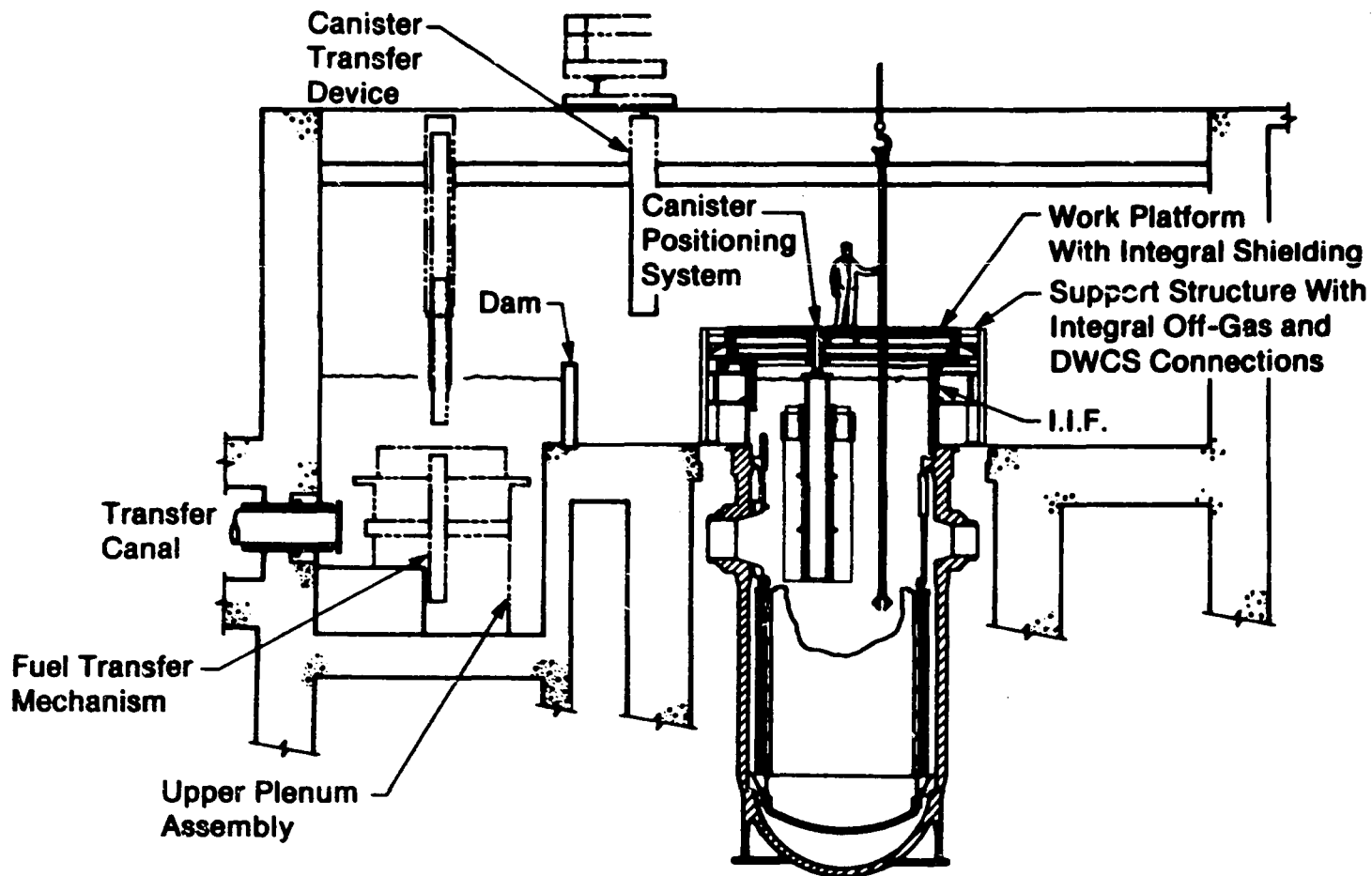
In May 1984, a GPUN task force (Reference 2) concluded that project resources should be used to support delivery of those defueling tools that would be used during the early stages of defueling (pick and place and vacuuming loose debris).

Also, in May 1984, the final decision on the defueling approach was made. The basic design was to maintain a dry shallow end of the refueling canal. A shielded work platform would then be placed over the reactor vessel/internals indexing fixture (IIF) to allow fuel handling operations to remain within the reactor vessel. The IIF would permit the reactor vessel water level to be raised above the shallow end of the refueling canal. The depth of the water would be sufficiently low as to facilitate the direct use of long-handled tools and also significantly reduce the volume of water that would have to be processed to maintain radiation levels ALARA. A dam was installed between the shallow end and deep end of the refueling canal so that the flooded deep end could provide water shielding for the stored plenum assembly and for defueling canisters in the fuel transfer upenders. (See Figure 1-1). To transfer the defueling canisters, new fuel handling trolleys with shield collars were required for the reactor building and the fuel handling building.

Core debris removal was planned to begin using the simplest, least developmental methods and to proceed toward more complex and developmental methods as knowledge and experience were gained.

Under task order 14 of subcontract K-9067 subtask 4, GPUN has provided a defueling system that will permit the start of defueling in 1985. Major components include a shielded work platform and associated support structure, canister positioning system, vacuum system, control system (including hydraulics), and video and lighting system. A toolbox for early defueling activities includes numerous end-effectors, poles, work stations, and debris buckets. Defueling tools for the bulk region of the core, based on the previously developed core condition, are in various stages of development. The Appendix provides a description of the equipment delivered by the major tooling subcontractor (Westinghouse).

Figure 1-1 Early defuelling system





A change in programmatic direction for future work was necessitated by the recognition that the probable core condition (based on 1985 data acquisition) includes a hard crust just below the loose debris, and once molten masses (oxidized and unoxidized ceramic/metallic properties) fused to structural components in the core support assembly lower grid and lower flow baffle regions. The new tools will be developed based on an integrated assessment of tool requirements to defuel the lower core region, including the core support assembly (CSA) and the lower head region.

Early defueling tooling, now on site, is capable of removing the debris in the upper section of the core. This tooling can remove the majority of debris located above the hard crust. It is expected that some "klinkers" (debris that cannot fit into a fuel canister and/or be cut up using shearing tools) will be moved around during early defueling, but not sectioned small enough to place into fuel canisters since early defueling cutting equipment has limited capabilities.

Bulk tooling will be provided to cut up klinkers, section and remove brittle hard crust material, remove partial fuel assemblies, cut and remove incore instrumentation, and vacuum limited areas of the lower grid.

New data available concerning the core condition in the lower core region (below the rubble bed) and the material characteristics identified by the analysis of debris samples indicate that the hard crust below the rubble bed may not be brittle and that it may extend and/or be mixed with large stainless steel components. These new data have required reevaluation of the bulk tooling capabilities and development of additional tooling, as well as rethinking the planning for lower vessel head defueling programs. Tooling to accommodate the new data includes additional core cutting equipment, hard crust defueling equipment, and incore instrument removal equipment. This new tooling will be an extension of the capabilities of the tooling provided for the core region. The tooling will also be designed to cut and remove ductile materials, both in place and as separate pieces that can be moved to cutting station. Unlike brittle materials, ductile materials require more rigid and precise cutting techniques. The tooling will also be required to adapt to a wide range of positions and orientation.

Based on the developmental nature of the program and the availability of core data, the next steps of defueling will have to be developed around the timing of data acquisition tasks. As data become available they will be input to each of the tool developments being affected, and the development program will be adjusted as required.

In addition to the data acquisition tasks feeding into the design of the new tooling, the integrated tooling approach allows feedback from ongoing operator training activities. These operators will continue to participate in design reviews. Their firsthand knowledge of tool operations will be a valuable asset for new equipment developments.

The EG&G core stratification sample drilling equipment is being evaluated as a production core cutting and lower vessel head access tool. Developments from this evaluation and modifications to the program plans will be integrated with the base tooling development program.

Subsequent to defueling the vessel's upper and central core region, the implementation of the additional defueling tooling, supported under other tasks, will permit the removal of most of the fuel and core debris remaining in the reactor vessel. As a means to this end, the tooling system will provide the capability to prepare, handle, and contain or otherwise control the CSA and lower head region's fuel, core debris, and related structural components for storage and ultimate disposal.

## 1.2 Scope

The functional requirements, technical specifications, integration of the tooling development, and methods of implementation associated with defueling operations are described in this report.

The defueling tooling system consists of the following major elements:

- Early defueling tools
- Bulk core region defueling tools

For this report, defueling operations are defined as those activities involved with placing core debris existing in the reactor vessel into defueling canisters and the transfer of those canisters to storage in the fuel handling building. The methods described represent planned operations used as design bases for development of the defueling tooling system. The actual approach and sequence of operations may differ depending on core conditions encountered.

Other components/systems that support the defueling effort but are not part of the scope of this report include defueling canisters (fuel, filter, and knockout), material handling devices (i.e., canister handling bridge and trolleys, reactor building service crane, and fuel transfer system), the fuel transfer canal dam, fuel storage racks, and the dewatering system.

The damaged TMI-2 core will be defueled by loading the debris into defueling canisters. The canisters are then transferred through several stages of canister transfer and storage and are dewatered before shipping. To maintain contamination control and radiation levels as low as reasonably achievable (ALARA), a defueling water cleanup system (DWCS) is provided to process the water volumes associated with defueling.

The defueling tooling system (see Appendix for detailed discussion) is made up of a work platform over the reactor vessel and associated tooling that is used within the reactor vessel. The work platform provides the following major functions:

- Support for operators working over the reactor vessel
- Shielding of operators
- Support and positioning of system components
- Support of defueling canisters during loading
- Contamination control

Fuel and fuel components from the damaged core will be placed in defueling canisters for transfer out of the reactor vessel and for shipping off the TMI-2 site. Shipping of the debris is not covered by the scope of this report.

## 2.0 METHODS AND APPROACH

The overall TMI-2 defueling program has been defined in the summary Technical Plan for TMI-2 Program Strategy (Reference 3), the Technical Plan for Reactor Disassembly and Defueling (Reference 1), and other management directions to TMI-2 Recovery Programs. The TMI-2 Defueling System Design Document (Reference 4) is intended to implement the TMI-2 defueling technical plans. It established the defueling system approach and functional requirements upon which all the defueling tools and activities are based. With the established defueling system approach and functional requirements, efforts were made to integrate all tools and equipment for core removal. To this end, the major design interfaces among the various participating engineering and vendor organizations were identified and controlled. This is being accomplished by the TMI-2 Reactor Defueling Interface Control Document (Reference 5). In addition, this document also identifies the major technical specifications that define the design criteria and requirements for each defueling tool.

Section 2.1 presents the TMI-2 defueling system approach and functional requirements for all defueling tools and equipment. Section 2.2 summarizes the various activities for integrating the defueling tools and equipment. Finally, all defueling tools and equipment are introduced in Section 2.3.

### 2.1 Defueling Approach and Functional Requirements

The prime objective of TMI-2 recovery is the completion of defueling. The defueling program is intended to evolve in stages. The initial priorities are being directed toward the first stage of defueling, which is designed to pick and place upper end fittings, to vacuum the loose debris, and to pick apart the upper layers of the damaged core below the loose debris. All these activities are planned to be consistent with the following defueling system approach.

- Fuel handling begins with the most simple and least developmental methods and proceeds toward more complex and developmental methods as they are needed and available.

- Water depths are sufficiently low as to make the direct use of long-handled manual tooling practical.
- As a result of using various types of defueling canisters, fuel handling operations remain within the reactor vessel. Thus, high activity and low activity waters are isolated and the volume of high activity water is minimized. The potential for wide distribution of irradiated fuel beyond the reactor vessel is also minimized.
- Tooling and equipment are straightforward and simple. The flexibility to use other fuel removal and transfer schemes is retained.
- The predicted radiation doses and potential contamination problems are acceptable and can be minimized for the given defueling system approach.

The defueling system approach described above consists of several general guidelines that the defueling tool design must follow. These general guidelines can be represented by the more specific functional approach described in Section 2.1.1.

The above defueling activities are also planned to satisfy the functional requirements described in Section 2.1.2. These functional requirements are for the design of the defueling tooling and plant modifications required to remove the damaged core.

### 2.1.1 Functional Approach

Following is the functional approach that guided the development of the defueling system.

- The basic defueling scheme is the dry defueling scheme with the water level approximately 5 feet above the reactor vessel flange, with the IIF in place. Fuel will be vacuumed or mechanically

placed in canisters within the reactor vessel. The canisters will be transferred, using the reactor building canister handling bridge, to the fuel transfer system in the deep end of the canal or to available storage positions in the deep end of the fuel transfer canal. Of the 11 canister storage positions in the canal, eight are occupied by the DWCS.

- The plenum was placed in the deep end of the fuel transfer canal, as far north as practical, on the normal storage stand.
- A rotating shielded work platform is designed to accommodate a remotely operated manipulator. The rotating platform design also accommodates the use of manual tools.
- Defueling tooling system component controls, including video controls, are located at the work stations in the reactor building. The only exceptions are the remote manipulator arm and video monitors, which have control locations both inside the reactor building and in the coordination center.
- The canisters have a singular outside design configuration to accommodate a variety of core debris such as partial fuel assemblies, including end fittings, vacuumable debris, and filter bundles. The canisters have a 14-inch nominal diameter and 150-inch maximum overall length.
- Design of defueling components is on the basis that they can be taken into the reactor building without removing the equipment hatch.
- Special efforts are made to ensure lowest practicable ambient radiation fields at work stations, both by reducing the concentration of radioactive materials in the water in the vessel and by reducing direct radiation from the fuel debris and the loaded canisters.

- The initial set of tools/end effectors to be provided to start each phase of defueling are based on a best estimate of core condition. As specific core conditions that require other tools are identified, the tools will be provided.
- Spent fuel pool A must be flooded to permit transfer of loaded defueling canisters.

## 2.1.2 Functional Requirements

The functional requirements consist of: a) general performance requirements, b) plant service requirements, and c) other requirements (i.e., equipment hatch, spare parts and maintenance). These are defined as follows.

2.1.2.1 General Performance Requirements. General performance requirements are divided into three categories.

### 1. Overall Requirements

- The requirements for ALARA, criticality safety, and the minimization of radwaste shall be given high priority in all defueling activities.
- The overall goal of the in-vessel fuel removal activity is the transfer of all readily accessible core material in the reactor vessel to storage in the fuel handling building. The program will have follow-up activities associated with removal of fuel from nonaccessible areas of the reactor vessel (under the core support assembly) and from the remainder of the reactor coolant system.
- Fuel is to be transferred from the reactor vessel only within closed canisters. The canisters may be partially or fully dewatered prior to transfer.

- Techniques and tooling shall be provided for removing all accessible core material from the reactor vessel and loading it into disposal containers.
- Techniques and tooling shall be capable of dealing with any combination of the core material physical conditions described in GPUN's Core Conditions Design Bases (Reference 6).
- Standardized, multipurpose tools should be used to the extent practical to minimize the number of tools required for the fuel removal program.
- Any intentional operation that results in damage to the core support assembly (CSA), which precludes CSA removal from the reactor vessel, is prohibited.
- Damage to the reactor vessel is prohibited, unless otherwise authorized by GPUN.
- Noncore materials are not to be placed into the defueling canisters, except to the extent that any of these materials may have become inseparably mixed with the core materials; however, if any such materials are unavoidably included, the canister inventory must identify the materials.
- Provisions shall be made for removing incore instrumentation strings through the reactor vessel.
- The capabilities for videotape recording of fuel removal and fuel canister loading operations and for weighing the physical quantity of fuel and fuel components removed from the reactor vessel are required for the fuel removal program.
- The defueling test assembly (DTA) shall be used for equipment qualification and operator training to the maximum extent practical.



- A canister dewatering station will be provided.
- Recovery equipment will not be designed to satisfy plant seismic requirements, unless identified specifically for a particular piece of equipment.
- Rigging design shall preclude lifting fuel debris higher than 4 feet (nominal) beneath the design basis water level or the equivalent shielded distance.

## 2. Capacities and Throughputs

- Normal maximum shipping weight of a dewatered, loaded canister will be 2800 pounds.
- The DWCS shall have the capacity to process the in-vessel reactor coolant water at the rate of 400 gpm for suspended solids processing, and at 60 gpm for soluble radioisotope processing.
- The target rate for canister loading and transfer to storage is one canister per day.
- For storage prior to offsite shipment, a minimum capacity of 250 canisters shall be provided.
- Total defueling effort (including ex-vessel defueling) should be accomplished with 288 debris-filled canisters or less.

## 3. Design Parameters Associated with Shielding, Source Terms, and Dose Rates

- The reactor coolant system fuel transfer canal and spent fuel pool A water shall be processed to maintain water clarity to 1 NTU. The reactor coolant system shall be processed to

maintain Cs-137 concentration below 0.02  $\mu\text{Ci/ml}$ . The concentrations of other radionuclides present in the RCS water will be controlled operationally.

- The defueling systems should be designed to operate such that the average dose rates are limited as follows (excluding background):

12 mrem/hour 18 inches above the open slot.

2 mrem/hour 18 inches above the rotating work platform.

10 mrem/hour on the canister handling bridge during canister transfer.

15 mrem/hour 7 feet from the canister transfer shield during canister transfer.

2.5 mrem/hour in the fuel handling building during non-canister transfer activities.

- Specific transient operations (especially canister transfers) may result in dose rates higher than the stated average dose rate goals. These transient operations will either be limited in time of duration or frequency, or both, so that the average dose rate goals are approached. Personnel protection during these operations will be determined operationally and may consist of area evacuation, restricted access, shield plate insertion into the work platform slots, or use of temporary shielding. Shielding should be flexible in design and not hamper or limit operations.

**2.1.2.2 Plant Service Requirements.** Plant service requirements are ded into seven categories.

**1. Criteria Governing Plant Arrangements**

- The plenum shall be removed from the vessel and stored in the north end of the canal.
- The IIF is installed on the reactor vessel flange and filled with water to elevation  $327'-6" \pm 3"$ .
- A work platform/support structure shall be provided above the IIF and shall be supported by the canal floor.
- Canister storage racks shall be provided in the deep end of the canal for temporary storage of 11 filled canisters, including installed locations of the DWCS filter canisters.
- The approved cable management system operates horizontally and avoids the need for a maypole or other protrusions above the work platform. The platform rotation is limited to about  $\pm 180$  degrees as a result.
- The major components of the DWCS for in-vessel cleanup are located in/next to the fuel transfer canal. The canal and pool processing equipment is located in or near spent fuel pool A.
- A dam shall be erected across the deep end of the canal to maintain a canal and fuel pool A water level at elevation  $327'-3"$  (+8", -2"). The dam seal shall meet commercial standards for leaktightness.
- A leakage collection system will be provided in the shallow end of the canal.

- The auxiliary fuel handling bridge in the reactor building and the storage fuel handling bridge in the fuel handling building shall be modified to transfer loaded canisters. The main fuel handling bridge shall be removed from the reactor building.
- A 5-ton reactor building service crane supported on the D-ring and extending beyond either side shall be provided.
- Compressed air (service and instrument) will be provided to support defueling activities as required.
- The canister dewatering station will be located in the fuel handling building.
- The plenum assembly removal audio system will be expanded to six channels in the reactor building and will be extended to the fuel handling building to permit direct conversations between the reactor and fuel handling buildings.

## 2. Required Plant Modifications

- The fuel transfer systems shall be modified to upgrade the carriage drive system and transfer canisters out of the reactor building.
- Electrical power supply for various systems will be provided.
- A spare reactor building electrical penetration shall be used to route cables from the reactor building to the coordination center for operation of the remote manipulator.

## 3. Material Handling Criteria

- The defueling operation shall be supported by overhead handling equipment, including the polar crane, the 5-ton reactor building service crane, handling equipment such as jib

cranes mounted on the work platform, the reactor building canister handling bridge, and the fuel handling building canister handling bridge.

- Rigging design shall preclude lifting fuel debris higher than 4 feet (nominal) beneath the design basis water level or the equivalent shielded distance.

#### 4. Airborne Radioactivity Control

- Criteria for airborne radioactivity control required that a means be provided to ensure a positive down draft ventilation through the defueling work platform of 150 feet per minute through the largest opening.

#### 5. Requirements for Control of Defueling Equipment

- Defueling tool manipulation will be from the defueling work platform aided by a local monitor. Video control and monitors will be provided on elevation 347'-6" and supplementary monitors will be provided in the coordination center.
- The reactor building canister handling bridge will be controlled from a control panel on top of the trolley inside the reactor building.
- The fuel transfer system is controlled from panels on elevation 347'-6" in the reactor building and elevation 349'-6" of the fuel handling building.
- The shallow end drainage collection system is operated from a control panel in the fuel handling building.
- The canister handling bridge in the fuel handling building will be controlled from a control panel on top of the trolley in the fuel handling building.

- The dewatering station will be manually operated from the system platform over the A pool and from a control area on elevation 347'-6".
- The vacuum system is controlled from two locations. The vacuum pump is controlled from the control console located near the rotating work platform, while the knockout canister connection/weighing apparatus is controlled from the local service panel located on the rotating work platform.
- The DWCS subsystem that processes the reactor coolant is controlled from a control panel located in the fuel handling building. Cleanup pumps will have local emergency stop and hand switches.
- The DWCS subsystem that processes the fuel transfer canal and spent fuel pool A is controlled from the same control panel located in the fuel handling building.

## 6. Canal Leakage

- The assumption that governed canal recovery is that a fuel transfer canal leak rate (gpm) can be determined in a 24-hour period with the fuel transfer canal water level monitoring system. This assumes that the transfer tubes are open to the spent fuel pool.

## 7. Health Physics Requirements

- Personnel doses are continuously monitored and tracked.
- Continuous air and area radiation monitoring will occur when defueling activities are in progress.
- Protective clothing and respiratory protection guidelines will be issued, as necessary, to maintain worker doses ALARA.

- Personnel access can be limited or restricted when high dose rates are expected or encountered.
- In the unlikely event of higher than expected dose rates, field-installed temporary shielding may be used to maintain worker doses ALARA.
- Fuel handling building and containment air will be filtered and monitored prior to release to the environment.

**2.1.2.3 Other Requirements.** Other miscellaneous functional requirements associated with tooling development include the following:

- Defueling equipment is designed so that it can be taken into containment without removing the equipment hatch.
- Spare parts shall be provided for all equipment whose breakdown is considered possible during normal defueling activities, and which could cause a significant delay in defueling activities.
- All equipment to be operated within the reactor shall be designed to be remotely removable and/or remotely maintainable.
- All equipment shall be supplied with scheduled (periodic) maintenance requirements and instructions.

## **2.2 TMI-2 Integration of Defueling Tools**

This section summarizes the various activities required for defueling tool integration.

### **2.2.1 Data Acquisition**

The accident at TMI-2 on March 28, 1979, caused extensive damage to the core. Many analyses were performed, using three general approaches to determine the extent of core damage. First, thermal-hydraulic events were

reconstructed using available data, thermal-hydraulic principles, and computer analyses. Second, determinations of the hydrogen generated yielded estimates of the amount of Zircaloy oxidized and embrittled. Third, the type and quantity of fission products released during the accident were used to estimate the location of core damage and fuel temperatures. Uncertainties exist in each type of determination due to the equivocal nature of the data. Further data on the fuel conditions have been obtained by the following inspections and operations:

- Camera examination of the center of the core region
- Removal of three control rod drive mechanism (CRDM) leadscrews
- Uncoupling of all but three CRDM leadscrews
- A probe insertion into the core debris bed
- Underhead characterization program
- Axial power shaping rod dynamic test

These inspections and operations, as well as others of substance, were documented in the report on the insertion of a camera into the TMI-2 reactor vessel through a leadscrew opening (Reference 7). In addition, the following operations have occurred:

- Core topography examination and explanations
- Multiple detailed video examinations
- Leadscrew segmentation/examination
- Core debris grab samples
- Axial neutron profile analysis
- Bottom head/lower CSA video examination

The data gained from these inspections and operations have been factored into the design bases for defueling tooling and are presented in the core conditions design bases (Reference 6).

Based on data acquisition (i.e., debris bed probe, lower head video, second lower head video, and hydraulic displacement test), a change in programmatic direction for future work was necessitated due to the recognition that the probable core conditions include a hard crust just below the loose



debris, and once molten masses (oxidized and unoxidized ceramic/metallic properties) are fused to structural components in the core support assembly lower grid and lower flow baffle regions.

Ongoing data acquisition tasks will be factored in the future defueling tooling design or modifications as they become available. Inspections will be carried out to determine the quantity of debris in the lower core region, lower internals, bottom head, and ex-vessel regions. All data acquisition tasks will be scheduled and performed in time frames that do not interfere with other data acquisition or defueling activities.

## 2.2.2 Defueling Systems Comparative Evaluations

2.2.2.1 Introduction. A major milestone in the TMI-2 Reactor Disassembly and Defueling Program is the removal of most of the accessible fuel from the reactor vessel. Accessible fuel is fuel that is found within the core support assembly and any fines/debris below the lower grid that may be accessible by vacuuming techniques.

Conceptual designs and cost estimates for defueling were prepared based on remote/manual and robotic defueling techniques (Reference 8). An overall systems cost/schedule/operations comparative analysis of the remote/manual versus robotic defueling method was performed.

Four major options were evaluated:

- Remote/manual, pick and place with canisters
- Remote/manual, pick and place with shredder
- Robotic, pick and place with shredder
- Robotic, mining, with shredder

The evaluation discusses the following programmatic decisions:

- Remote/manual versus robotic tooling
- Pick and place versus mining core removal
- In-containment versus slurry/vacuum to fuel handling building

2.2.2.2 Conclusions and Recommendations. The objective of the comparative evaluation was to focus on the major decisions that needed to be resolved in order to initiate the design of the defueling system. After examining the concepts presented by the tooling vendor and previous studies (TMI-2 Preliminary Design Study for Defueling), three issues were identified that required programmatic direction.

- Should the defueling be performed largely manually from inside the containment, or should remotely controlled (i.e., robotic) tooling be provided that can be operated primarily from outside the containment?
- Should a cautious approach to removing the core debris be invoked in the tool design, or can higher production techniques (with a possible less conservative approach) be employed?
- Should the slurry effluent of debris from the vacuum system be transported to canisters located in the containment, or to canisters located in the fuel handling building?

The tooling concepts included a) the remote/manual concept, which consists of long-handled tools operated remotely through 40 feet of water from inside the containment, and b) the robotic concept, which consists of a robotic positioning arm and remotely controlled mining jaws that place the core debris in a shredder. These were evaluated comparatively with and without the shredder tool and with the slurry effluent being transported to the containment and to the fuel building.

In May of 1984, the final decision on the defueling approach was made. The basic design was to maintain a dry shallow end of the refueling canal. A shielded work platform would then be placed over the reactor vessel from which operators using the long-handled tools could operate the defueling equipment. This approach had the following advantages over the other methods:

- The use of long-handled tools becomes more feasible (30 feet maximum versus 45 feet).

- All canister filling is done in the vessel, which confines all contamination to one area.
- There is a smaller volume of water to be processed by the DWCS.
- The equipment operators on the shielded work platform perform the defueling operations in a lower background radiation field than if they were working over a flooded canal.

Since the operators will be standing approximately 9 feet above the reactor vessel flange, a work platform is provided. This shielded work platform provides the shielding so that the contaminated water and the radioactive debris in the reactor vessel would not be a major radiation source for personnel.

The shielded work platform is positioned over the reactor vessel and supported from the refueling canal floor by the shielded support structure. Various lines for water treatment and air ventilation are routed under and through the shielded support structure into the reactor vessel. Other defueling equipment such as vacuum system, canister positioning system, local service panel of the control system, and jib cranes are supported from the shielded work platform.

### 2.2.3 ALARA

It was recognized early in the defueling system design program that tooling must be designed to ensure that radiation exposures during core removal operations were minimized.

To ensure that appropriate design consideration was given to operator doses during the recovery, an ALARA design implementation program was established, which is based on two project documents. The General Project Design Criteria lists the design bases for all recovery engineering work. Included in the design criteria is an ALARA Items List. This list presents detailed guidelines to design engineers for incorporating features that will:

- a) minimize installation, operation, and maintenance time in radiation areas,

b) minimize the spread of contamination and the buildup of contamination sources, and c) maximize shielding consistent with structural and operational constraints. The ALARA Design Implementation Instruction documents the individuals responsible for implementing the ALARA program. Specific responsibilities are listed for design engineers, the nuclear discipline group supervisor, the design engineering manager, and the ALARA coordinator. The method of documenting ALARA design considerations is also included.

All design work was required to be carried out within the ALARA program. The major defueling system design vendors were also required to develop ALARA programs. These programs were evaluated to ensure that the proper ALARA design overview would be provided throughout the design phase. Documentation of ALARA review was submitted as part of the design packages.

The implementation of the ALARA program resulted in a defueling system that should allow for relatively low worker dose, given the special problems of the damaged core and continuing background radiation sources from building contamination. Several design optimization studies were performed and are summarized as follows.

The defueling work platform was designed so that operators would have maximum operational flexibility during canister loading operations. Specific features include a rotating capability, removable shield panels for access to the vessel, and a canister positioning system that may contain up to five canisters. The defueling work platform provides sufficient shielding to ensure that dose rates to operators are maintained low during normal operations and during defueling canister transfer operations.

Defueling canisters in the reactor vessel are shielded to ensure that dose rates to operators working over the open tool slot are minimized. A 4-inch-thick steel plug may be placed on loaded canisters in the canister positioning system, and all canisters in the vessel are positioned in 1-inch-thick steel-shielded baskets. This was done so that the dose rate to operators from canisters would be equivalent to the dose rate from the reactor coolant, a source that cannot be easily shielded.

The canister transfer shield (CTS) was designed so that the entire canister length would be shielded during all canister transfer operations. The shielding thickness was limited by the structural loading of the existing refueling bridge, and by space limitations. It was a goal to limit the dose rate to the trolley operators to 10 mrem/hour from a canister in the CTS. A 3-inch-thick shield plug inside the CTS reduces the dose rate to the trolley operator to 5 mrem/hour or less. The maximum dose rate to operators on the rotatable work platform will be limited to 100 mrem/hour for all transfer operations.

To provide a training facility for defueling operators, a large tank was modified to provide a reactor vessel mock-up. The defueling test assembly (DTA) is used to test tooling, check for tooling interferences, and train operators. The DTA was fabricated to simulate the reactor vessel during defueling. Portholes were provided to allow visual monitoring of tooling operations.

Various long-handled tools were designed to perform specific functions related to core debris removal. Ease of operation and maintenance was a major design factor. Long-handled tools are rigged by overhead jib cranes to facilitate operations, and rigging is designed to prevent the inadvertent lifting of fuel debris close to the water surface.

#### 2.2.4 Preliminary Design Reviews

As part of general program requirements, a preliminary design review was required for each defueling tool group (Reference 9). Before conducting a design review meeting, the Preliminary Design Review Package was submitted by the vendor for review. This review included various defueling organizations. The package included at least the following information associated with the tool group:

- Preliminary design documents of sufficient detail to verify that both the vendor-developed design criteria and functional requirements were satisfied.

- The cost, success potential, schedule impact, operating efficiency, and ALARA review used in selecting the design.
- Any problem areas with the selected design were identified and an action plan given, including testing required, for resolving these problems.
- Vendor-developed design criteria and functional requirements for each tool item of the tool group.
- The steps, techniques, and tooling that form the design were described. Plant interface requirements were also identified.
- A description of and results of any tests required to aid in the selection of the design were included.
- Any hardware items that required a long time to procure and thus affected the schedule were identified. Actions were recommended to prevent schedule delays.

Technical design issues and operation issues were addressed in the meeting and direction provided for incorporation in the final design package.

#### 2.2.5 Final Design Reviews

A final design report for the final system design was then provided with the following items:

- Assembly and detail drawings
- Piping and instrument diagrams (P&IDs)
- Vendor drawings
- Outline dimensions, services, and foundation/mounting detail drawings
- Control logic diagrams
- Cleaning and coating procedures

- Test procedures for resolving problem areas
- Wiring diagrams
- Critical weld review package
- Inventory list and recommended spare parts list
- Operating instructions

The final system description for each tool group was submitted for permission to proceed with fabrication and to document the final system design. The description included at least the following information:

- A description and results of analytical evaluations or tests required to resolve problem areas identified in design review meetings.
- The final design criteria and functional requirements for individual tooling and equipment items.
- All plant interface requirements, such as service air, water, power, access, and material handling requirements.
- A program plan outline for equipment checkout at the vendor's facilities. The test assemblies to be used for equipment checkout were identified in this outline.

For final design review, GPUN conducted a review for compliance with the design specification, for technical adequacy and interface dimensions, and for site operations requirements.

## 2.2.6 Fabrication, Testing, and Acceptance

2.2.6.1 Fabrication. Assembly and detail drawings for each tool item provide sufficient detail to fabricate and assemble the component parts of each equipment item. These drawings also provided all dimensions, weights, interface connection points, materials, and the electrical power requirements of each equipment item. The drawings contained sufficient information, such as reference drawing numbers, for use at the jobsite in handling and storage

of equipment, writing procedures, and training operators. All vendor drawings, catalogs, and descriptive/maintenance information for equipment subcontracted by the vendor for off-the-shelf items were submitted for information.

#### 2.2.6.2 Testing

##### 1. Checkout Guidelines

To ensure that the defueling tool systems will perform as intended, the vendor conducted suitable testing to verify the systems design features. Transition from equipment development and fabrication, through checkout, and into defueling was made up of the following key steps:

- Component checks
- Subsystem checks
- Qualification of equipment on test assemblies
- Training of operators on defueling test assembly (DTA)

The guidelines for managing these steps are discussed in the following paragraphs.

Defueling components as a whole were checked at the completion of fabrication per procurement requirements. These checks included dimensional checks, fit-up tests, operability, etc. For most components, these checks were the responsibility of the component vendor.

Qualification of equipment on test assemblies or on the defueling test assembly was not the sole responsibility of the vendors and their subvendors. In many cases Recovery Programs, in conjunction with the vendors, was responsible for qualification tests. In general, for qualification tests performed at TMI-2, Recovery Programs had the lead responsibility. For tests at vendors' facilities, the vendors had the lead responsibility.



## 2. Specific Mock-up Equipment

The following mock-up equipment on the defueling test assembly (DTA) was used to qualify the defueling tools and equipment. It will be used for operator training.

- Simulated support structure on the DTA is only to provide support for the simulated work platform.
- Simulated work platform was installed on the operating deck of the turbine building above the defueling test assembly. The platform was used to qualify some defueling tools and will be used in defueling operating training. It includes the following features:
  - The platform simulates the beam support configuration to the maximum extent practical.
  - Shielding on the platform is simulated with box sections. Panel geometric shapes are identical to the actual work platform.
  - The platform does not have a rotational capability.
  - The Thomson rail systems, which allow travel of the supported tools along the work platform slots, and the geometry of the handrails are identical to the actual work platform.
  - The interfaces between the simulated work platform and the following equipment are identical to actual work platform interfaces:
    - 1) Vacuum system
    - 2) Canister positioning system
    - 3) Single canister support bracket
    - 4) Jib cranes
    - 5) Local service panel
  - The simulated work platform does not consider future use with core drill equipment.
  - The platform simulates the "T" slot and long-handled tool slot.

- The platform cover has a checker plate surface.
  - A spray or wash-down system simulating the defueling equipment is part of the simulated work platform design.
- The following equipment is actually a duplicate of equipment used in the reactor vessel:
    - Jib cranes
    - Underwater viewing system
    - Vacuum system
    - Canister positioning system
    - Single canister support bracket
    - Long-handled tools
    - Local service panel
  - Simulated debris was provided in the DTA to use for tooling checkout and training operators in equipment and tool use.
  - A minimum number of fuel and knockout canisters will be used for training and checkout.

### 3. Specific Functional Checkouts Accomplished by GPUN

Based on developed checkout guidelines and mock-up equipment available in the DTA, the following functional checkouts were accomplished by GPUN:

- Work Platform
  - Interfaced work platform with jib cranes, mock-up support structure and handrail, adjusted roller assemblies.
  - Interfaced work platform mounted on the mock-up support structure with the cable management system, south auxiliary platform, platform shielding, vacuum system, and single canister support bracket.
  - Functionally tested work platform operation. Checked drive motor power use, motor resistance, and smooth operation.

- **Cable Management System**

- Interfaced with work platform and south auxiliary platforms. Verified fit-up.
- Functionally tested system operation with work platform rotation. Verified hydraulic line and electric line connections. Verified continuity of electric lines. Verified counterweight and power track operation.

- **Auxiliary Platforms (south of the support structure)**

- Interfaced with work platform, service platform, cable management system, and support structure. Verified fit-up.

- **Vacuum System - Canister Positioning System**

- Interfaced with work platform mock-up and the DTA. Verified fit-up.
- Operated vacuum system and checked pump performance. Verified that hose connect/disconnect tools and equipment were functional. Verified that pressure and flow transducers were operational. Verified that system controls were operational.
- Functionally tested canister positioning system. Verified that canister positioning system interlock was operational. Verified that canister connect assembly was operational. Verified that hydraulic system was leaktight.

- **Control System and Long-Handled Tools**

- Interfaced with each other and with simulated work platform.
- Functionally tested control system operation and checked hydraulic system performance (including modified redundant isolation capability)

2.2.6.3 Acceptance. Acceptance checkout of specially manufactured tools and equipment for defueling was performed on the site. Modifications to the tools and equipment necessary to satisfy defueling operations were made. After tools and equipment satisfactorily passed the acceptance checkout, they were formally accepted by GPUN for defueling purposes.

## 2.2.7 Defueling Tooling Sequence Document

The TMI-2 defueling will be accomplished by loading the core debris into defueling canisters and transferring the canisters into the fuel handling building via the transfer tube. To ensure smooth operations during defueling, a defueling tooling sequence document (Reference 4) was developed to satisfy the following objectives:

- To verify the adequacy of the tool inventory list.
- To consider the interactions of all the defueling tooling equipment to ensure that the equipment can perform as a system.
- To consider the interaction of in-vessel activities with canister handling activities.
- To present a plan that deals with potential contingency situations.

The following operational constraints for defueling tools were assumed during the development of the defueling tool sequence document.

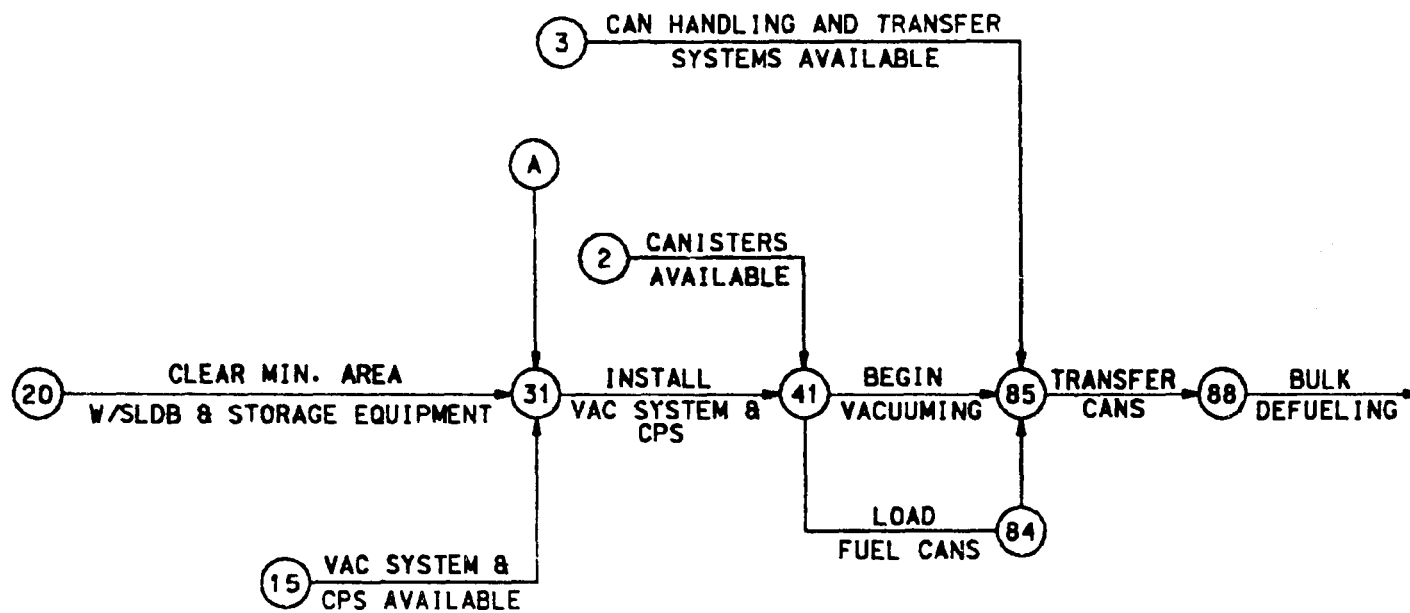
- The tool slot, an 18-inch-wide diametral opening in the work platform, provides access to the reactor vessel for tools. It is assumed that tools that come in direct contact with debris could be difficult to decontaminate. Therefore, the sequence assumes that these tools should remain hanging in the slot for multiple steps and will not be removed unless absolutely required. Examples of these tools include shear tools, debris scoops, tongs, vacuum nozzle, etc.

- Tools that do not come in direct contact with core debris should be more easily decontaminated. These can be inserted, used, removed from the slot, decontaminated, and stored in a rack near the vessel or in a more remote storage location. Therefore, the sequence does not consider these tools to require reactor vessel space allocation when changing operations. Examples of these tools include canister/sleeve and vacuum hose handling tools, valve actuating tools, weighing system components, etc.
- There are several tools that come in contact with fuel that either require some contact operations on the work platform (e.g., threading the steel loop through the clamp of the banding tool) or maintenance (e.g., changeout of cutter blades). For this sequence, the assumption is that these steps can be accomplished with reasonable effort in conjunction with the ongoing defueling operations.
- Vertical movement of fuel will be limited so that there is always at least the equivalent of 4 feet of water shielding, based on the nominal water level, above fuel (fuel debris) being handled in the reactor vessel. This is intended to prevent the inadvertent lifting of a large mass of fuel high enough to cause excessive exposure to personnel on the work platform. The lift restriction will be implemented mechanically through the use of rigging bars and limit switches.

The logic diagram for defueling operations is shown in Figure 2-1.

Figure 2-2 provides a listing of the detailed operations and typical tools required to perform the steps in the logic diagram shown in Figure 2-1. A defueling operation in the figure is defined as an activity that results in the movement or change in one item of fuel debris or to one part of a configuration. This involves one tool or set of tools working on one item of debris. For example, loading an end fitting into a fuel canister is a defueling operation. A defueling step, represented by a circle with a number in Figure 2-1, is defined as a series of defueling operations resulting in movement or change to a class of items of fuel debris. For example, surveying the debris bed is a defueling step. By examining the interaction of several

Figure 2-1 Defuelling logic



20 to 31	Survey top of bed	Position lights and cameras, photograph with CCTV tooling Use hook tool to move debris Use probe to test depth of debris	Camera handling tools  Debris probe/measuring tool Grapple assemblies/hook tools
20 to 31	Clear minimum area for installing CPS (Objective: clear an area down to El. 308')	Install debris bucket stands Install side loading debris bucket (SLDB) and TLDB Move partial fuel assemblies Install debris clamping station Pick up end fittings Load into debris clamping station Cut off tubes Load small debris into SLDB, store endfittings Cut individual tubes	Camera handling tools Debris bucket handling tool Debris clamping station Work platform debris bucket hanger Tong tools Vise grips Grapple assemblies/hook tools Bolt cutters Single rod shears Heavy-duty shears Parting wedge
31 to 41	Install CPS	Move CPS, work platform shield section Install CPS structure Install one or more can sleeves Install canisters (knockout or fuel)	CPS maintenance lift fixture Sleeve handling tool Grapple tool Seal cover/index sleeve handling tool Vacuum system socket wrench
31 to 41	Install vacuum system	Move shield plates Install vacuum system Install vacuum nozzle tool Connect piping Test system	Manually operated grapple Vacuum system socket wrench Hose connection tool Quick disconnect tool Hook tool Disconnect tool Standard rigging
41 to 85	Start vacuuming operations		Vacuum nozzle handling tool

Figure 2-2. Canister positioning system (CPS).

<u>Step</u>	<u>Operation</u>	<u>Tools Required</u>
41 to 84	Load fuel canisters	Camera handling tools Debris bucket handling tools End fitting loading tool Partial fuel assembly loading tool Clamshell tool Tong tool Vise grips Grapple assemblies/hook tools Spade bucket tools
85 to 88	Transfer fuel canisters Remove funnel Weigh canister Move fuel canister from loading elevation to transfer elevation Inspect seal and install cover Rotate CPS to position subject canister in transfer position Install working slot shielding Transfer canister Replace canister and remove slot shielding	Seal cover/index sleeve handling tool Sleeve handling tool Socket wrench Camera handling tool Closure head handling tool Grapple tool Canister handling bridge grapple
85 to 88	Transfer knockout canisters Verify correct weight from load cell monitor Disconnect (automatically) hose couplings/weighing system Rotate CPS to position subject knockout canister in transfer position Transfer canister Replace canister and remove slot shielding	Seal cover/index sleeve handling tool Socket wrench Grapple tool Canister handling bridge grapple

Figure 2-2. (Continued)



steps, one can determine how many tools are likely to be in the tool slot at any one time. This exercise involves certain assumptions concerning the nature of the debris geometry, etc.; therefore, it is not meant to dictate tool management, but to provide preliminary input. The knowledge gained during checkout/training will provide valuable input in this regard.

The prerequisites to the listed logic sequence are removal of the plenum, installation of the support structure and work platform, availability of the reactor vessel portion of the DWCS and work platform ventilation system, and the viewing system provided for the plenum assembly removal (PAR) efforts and long-handled tools availability. Fuel and knockout canisters and/or the canister handling bridges and transfer systems are not required to begin the sequence.

Partial fuel assemblies, peripheral, standing, and full length fuel assemblies, and end fittings have been separated from the plenum and are now in the void region. Due to the difficulty of clearing this space, a significant area of uncertainty exists in defining the preparation needed for installing the CPS. This preparation will consist of moving, rearranging, and storing debris that has fallen down from the plenum onto the debris bed such that room can be ensured for the placement of a canister at an elevation compatible with debris loading while satisfying the 4-foot exclusion zone.

The preferred approach is to install the CPS as soon as possible, since it offers maximum flexibility in loading canisters and vacuuming operations, and promotes efficient canister transfer operations.

Only debris that is 2 feet 6 inches long or less can be directly loaded during the initial period of defueling operations using the CPS, due to the 4-foot exclusion zone. This limitation will persist until vacuuming operations lower the existing debris bed (including debris knocked off the plenum) by approximately 2 to 3 feet. At that time, the length of debris that can be accommodated by a fuel canister will be increased to 6 feet 6 inches.

A debris bed survey performed during the initial stages of defueling activities will clearly be valuable input to continued sequence planning. Although there are many uncertainties in the core condition, the tool

inventory is adequate to handle those core conditions identified to date. Sufficient equipment for core data acquisition activities will be available at any time during the defueling sequence, although no provisions for these activities are shown in the overall sequence.

A matrix of the functional requirements was developed using the previous two major sequences and anticipated future defueling operations. Table 2-1 represents a matrix of the various planned operations versus the tooling required. The applicability of a particular tool to a specific task is indicated in the matrix by the presence of a circle at the intersection of that column and row. Solid circles represent the primary choice for tooling when more than one tool can perform the same task.

This matrix identifies all currently anticipated tooling for the early and bulk defueling tasks. The objective of this matrix is to provide a system of tools necessary to defuel the TMI-2 reactor vessel, including lower fuel core region, CSA, and head in a well-organized manner. Subsequent to developing the early defueling tools, the development of the remaining defueling tools will ensure the removal of essentially all the fuel and core debris in the reactor vessel.

#### 2.2.8 Interface Control Document

In an effort to establish a means for control of TMI-2 reactor defueling tooling system design features that require the interaction of various designs, constructions, or manufacturing organizations to ensure compatibility, the Interface Control Document (Reference 5) was developed for implementation. This document covers interface features deemed essential to proper integration of various defueling tools and equipment. It is largely for the purpose of integrating various design activities under the control of Design Engineering.

The major interfaces for defueling tools and equipment are briefly described in Section 2.2.8.1. Section 2.2.8.2 includes the definitions for interface and control interface. The procedures to implement the Interface Control Document are presented in Section 2.2.8.3.

TOOLS		OPERATIONS																			
		INSPECT BEFORE EACH DEFUELING OPERATION	INSPECT AFTER EACH DEFUELING OPERATION	VISUAL REPORT OF OPERATION	EARLY	1. VACUUM	2. PICK AND PLACE LOAD	3. LOAD BUCKETS INTO CANISTERS	4. TRIM TUBES OFF AND FITTINGS	5. LOAD CANISTERS	6. CORE REGION	1. VACUUM	2. DEBRIS LARGER THAN 1/2" x 1 1/2" LONG	3. LOAD DEBRIS BUCKETS	4. BREAK UP LARGE PIECES & CRUSH IN PLACE	5. SIZE LARGE PIECES 20" x 50" PIECES	6. PICK & PLACE LOAD CANISTERS	7. REMOVE REMAINING FUEL ASSEMBLIES	8. CUT IN-CORE TRIM	9. TRIM REMAINING FUEL ASSEMBLIES	10. LOAD CANISTERS
EARLY DEFUELING TOOLS																					
	VACUUM SYSTEM					•						•	•								
	CANISTER POSITIONING SYSTEM					•	•	•		•											
	VIEWING SYSTEM	•	•	•																	
	LONG HANDLED TOOLS																				
	CUTTING TOOLS								•											•	
	GRIPPERS					•		•				•			•						
	LOADING TOOLS								•				•				•				•
	HANDLING TOOLS						•							•		•	•				
	AUXILIARY EQUIPMENT					•	•	•	•				•				•	•			•
A-1	CUTTING STATION															•				•	
A-2	MANUAL TOOL POSITIONER											•			•		•				
A-3	PARTIAL FUEL ASSEMBLY TOOLS																	•			
A-4	VIEWING SYSTEM	•	•	•																	
A-5	INCORE INSTRUMENT REMOVAL/CUTTING TOOLS																		•		
A-6	LOWER GRID VACUUM NOZZLES											•									
A-7	IMPACT CHISEL													•							
B-1	LOWER GRID CUTTING EQUIPMENT																				
B-2	STORAGE PROVISIONS																				
B-3	LOWER HEAD ACCESS USING NTP																				
B-4	INCORE REMOVAL/CUTTING EQUIPMENT																				
B-5	TRANSITION ZONE DEFUELING EQUIPMENT																				
B-6	CORE REGION CUTTING EQUIPMENT																				
B-7	HYDROLASER CUTTING EQUIPMENT																				
B-8	ABRASIVE SAW CUTTING EQUIPMENT														•						
B-9	REMOTE MANIPULATOR											•									
C-1	LOWER HEAD REGION FUEL REMOVAL TOOLS																				
C-2	VACUUM NOZZLES																				
C-3	LARGE DEBRIS VACUUM EQUIPMENT																				
D-1	VACUUM NOZZLES																				
D-2	ACCESS HOLE CUTTING EQUIPMENT																				
D-3	REACTOR VESSEL ISOLATION																				
D-4	COLD LEG ACCESS EQUIPMENT																				
E-1	CORE BORE																				

## REQUIREMENTS

[illegible]

**LEGEND :**

- PREFERRED CHOICE
  - ⊙ SECONDARY CHOICE
  - TERTIARY CHOICE
- A: CORE REGION FUEL REMOVAL EQUIPMENT
  - B: FLOW BAFFLE REGION OF CSA (ACCESS FOR LOWER HEAD REGION, AND DEFUELING)
  - C: LOWER HEAD REGION FUEL REMOVAL
  - D: CSA FUEL REMOVAL
  - E: CORE SAMPLING

2.2.8.1 Major Interfaces. Early defueling of TMI-2 will be accomplished primarily by vacuuming the small loose debris in the upper region of the damaged core. This can be achieved by using the fines/debris vacuum system, which is located under the rotating shielded work platform. The vacuum system, supported and operated from the rotatable shielded work platform, can access multiple knockout canisters mounted on the canister positioning system without the transfer of canisters outside the reactor vessel. Since the canister elevations must vary to meet operational requirements, the canister positioning system can support canisters at three elevations (top of canister: 324'-11", 321'-0", and 317'-0").

In addition to the removal of small loose debris, additional core material such as fuel rods, spacer grids, etc. will be removed during early defueling. This material is too large to be vacuumed but small enough to be handled with relative ease using manually operated or hydraulically operated long-handled tools. The tools will be used through the T-slot and the long-handled tool slot of the rotatable shielded work platform, to pick and place this additional core material into debris buckets for subsequent deposition into fuel canisters. In addition, these tools will be used to move heavier material, such as end fittings and partial fuel assemblies, out of the way to facilitate vacuuming.

The long-handled tools are hydraulically powered using a specific hydraulic fluid in limited and controlled quantities supplied by the TMI-2 control system. The control system provides the electrical, hydraulic, and air distribution systems to operate the shielded work platform, vacuum system, long-handled tools, and viewing system. The control system also provides a cable management system to organize and control the movement of the electrical cables and hoses, which must rotate with the shielded work platform. The cable management system routes the cables and hoses from the canal floor onto the shielded work platform.

Compatibility is one of the prime objectives in designing the above systems. This can be achieved by controlling the interface characteristics.

### 2.2.8.2 Definitions.

- Interface - a point, feature, dimension, envelope, or characteristic, the details of which must be known and agreed upon by more than one organization.
- Control interface - an interface, which once established by issuance of the Interface Control Document, shall not be changed or revised in any way by any organization except by means described in the TMI-2 Reactor Defueling Interface Control Document Change Procedure.

### 2.2.8.3 Procedures.

- Identification of Interfaces

Interfaces are identified in the course of design development. External interface information to be controlled shall be determined based on the purpose and scope described above. Any involved organization may identify proposed controlled interfaces as the need arises. Design Engineering shall, however, decide which interfaces are to be a part of the Interface Control Document.

- Exchange of Interface Information

Exchange of design and interface information among the various organizations shall be through Design Engineering. Design Engineering shall provide design drawings or communication by other methods as deemed appropriate to ensure coordination of interface information. Those interfaces requiring a high degree of interorganizational coordination are identified by this document. Interfaces identified shall not be changed except as described in the change procedure.

- **Interface Control Document Issue**

The Interface Control Document shall be issued in accordance with Design Engineering procedures. Revisions of the document will be issued as deemed necessary to add, delete, or revise interface information. Generally, a revision will consist of the cover sheet, revision index, and affected pages and figures. Additions to, deletions from, and changes to interface information shall not be incorporated in the document, nor used by the involved organizations, except as described in the change procedure.

- **Distribution**

This document is provided to various organizations for their use. It is also provided to other entities of the TMI-2 Recovery Project for their information.

- **The defueling related equipment/systems having interfaces controlled by the Interface Control Document include the following:**

- Interface coordination
- Canister design
- Shipping cask
- Fuel removal tooling and fines/debris vacuum system
- Defueling water cleanup system
- Fuel transfer system modifications
- Fuel canister storage racks
- TMI-2 facility arrangement and service
- Interim storage and handling facility
- Core data acquisition
- Fuel canister fabricator
- Reactor building and fuel handling building, canister handling bridges/trolleys
- Fuel transfer cask and loading collar
- Dewatering system
- Canister handling tools

## **2.2.9 TMI-2 Defueling Safety Evaluation Reports**

The following licensing documents were prepared in support of early defueling activities.

**2.2.9.1 Safety Evaluation Report for Early Defueling.** This safety evaluation report (SER) is the basic document describing the early defueling activities and providing the justification for concluding that early defueling activities will be performed in a safe manner. It provides a summary description of the early defueling activities and the equipment and systems to be used. The document assesses the safety aspects of early defueling activities and various accidents that could potentially occur while performing the early defueling activities. It also assesses the environmental impact of the early defueling activities. Where appropriate, this SER references the other licensing documents associated with the early defueling activities.

**2.2.9.2 Safety Evaluation Reports for Heavy Load Handling.** These documents provide the NUREG-0612 evaluation for handling heavy loads during early defueling activities. The criteria to be satisfied are provided along with guidelines (e.g., lift height vs. weight) to ensure compliance. The effects of dropped loads on plant structures and systems are addressed.

**2.2.9.3 Technical Evaluation Report for Defueling Water Cleanup System.** This technical evaluation report (TER) presents the design bases for the completed DWCS and provides the information needed to demonstrate that the system will satisfy its safety functions. It addresses interfacing requirements with other plant systems and equipment; in particular, interface requirements with the canisters are discussed. The system described in the DWCS TER is more extensive than the portion to be used for early defueling activities.

**2.2.9.4 Criticality Report for the Reactor Coolant System.** This report establishes the boron concentration needed in the reactor vessel coolant to ensure subcriticality during early defueling activities. The report describes the various analyses that have been performed in establishing the boron concentration and the conservatisms inherent in those analyses.



2.2.9.5 Technical Evaluation Report for Defueling Canisters. This TER presents the design bases for the three types of canisters (fuel, filter, and knockout) that will be used during early defueling. It provides the information needed to demonstrate that the canisters can safely perform their functions.

2.2.9.6 Technical Evaluation Report for Defueling Canister Storage Racks. This TER presents the design bases for the canister storage racks in both the fuel transfer canal and the spent fuel pool. It provides the information needed to demonstrate that the canister storage racks will perform their safety functions. Summaries of the relevant analyses are included.

#### 2.2.10 Integration of Knockout and Filter Canister with Vacuum System Design

The vacuum system is designed to remove debris from the reactor core by vacuuming. Debris is vacuumed through the nozzle and transported through 2-inch stainless steel pipe and 2-inch flexible hose to a knockout canister (Figure 2-3). The knockout canister can be supported either from the canister positioning system or the single canister support bracket. Because of the hydraulic flow profile established in the canister, debris particle sizes up to an intact fuel pellet are deposited. The effluent from the knockout canister is then drawn through the pump and discharged into a filter canister, where debris down to a size of 0.5 micron is entrapped. The discharge is then returned to the reactor vessel. The system test results established a required flow rate of 60 gpm to vacuum debris up to a fuel pellet in size. This is 79 percent of the maximum design flow rate (76 gpm), thus providing the design margin that ensures system flexibility.

#### 2.2.11 Arrangements in Reactor Vessel

The early defueling tooling equipment is available prior to the start of defueling; however, its actual installation and use will be conducted in a staged approach. The following sections describe this two-phase approach to defueling.

2.2.11.1 Initial Early Fuel Removal Arrangement (Phase I). The goal of this phase of defueling is to prepare the upper surface of the core debris bed

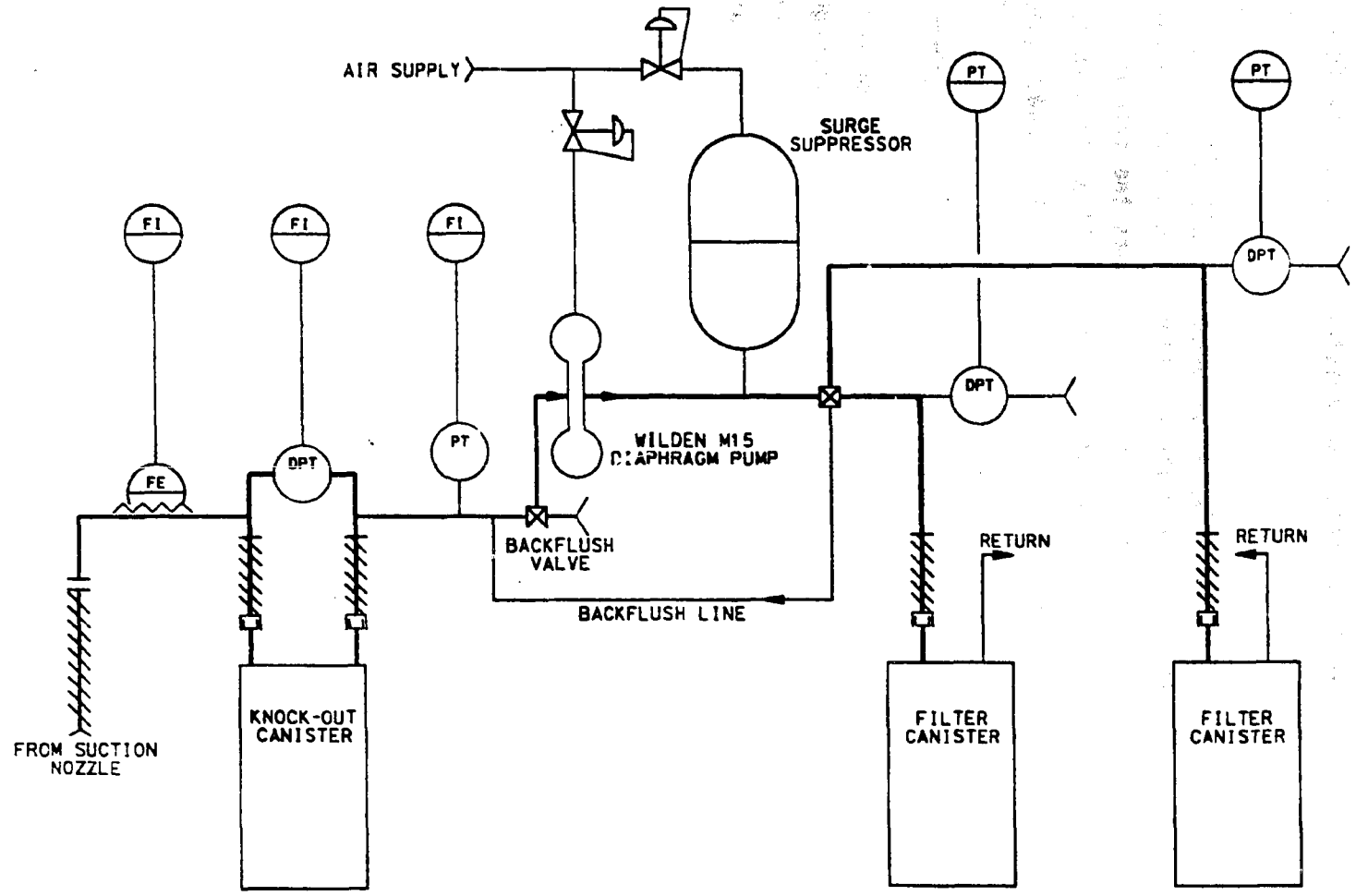


Figure 2-3. Vacuum system P&ID.

for the start of fines/debris vacuuming. There is limited pick and place capabilities, using long-handled tools, debris buckets, etc., and limited canister loading ability. Figure 2-4 illustrates a general arrangement of equipment for this phase.

The key defueling equipment and tools, in addition to the work platform and support structure, are the canister positioning system (or the single canister bracket) and miscellaneous long-handled tools. Debris buckets and stands will be used for temporary storage of debris and are designed to maximize final packing density of the fuel canisters.

Types of defueling operations for Phase I are:

- Loading fuel canisters with debris small enough to be loaded without cutting
- Reorganizing large debris fragments (assembly fragments) to make way for vacuuming
- Scooping of small loose debris into fuel canisters
- Loading debris buckets with debris
- Loading fuel canisters with debris buckets
- Sizing and loading end fittings into fuel canisters
- Transferring of loaded fuel canisters

2.2.11.2 Early Fuel Vacuuming Arrangement (Phase II). The goal of this phase of defueling is to vacuum as much of the vacuumable debris as practical from the core region. Figure 2-5 illustrates a general arrangement of equipment for Phase II.

Equipment used in Phase I will be augmented by the vacuum system and the canister positioning system. If the single canister bracket can continue to be a productive component it need not be removed. Its removal is an operational decision. The vacuum and canister positioning systems will be available for use at the start of Phase I. The point in time in which they are installed is another operational decision.

Types of defueling operations for Phase II are:

- Reorganizing and/or segregating large debris fragments

Figure 2-4. Defueling — Phase I.

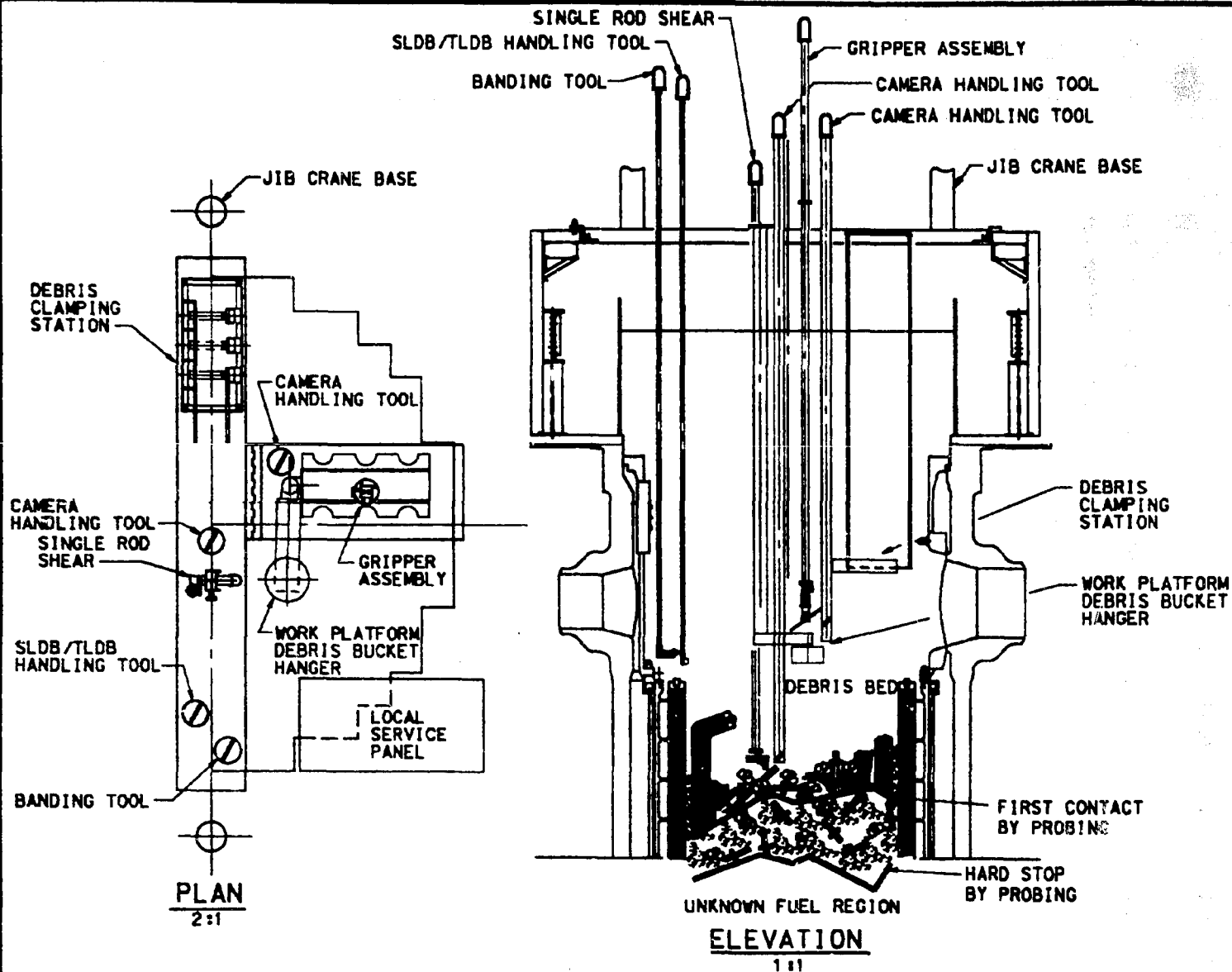


Figure 2-5. Defueling — Phase II.

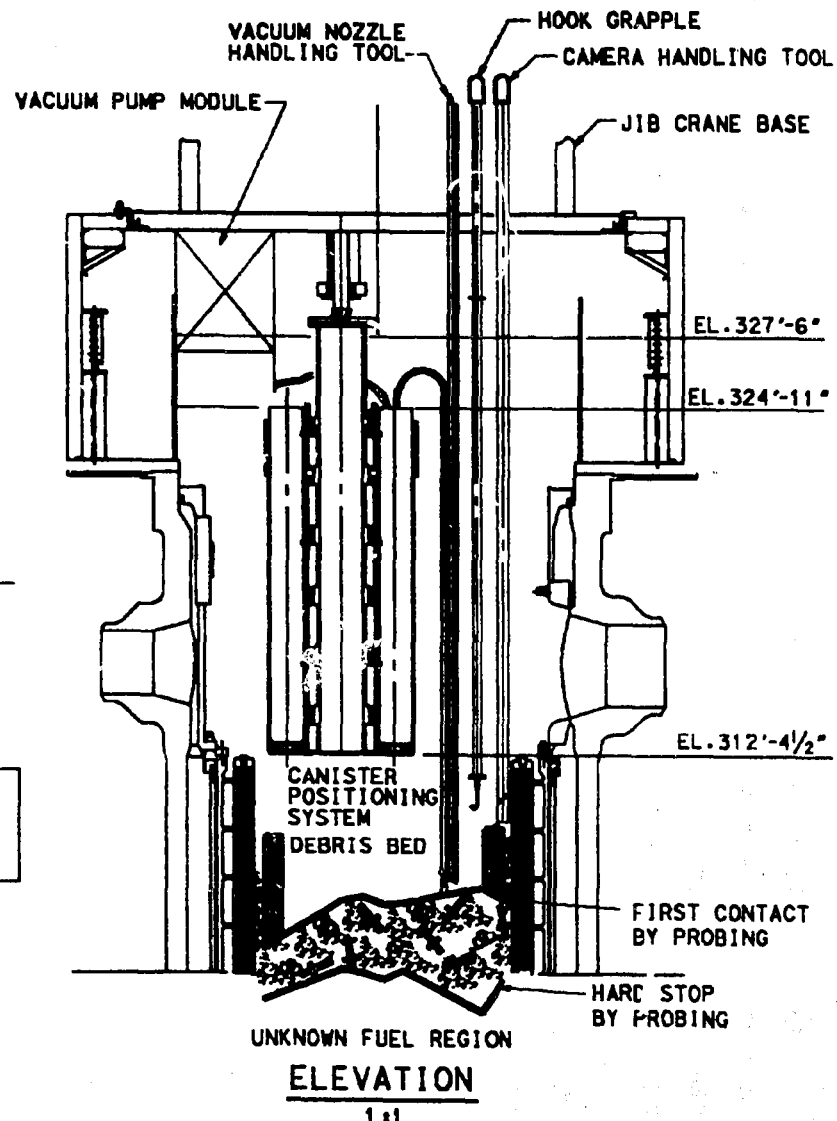
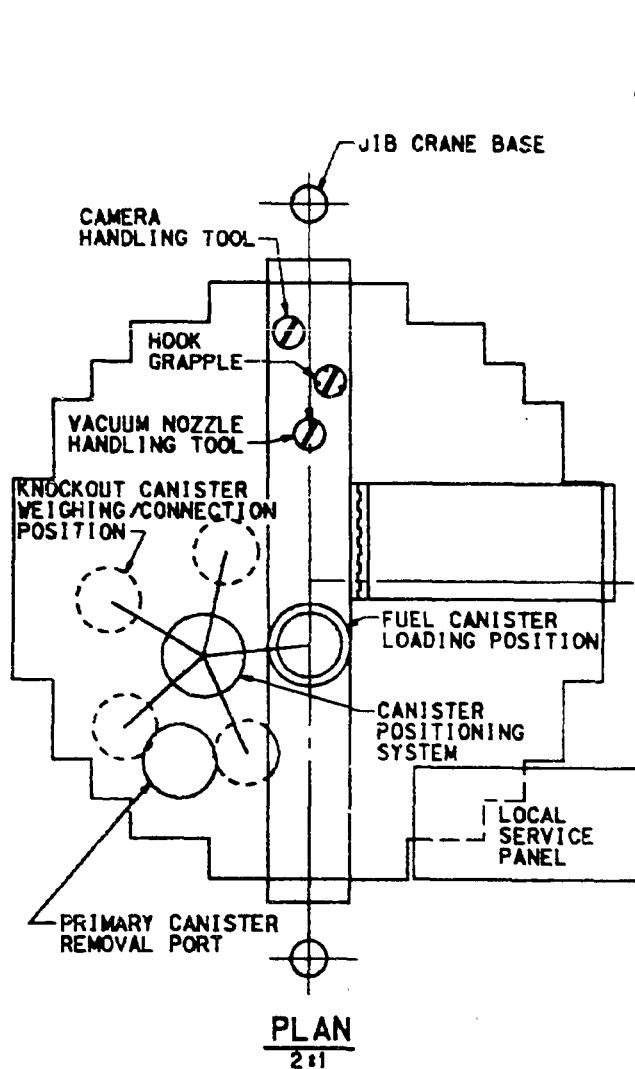


Figure 2-4. Defueling - Phase I.

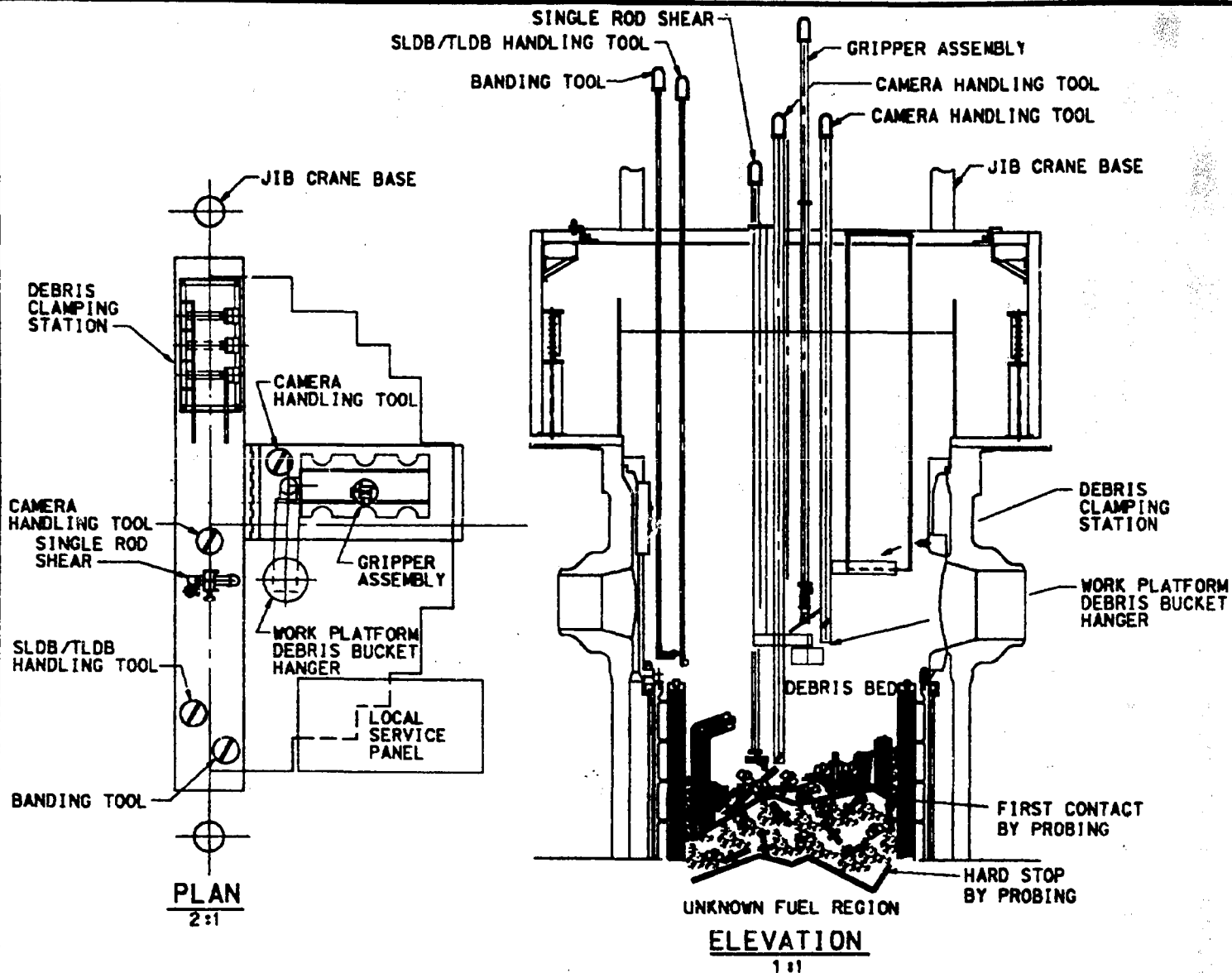
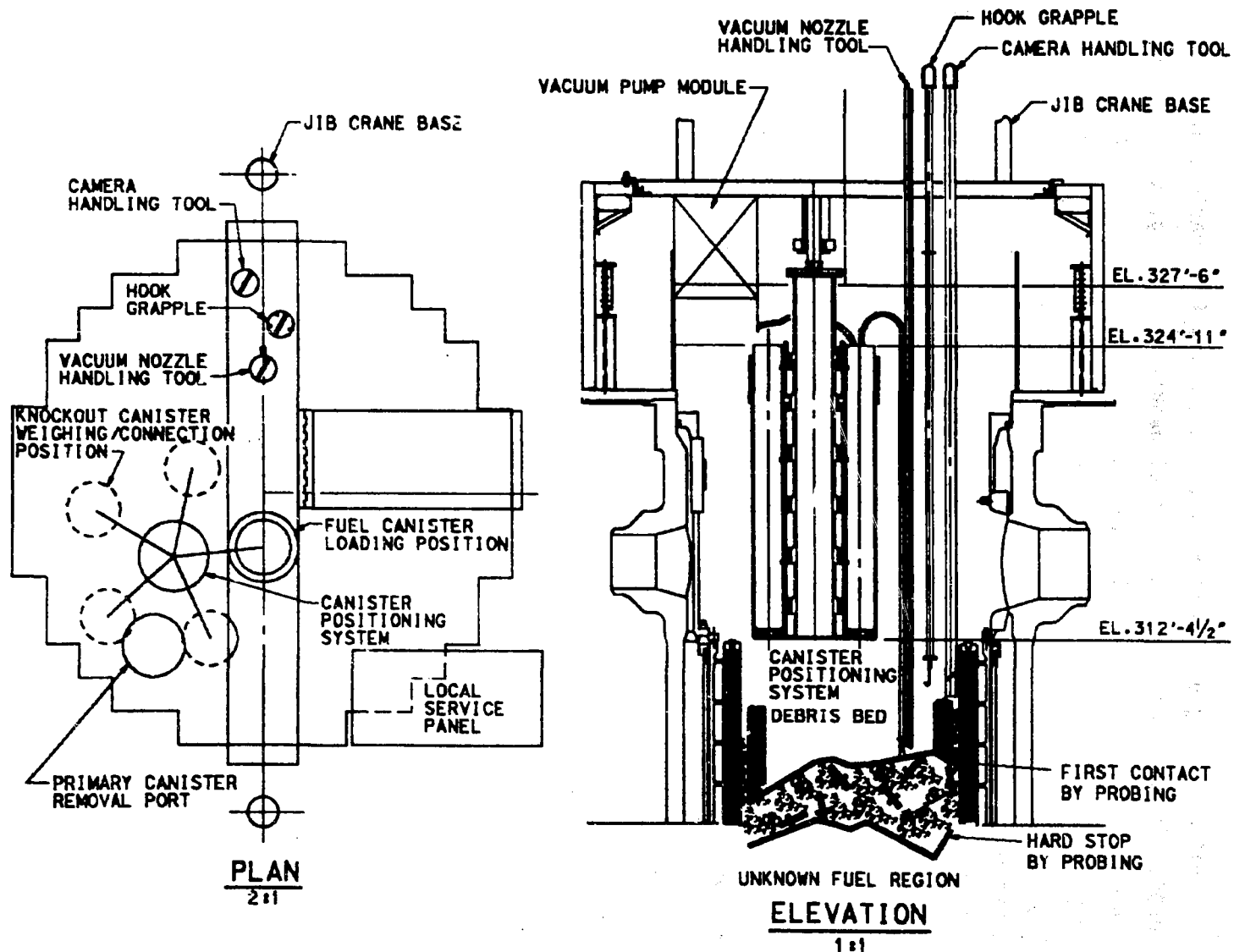


Figure 2-5. Defueling — Phase II.



- Vacuuming of fines/debris into knockout and filter canisters
- Transferring of all types of defueling canisters

The defueling equipment will be controlled from various locations throughout the reactor building, fuel handling building, and coordination center. Figures 2-6 and 2-7 illustrate these general arrangements. The proposed layout of the coordination center for defueling is shown in Figure 2-8. Defueling operations involve many simultaneous operations at different places in the TMI-2 containment building, fuel handling building, and the coordination center. Figure 2-9 illustrates the audio and video systems used for defueling.

#### 2.2.12 Miscellaneous Activities Related to Defueling Tools

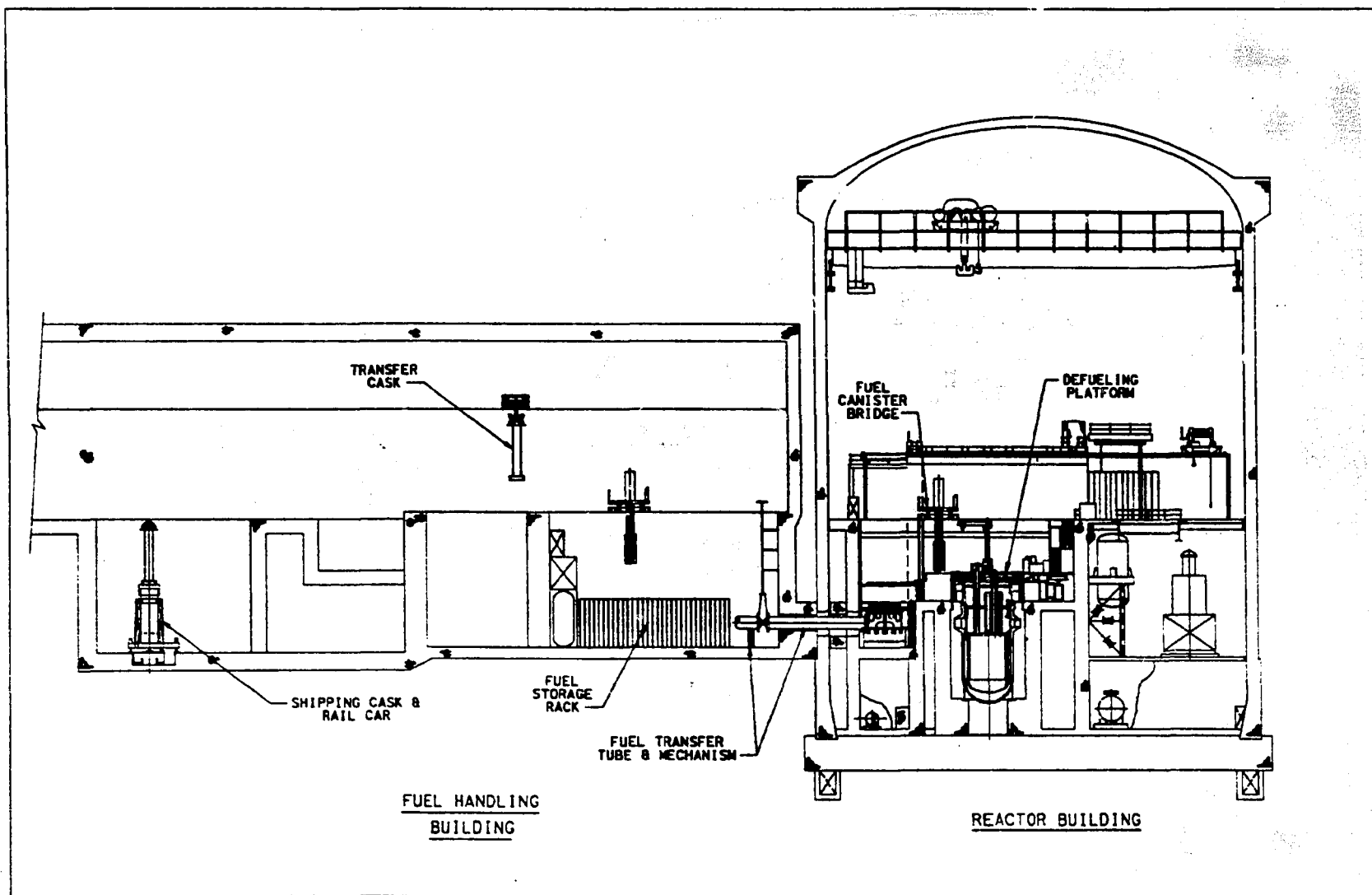
2.2.12.1 Quality Classification of Defueling Tools. Criteria for assigning quality classification to the defueling equipment are:

1. Supports for equipment and equipment packages installed over or in the vessel and weighing more than 2,400 pounds (the weight of a fuel assembly) should be classified as important to safety (ITS) for structure integrity.
2. Tools and equipment handled or installed over or in the reactor vessel should be classified as ITS for material certification. This includes material certification for hydraulic and other types of fluid used in equipment and tools.
3. Items classified as ITS per criterion 1 should be ITS for both structural integrity and material certification.
4. Any item not indicated in criteria 1, 2, and 3 or not specifically designated by the project as ITS or nuclear safety related may be classified as not important to safety (NITS).

Quality classification equipment list for TMI-2 defueling tools is presented in Table 2-2.



Figure 2-6 TMI-2 defueling arrangement



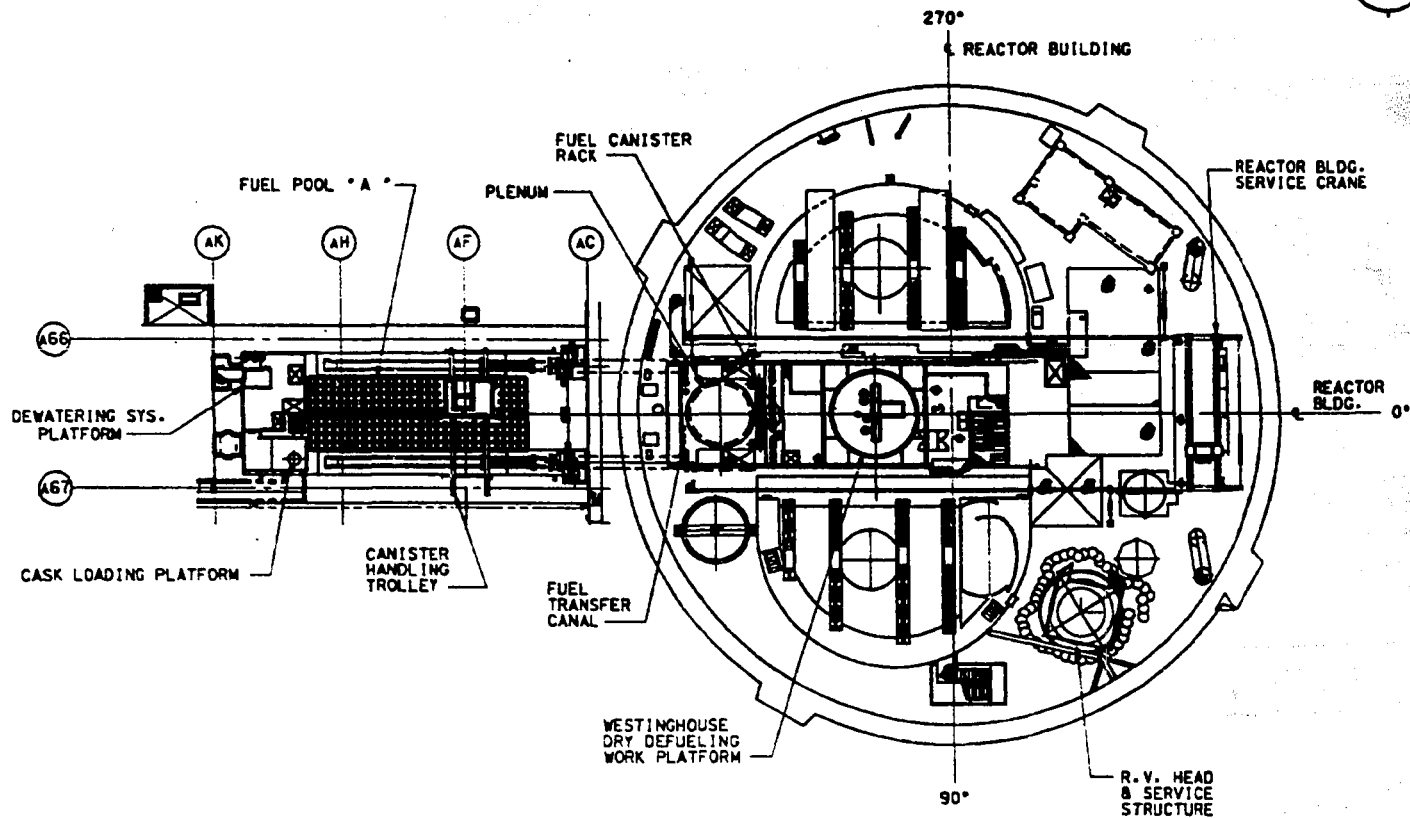


Figure 2-7. TMI-2 defueling general arrangement.

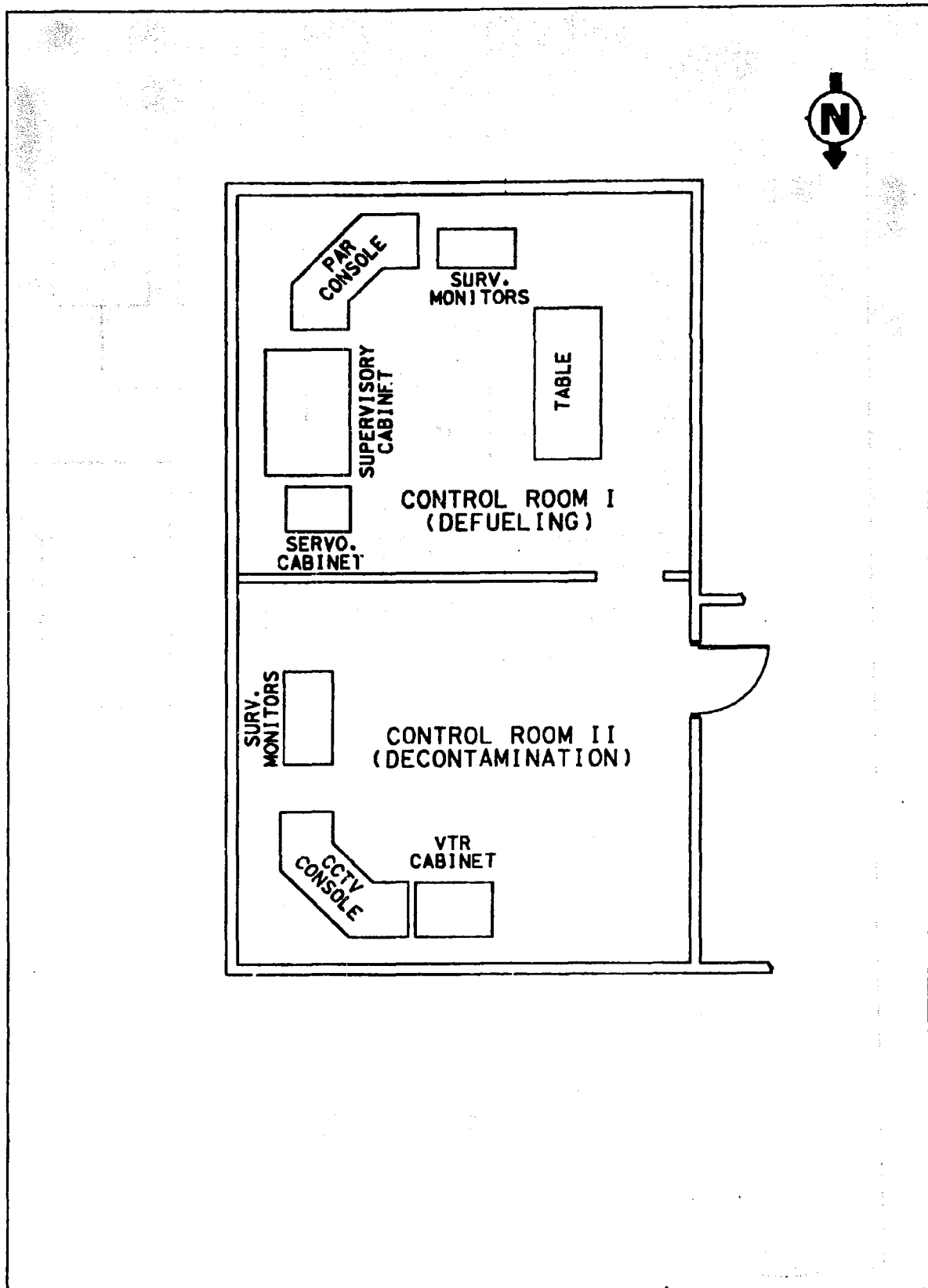


Figure 2-8. Coordination center — layout for defueling.

Figure 2-9. TMI-2 defuelling configuration — audio and video arrangement.

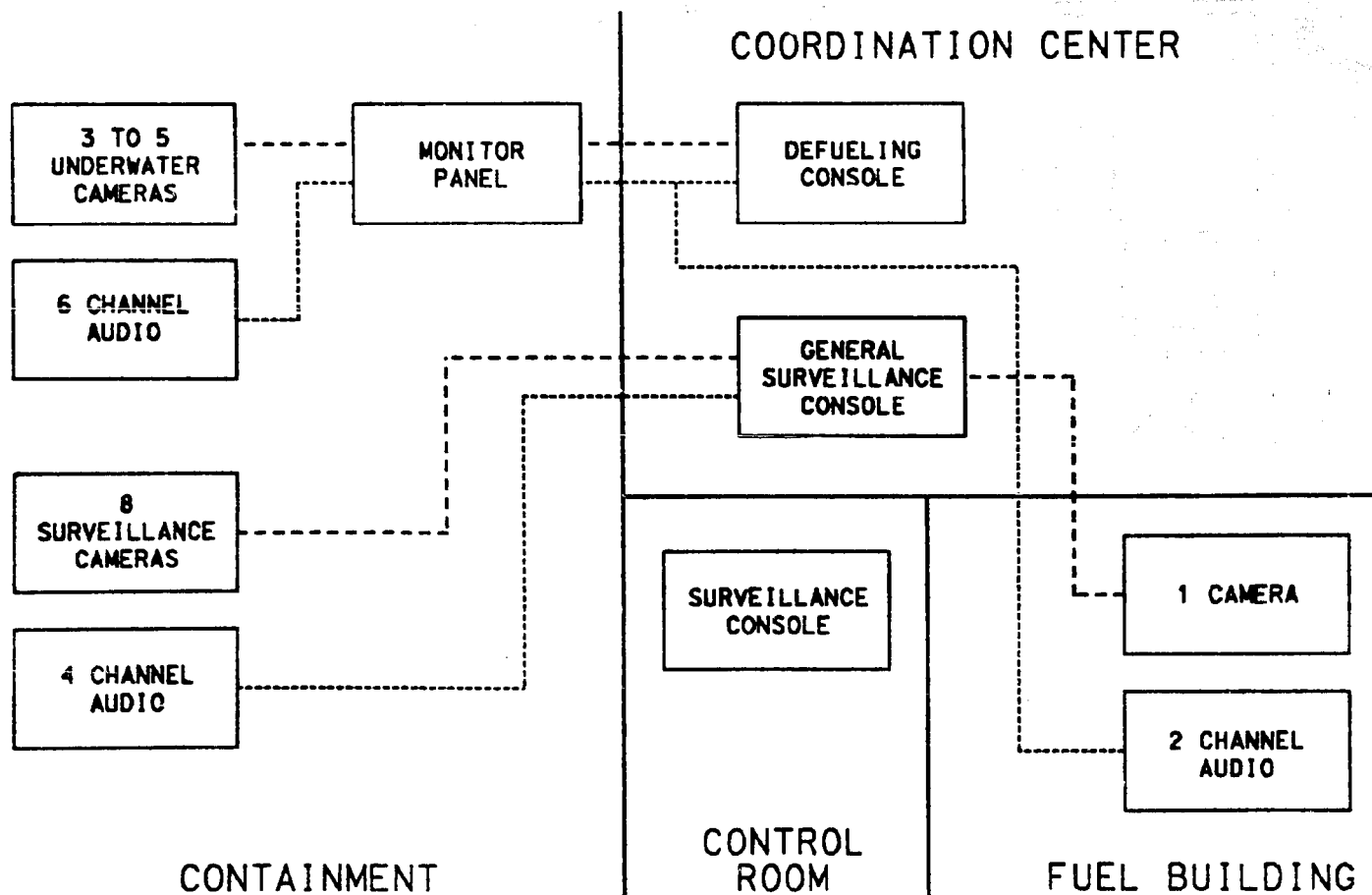


TABLE 2-2. QUALITY CLASSIFICATION EQUIPMENT LIST  
FOR WESTINGHOUSE TOOLS

<u>System/Tools</u>	<u>Quality Classification<sup>a</sup></u>
<u>Vacuum System</u>	
Vacuum system, including submersible pump, support system, declogging system, piping, and pickup nozzles	ITS-M except support system; support system ITS-S, M
Vacuum system handling tool	ITS-M
Control system	NIT for hydraulic system
Canister weighing system	ITS-M
Flexible hose handling tool	ITS-M
Filter canister support racks	ITS-S, M
Installation and changeout tools	ITS-M
<u>Long-Handled Tools</u>	
Segmented long-handled pole (heavy duty)	ITS-M
Three- and four-point grippers	ITS-M
<u>End Effectors (Low Capacity)</u>	
Grapple	ITS-M
Single rod shear	ITS-M
Parting wedge	ITS-M
Backhoe/shovel	ITS-M
Vice grips - remotely operated	ITS-M
Hook tools	ITS-M
Fuel rod pickup tool	ITS-M
End fitting lift tool	ITS-M
Hydraulic impact chisel	ITS-M

a ITS-M = Important to safety for material certification only  
ITS-S = Important to safety for structural integrity only  
NITS = Not important to safety

TABLE 2-2 (Continued)

<u>System/Tools</u>	<u>Quality Classification<sup>a</sup></u>
<u>End Effectors (High Capacity)</u>	
Lightweight chisel	ITS-M
Disposable debris buckets	ITS-M
Reusable debris buckets	ITS-M
Top access fuel assembly lifting tool	ITS-M
Side access fuel assembly lifting tool	ITS-M
Tong lifting tool	ITS-M
Clamshell tool	ITS-M
Spade bucket tool - remotely operated	ITS-M
Hook tool (high capacity)	ITS-M
<u>Control System</u>	
Cable management	NITS
Control console	NITS
Central hydraulic pump	ITS
Electrical power distribution	NITS
Light controls	NITS
Local electric/hydraulic/pneumatic service panel	NITS
<u>Viewing System</u>	
Camera positioners and supports	ITS-M
Light positioners and supports	ITS-M
General work area light positioners	ITS-M
Lighting control system	NITS

TABLE 2-2 (Continued)

<u>System/Tools</u>	<u>Quality Classification<sup>a</sup></u>
<b><u>Shielded Support Structure</u></b>	
Support structure	ITS-S
Piping	NITS not over vessel ITS-M over vessel
<b><u>Shielded Work Platform</u></b>	
Work platform	ITS-S
Drive	NITS
<b><u>Canister Positioning System</u></b>	
Canister support system	ITS-S, M
Fuel canister seal protection lids	ITS-M
Sleeve handling tool	ITS-S, M
Single canister support bracket	ITS-S, M
<b><u>Canister Tools</u></b>	
Center point grapple	ITS
Fuel canister grapple	ITS
Staging handle	ITS
3/8-inch Hansen cap tool	NITS
3/8-inch Hansen dewatering outlet tool	NITS
Filter/knockout canister plugging tool	NITS
<b><u>Canisters</u></b>	
Filter canister	Nuclear safety related
Knockout canister	Nuclear safety related
Fuel canister	Nuclear safety related

For canister tools, the center point grapple, fuel canister grapple, and staging handled are classified as ITS. The remaining tools are classified as NITS.

Fuel, knockout, and filter canisters are classified as nuclear safety related.

**2.2.12.2 Operational Feedback from Fuel Handling Senior Reactor Operator (FHSRO) DTA Training.** To ensure that the tools and equipment provided for defueling will be operated smoothly during actual defueling, comments resulting from FHSRO DTA tooling training will be used in improving the overall effectiveness and efficiency of the upcoming defueling operations. These comments and observations will also be used in future bulk defueling equipment development.

**2.2.12.3 Defueling Tool Racks.** During the defueling operations, various long-handled tools and end effectors will be used as necessary depending on the condition of the core/fuel at a particular location. Because all the tools will not be constantly operating, tool racks are needed to store the equipment.

Based on the Defueling System Design Description and the Defueling Sequence Document, tool racks will be designed and fabricated by GPUN. The tool racks will be designed to interface with other related equipment and to provide for satisfactory defueling operations.

**2.2.12.4 Defueling Tool Maintenance.** The defueling operations at the TMI-2 reactor will require the use of a wide variety of tools and equipment. It is expected that the tools and equipment used will require preventive and corrective maintenance to replace broken or worn parts, or parts no longer fit for service due to degradation from the operational environment. These tools are expected to be highly contaminated. Consequently, maintenance activities to restore these tools to an operating status must be performed in such a manner as to protect personnel and prevent the spread of contamination.



Components such as hydraulic tools, shear blades, and bearings will wear during use and will require repair or replacement on a planned basis to ensure maximum operation efficiency. All of the above referenced maintenance must be performed under controlled conditions in an acceptable service/work area. Depending upon the nature of the maintenance work to be performed and the radiation exposure involved, maintenance of tools/equipment would be performed either inside the containment building or removed to an exterior service/work area.

For each defueling tool, the required scheduled maintenance, corrective maintenance, and the recommended spare parts are included in the system final design report. All special maintenance equipment and spares required for all defueling tools have been identified. GPUN has overall responsibility for maintenance planning and requirements; therefore, they should ensure that adequate equipment, spare parts, and personnel are available for the maintenance activities.

## 2.3 Defueling Tools

The TMI-2 defueling tools can conveniently be divided into two groups: early defueling tools and bulk core region defueling tools. Section 2.3.1 describes the efforts on the tool matrix for tool integration. The early defueling tools are presented in Section 2.3.2 and bulk defueling tools in Section 2.3.3. Except for tools (i.e., tools required after early defueling) presented in Section 2.3.3.2, all tools are now on the site and are capable of removing the debris in the upper section of the core.

### 2.3.1 Tool Matrix for Tool Integration

Integration of all defueling equipment, including early and bulk defueling tools, has been considered since the early stage of the defueling program. As a result, a matrix for the defueling tools and the defueling requirements was developed (Table 2-1) to ensure the core debris removal. As indicated in the matrix, the early defueling tools, in anticipation of their use in subsequent defueling activities, were developed not only for the removal of the majority of debris located above the hard crust but also for

some of the planned bulk defueling activities. As also indicated in the matrix, every functional requirement anticipated for defueling activities can be met by at least one defueling tool. In most cases, more than one tool can perform the same task. Early tool integration for defueling resulted in lower equipment costs and more efficient in-containment activity.

### 2.3.2 Early Defueling Tools

The early defueling tool systems consist of the following:

- Shielded work platform
- Shielded support structure
- Vacuum system
- Long-handled tools
- Control system
- Viewing system
- Canister positioning system
- Single canister support bracket
- Test assemblies
- End effectors
- Tool positioning system
- Support tools

Descriptions of each of the tool systems are in the Appendix.

The steps to operate a specific defueling tool or a set of tools are not included in this report. Operating instructions are supplied for each tool in the form of operation and maintenance manuals.

### 2.3.3 Bulk Core Region Defueling Tools

Bulk defueling tools consist of the existing viewing system provided for plenum assembly removal (PAR) (Section 2.3.3.1) and future bulk tools (Section 2.3.3.2). The bulk tools are currently under development and some of them will soon be available for early defueling purposes.

2.3.3.1 PAR Viewing System. Although the viewing system provided for the plenum assembly removal was developed specifically for plenum assembly removal activities, general provisions have been incorporated into its design in anticipation of their use in subsequent defueling activities. The viewing system has two basic parts: in-containment equipment and coordination center equipment.

The in-containment system primarily acquires the information and provides immediate monitoring and control of the video equipment by the operator manipulating the tools. The coordination center provides control for monitoring and recording operations from outside the reactor building.

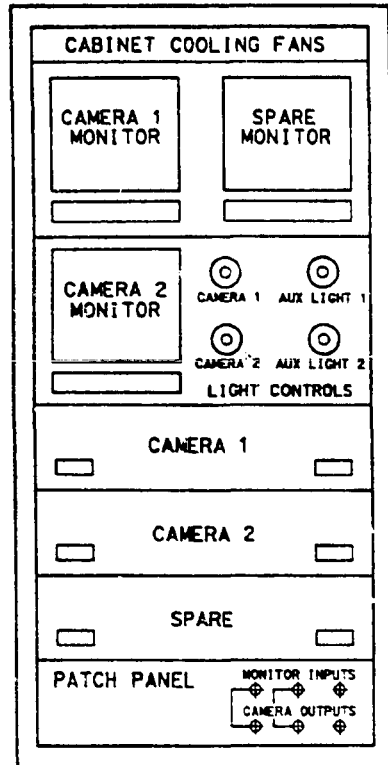
The in-containment equipment consists of three cabinets which house the in-containment video hardware--two to hold the camera controls and associated electronic equipment and another to store the cameras and cable when not in use. (There is also a portable rack with three, 6-inch video monitors should the stationary system not be within easy access of the operators.)

The two control cabinets are each 22 inches wide x 47 inches high x 22 inches deep and will hold all camera controls, light controls, monitors, and the audio base repeater unit (see Figure 2-10). The entire system comprises five cameras/control units; eight lights, some with reflectors; six 6-inch monitors; and one audio base repeater station. The camera system has three Rees R-93 units and two Diamond ST-5 units. These cameras are all completely sealed, stainless steel housed underwater units.

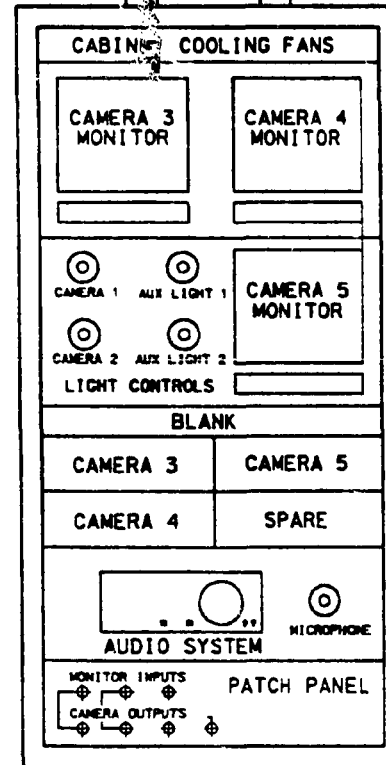
The Rees units are smaller (1.6 inch OD) than the Diamond cameras (2.88 inch OD) and will be used in instances that make it necessary to place the cameras in very space-restricted areas.

Both types of units have focus and iris controls and are capable of either straight or right-angle viewing. All five cameras have internal lighting, although auxiliary lighting is also provided.

TO TRANSMIT ANTENNA ← → TO RECIEVE ANTENNA



CABINET "A"



CABINET "B"

Figure 2-10. In-containment cabinets.

Should a control unit unexpectedly fail, the cabinets contain one spare Diamond and one spare Rees camera control unit (CCU). Each of the five camera CCUs feeds a 9-inch monitor; the sixth monitor is a spare. The output signals to the coordination center will come directly from the six video monitors.

The lighting portion of the in-containment system provides for up to eight lights with individually controlled intensity. Three lights will be standard Hydro Products SQ-500 units; five lights are modified for a 2.4-inch restricted access. These modified lights will be provided with a reflector that will limit the light beam to a 180-degree pattern.

The audio communications between the camera/tooling operators and the coordination center will be handled by a duplex base repeater station. This unit will receive the RF signal from the operators' microphones via the antennas on top of one of the cabinets and transfer it to the coordination center through two twisted-shielded pairs. Should the control consoles not be near the tool operators, a rack with three 6-inch monitors can be attached to the handrails of the shielded work platform. This monitor rack, though more portable than the large control cabinets, has no controls for the video cameras or lights. It provides a display of selected images monitored at the control cabinets to aid the tool operator.

Provisions for in-building storage and decontamination are provided by a stainless steel equipment locker with storage space for all camera/cables and auxiliary lights/cables. The storage cabinet is approximately 72 inches wide x 72 inches high x 18 inches deep.

The coordination center system consists of a desk top console with three side-by-side racks each 22 inches wide x 28 inches high x 22 inches deep. The consoles contain three monitors, camera signal distribution amplifiers, camera signal identifiers, and two video cassette recorders (VCRs) that can be switched to view the four input camera signals with picture identification information.

The system includes camera selection switchers for each monitor and VCR (see Figure 2-11).

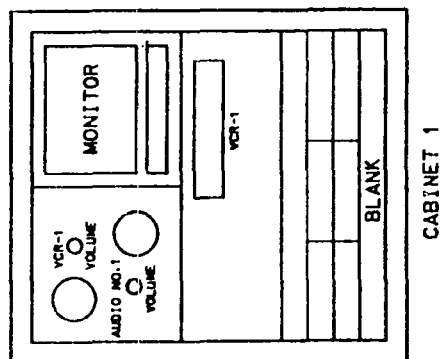
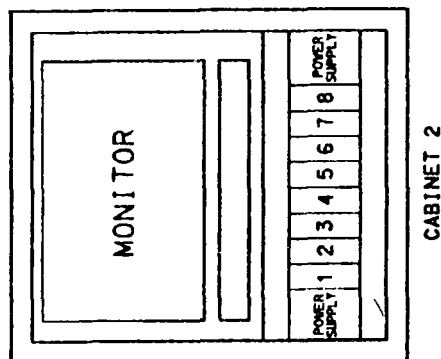
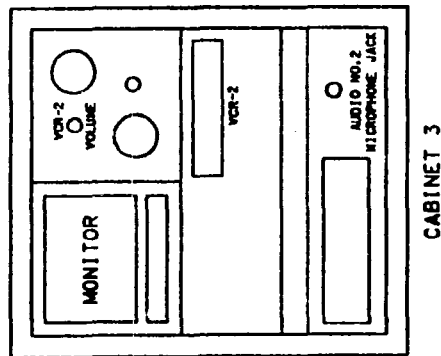


Figure 2-11. Coordination center cabinets.

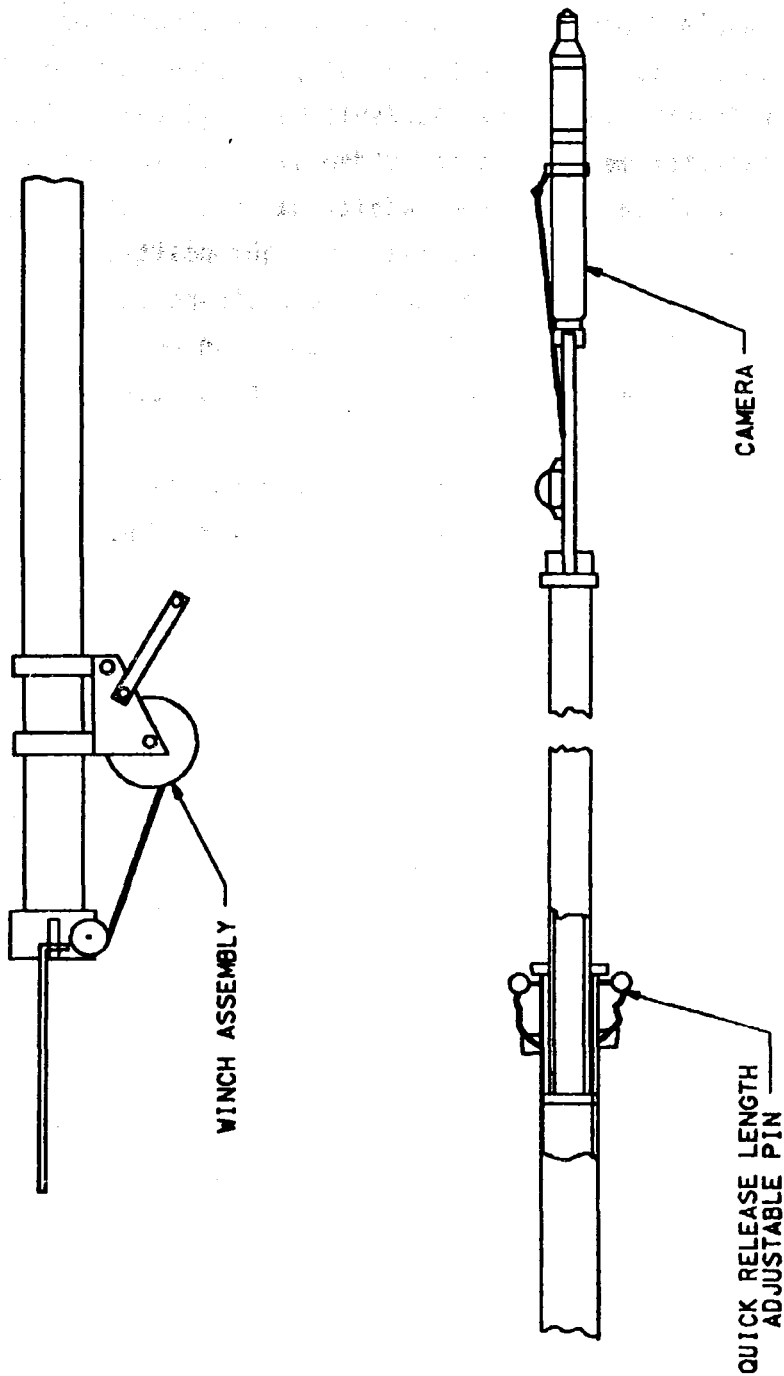
The system can accommodate four camera signals, each feeding a distribution amplifier module which in turn feeds both the switcher of the cabinet 2 direct viewing monitor and the video identifier/switcher combination. The four distribution amplifier modules supply two additional high-resolution signals: one feeds a six-position switcher for a supervisory monitor, and the second is available for display on other monitors as an unidentified spare input. The identifier/switcher will add a time/date/camera number and a 16-character message to the video signal. The outputs of the switcher/identifier will be fed to four additional distribution amplifier modules. These modules will, in turn, feed an eight-position switcher for each of the cabinet 1 and 3 9-inch monitors and a six-position switcher for each of the two VCRs. The VCRs will feed one position on the six-position switchers for record/playback viewing on the 9-inch monitors.

One direct viewing monitor will be switchable to any of four camera input signals. This monitor will have a direct input from the amplified high-resolution signal of the camera that will be unaffected by high-frequency roll-off in either the video identifiers or the video records and thus will provide the highest quality picture. Picture identification will be provided by the lighted number displayed on the switcher of this monitor.

A desk microphone will also be fed into the coordination center.

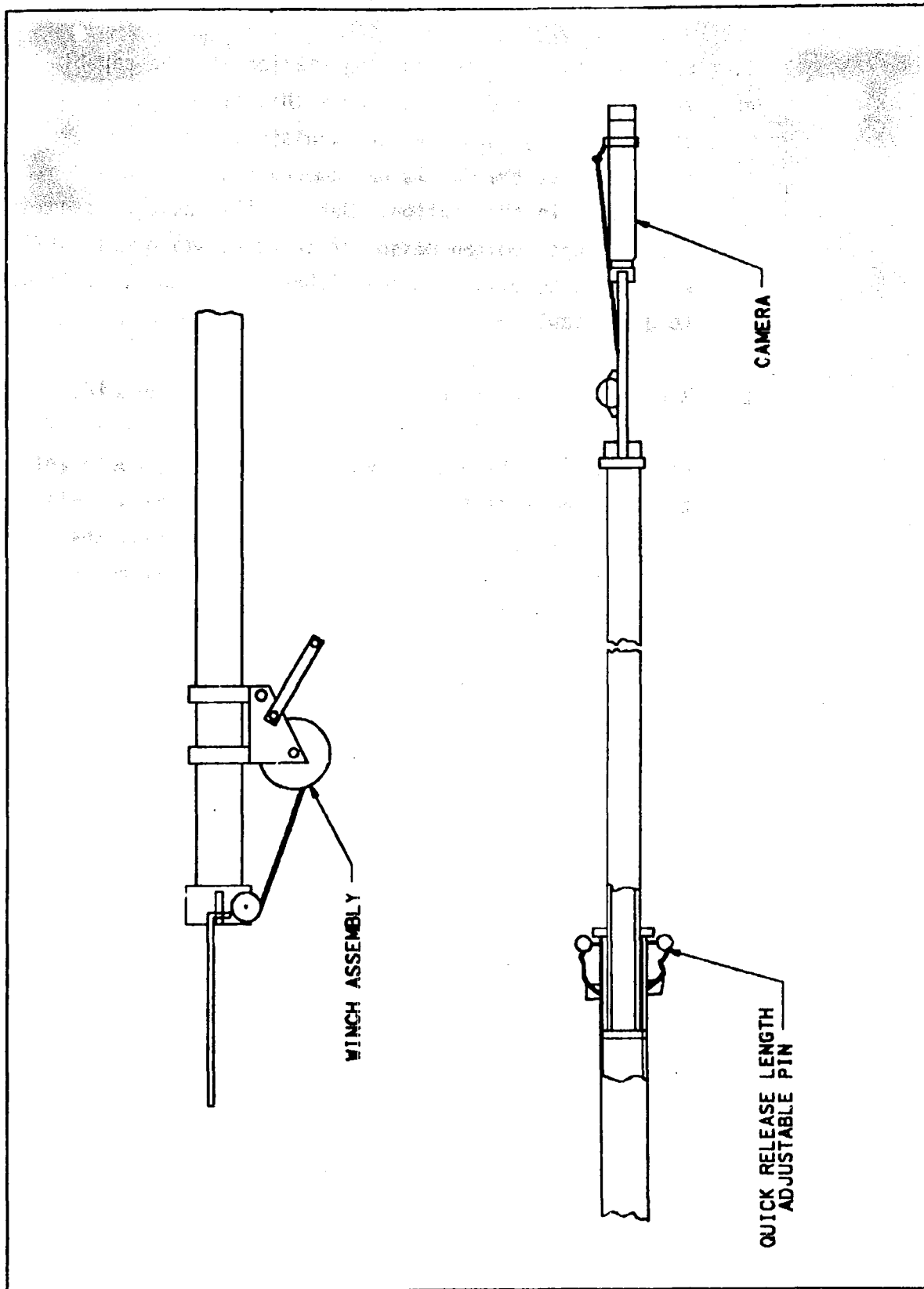
Two camera manipulators can be used in viewing activities. The camera manipulators (see Figures 2-12 and 2-13) consist of a camera handling tool end, winch assembly, camera cable, camera, and a tool handle. With this setup, the operator can remotely position the camera in predefined locations.

**2.3.3.2 Tools Required After Early Defueling.** The following list identifies defueling tools required after early defueling. A functional description of each tool is also provided. The list is based on the known core conditions.



**Figure 2-12. Camera handling tool — right-angle lens.**





**Figure 2-13. Camera handling tool — straight lens.**

- Core Region Fuel Removal Equipment--

1. Cutting Station - The cutting station will be capable of sectioning debris from the core that is too large for direct loading into the fuel canister. This item requires that the debris be removed from the core region and placed in the station. Debris will include deformed end fittings, molten masses of ceramic, stainless steel, etc. Cutting will be accomplished by mechanical cutting (e.g., a saw).
2. Manual Tool Positioner (MTP) - The MTP will provide a more rigid mount for lower core removal equipment. This equipment will be used to mount core cutting equipment and the remote manipulator (see item 8). The MTP will be supplemented by a stabilizer that will increase the reaction limits of horizontal forces that may be applied to tooling which interface with the MTP.
3. Partial Fuel Assembly Tools - The following tools will have the capability of removing partial fuel assemblies located above or below the crust region of the core. Specifically, a side access removal tool is envisaged that, once side access to fuel assemblies is available, will transfer the assembly from the core region to the clamping station for loading it into a canister.
4. Viewing System - The viewing system will provide viewing capabilities away from the work platform working slots to support defueling operations with the MTP, the remote manipulator, and other defueling equipment.
5. Incore Instrument Cutting Tools - These tools will be used to cut incore instrument guide tubes and instrument clusters below the fuel assembly lower end fittings.

- This will permit raising of the fuel assemblies without transmitting loads through the guide tubes or instrument clusters to the vessel lower head.
6. Lower Grid Vacuum Nozzles - The existing nozzles will be modified or new nozzles provided to remove fines/debris in the lower grid under the limited access to this region.
  7. Impact Chisel - This tool will be used to fracture the brittle portions of previously molten parts of the core. It may be used with the end effector handling tool or the MTP.
  8. Remote Manipulator - The remote manipulator will be mounted on the MTP. It will have the capability of performing defueling operations away from the work platform access slots, in parallel with other defueling operations. It will be capable of control from inside or outside the reactor building.
  9. Hard Crust Region Defueling Equipment - There may be several inches of crust material. The hard crust region defueling equipment will be capable of gaining access to embedded fuel assemblies. Equipment will be provided to remove/dig fuel assemblies out of the crust region from the top down. The equipment will consist of digging tools and impact drills.
  10. Core Region Cutting Equipment - New core data indicates that the crust material ranges from brittle to very hard/ductile. If the material is not brittle, the chisel will be supplemented with additional cutting equipment. The cutting equipment will be capable of sectioning ductile material, in-place, within the core region, and cutting ductile material attached to the core former plates. Core region cutting equipment will, as a minimum, consist of a hydrolaser (item 6) and an abrasive saw (item 7).

- **Flow Raffle Region of CSA (access for lower head region and defueling)--**

1. **Lower Grid Cutting Equipment** - This equipment will be capable of cutting portions of the lower grid to gain access to the lower head.
2. **Storage Provisions** - The pieces cut from the lower grid will either be stored in the reactor vessel or removed from the vessel for ultimate disposal. Application of these options will be addressed during preparation of the defueling for this region.
3. **Lower Head Access Using the MTP - Modifications/ extensions** will be provided for the MTP to support lower head access/defueling.
4. **Hydrolaser Cutting Equipment** - A hydrolaser will be provided to cut very hard, abrasive materials without requiring rigidity or accurate positioning of the cutting tool. The hydrolaser will be used to cut debris in hard-to-access areas and/or to cut debris into geometric configurations that will permit its loading into debris buckets or fuel canisters. The hydrolaser is designed to be mounted to the MTP.
5. **Abrasive Saw Cutting Equipment** - This tooling will be used to cut debris into geometric configurations that will permit its loading into debris buckets or fuel canisters.

The abrasive saw cutting equipment will be designed for mounting to the MTP.

- **Lower Head Region Fuel Removal**--Based on current lower head debris assumptions, no cutting tools will be required. All debris can be removed by pick/place and vacuuming operations.
  1. **Lower Head Fuel Removal Tools** - These tools will be used to defuel the lower head. These tools will include scoops, grapples, chisels, picks, etc. For the majority of these operations, existing tooling may be modified (added length and/or size changes for restricted access) at the site. Some new equipment will be designed and supplied.
  2. **Vacuum Nozzles** - Similar to the nozzles provided for the lower core region, these nozzles will be designed to be more efficient at defueling the lower head regions using the access holes provided by flow baffle cutting equipment. These nozzles may be provided by site modification of existing equipment.
  3. **Large Debris Vacuum Equipment** - This equipment will be an extension to the existing defueling vacuum system. One approach being considered is the use of an additional large debris knockout device in conjunction with the increased flow capabilities of the existing vacuum system. The large debris knockout device would then be unloaded by transferring debris into defueling canisters using pick and place tooling and the existing vacuum system.
- **CSA Fuel Removal**--
  1. **Vacuum Nozzles** - Nozzles, hoses, and long handles will be provided to access the areas behind the baffle plates to vacuum accumulated debris.

2. Access Hole Cutting Equipment - This equipment will be capable of performing the complex geometric cuts in access holes in the CSA baffle plates to provide access for the vacuum nozzles.
3. Reactor Vessel Isolation - This equipment (expandable plugs) will be used to isolate the reactor vessel from the remainder of the RCS. This will allow the water levels to be changed in various sections of the RCS.
4. Cold Leg Access Equipment - Cutting equipment will be developed (as necessary) to provide access to the cold leg nozzles and the annulus between the core barrel and the thermal shield. The need for new equipment will be dependent on inspection results and the evaluated usefulness of other cutting tools.

#### 2.3.4 Defueling Canisters

The canisters consist of a cylindrical pressure vessel encapsulating one of three internal modules, depending on the function of the canister (Reference 5). Except for the bolted upper closure head on the fuel canister, the basic pressure vessel (outer shell) is the same for all three canister designs. Similarly, the handling interfaces are identical to allow the same handling tool to be used. Different functional requirements dictated differences in the piping interfaces and the design of the internal modules.

The fuel canister (Figure 2-14) is a receptacle for large pieces of core debris that can be picked up by the defueling grapple and placed in the canister. For this reason, the upper closure head is removable to permit easy access for debris loading. An internal shroud controls the size of the internal cavity and provides a means of encapsulating the neutron absorbing material used for criticality control.

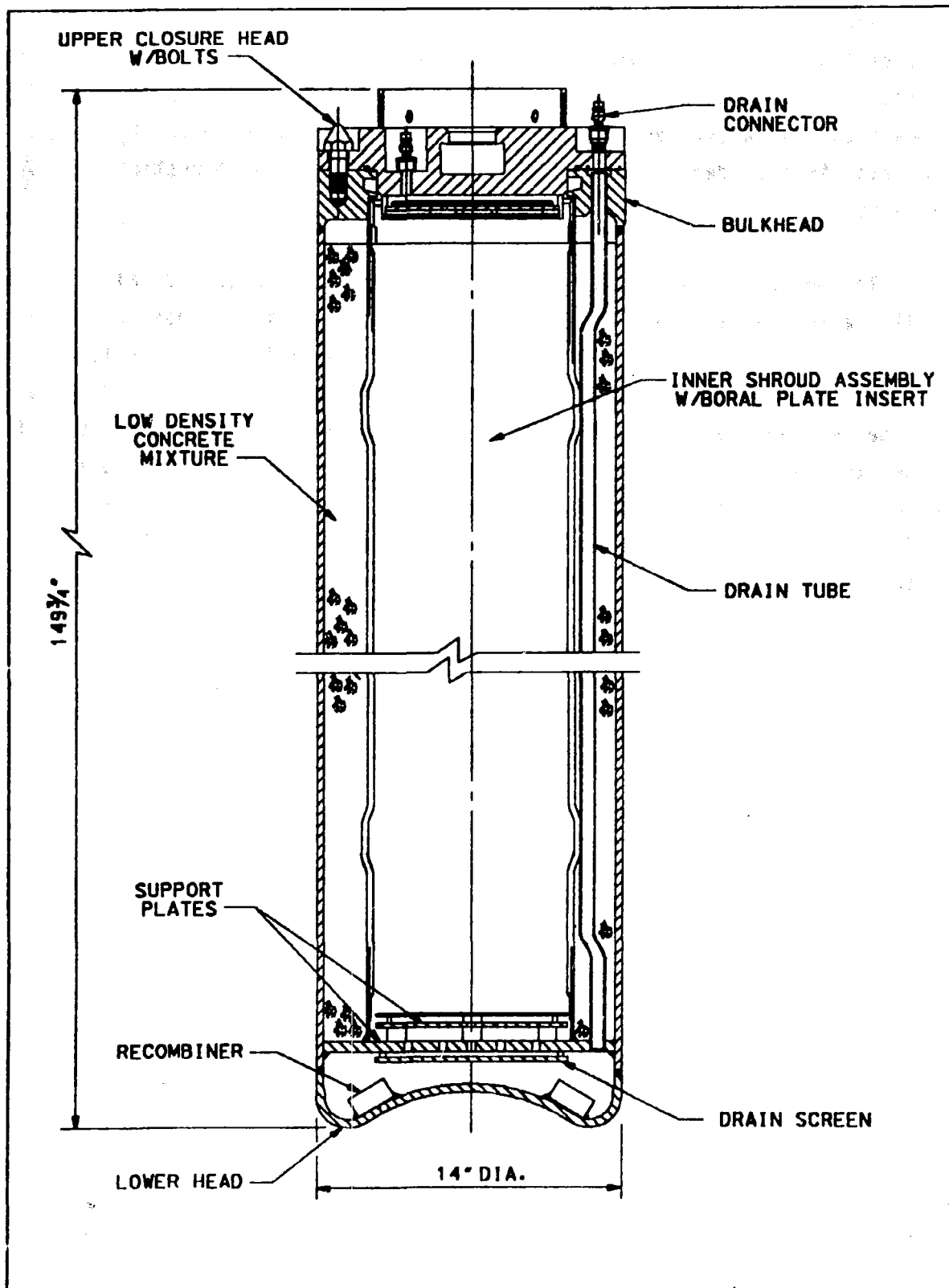


Figure 2-14. Fuel canister.

As part of the debris vacuum system, the knockout canister (Figure 2-15) separates the medium size debris from the water by reducing the flow velocities, thereby allowing the particles to settle out. An internal screen helps retain all but the very small fines in the canister. An array of four rods around a larger central rod, all containing boron carbide ( $B_4C$ ) pellets, is included for criticality control. All flow connections are located on the upper head.

To remove very small fines, the filter canister (Figure 2-16) utilizes filter elements fabricated from a stainless steel medium. These elements are joined together to form a filter bundle permitting a flow rate up to 125 gpm while filtering out particles as small as 0.2 micron. A center rod containing  $B_4C$  pellets ensures that the canister contents remain subcritical. Like the other two types of canisters, all the interface connections (piping and handling) are on the upper head. Both in the fines/debris vacuum system and DWCS, a system pressure relief valve maintained by GPUN keeps the pressure within design values.



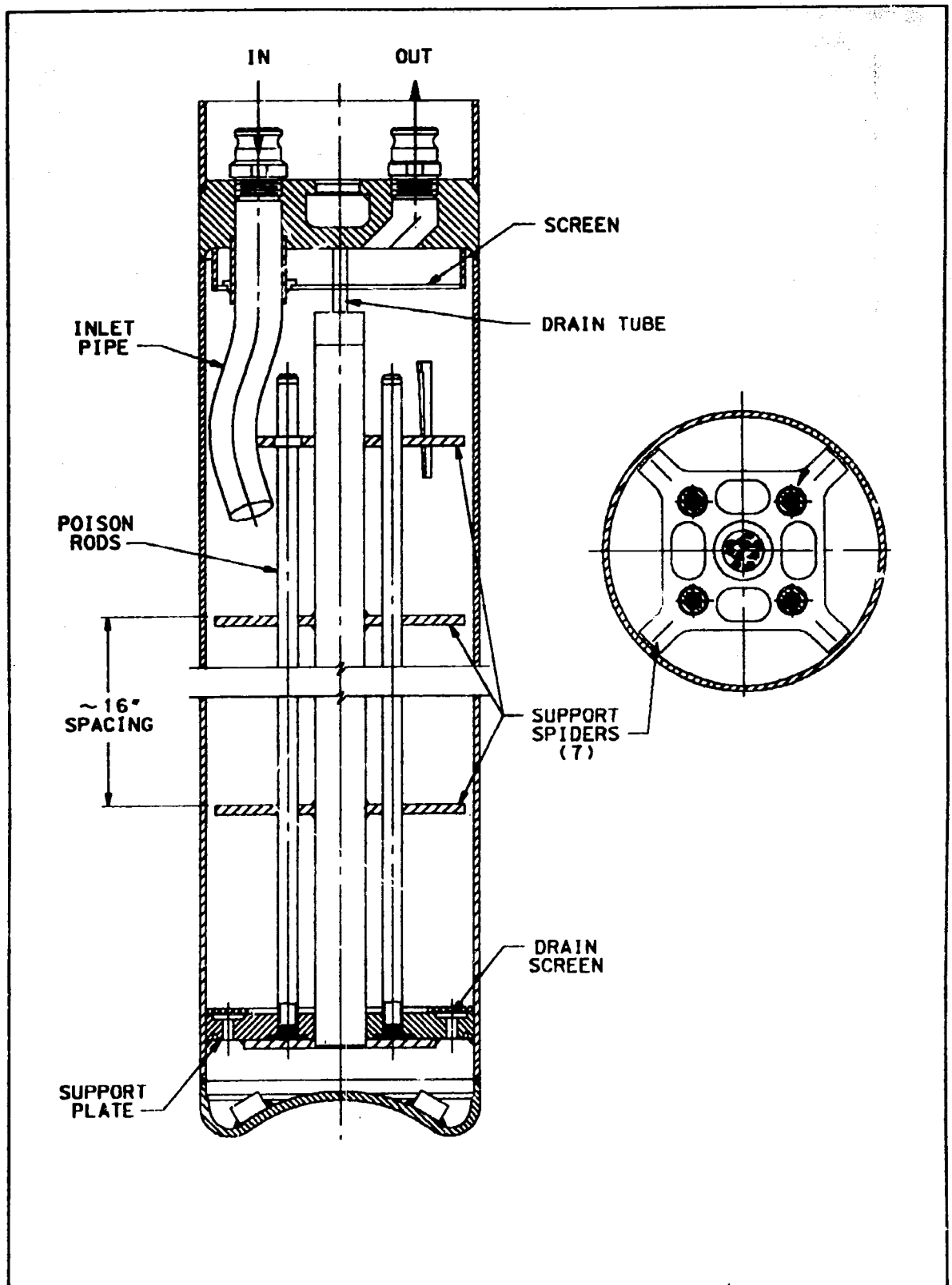


Figure 2-15. Knockout canister.

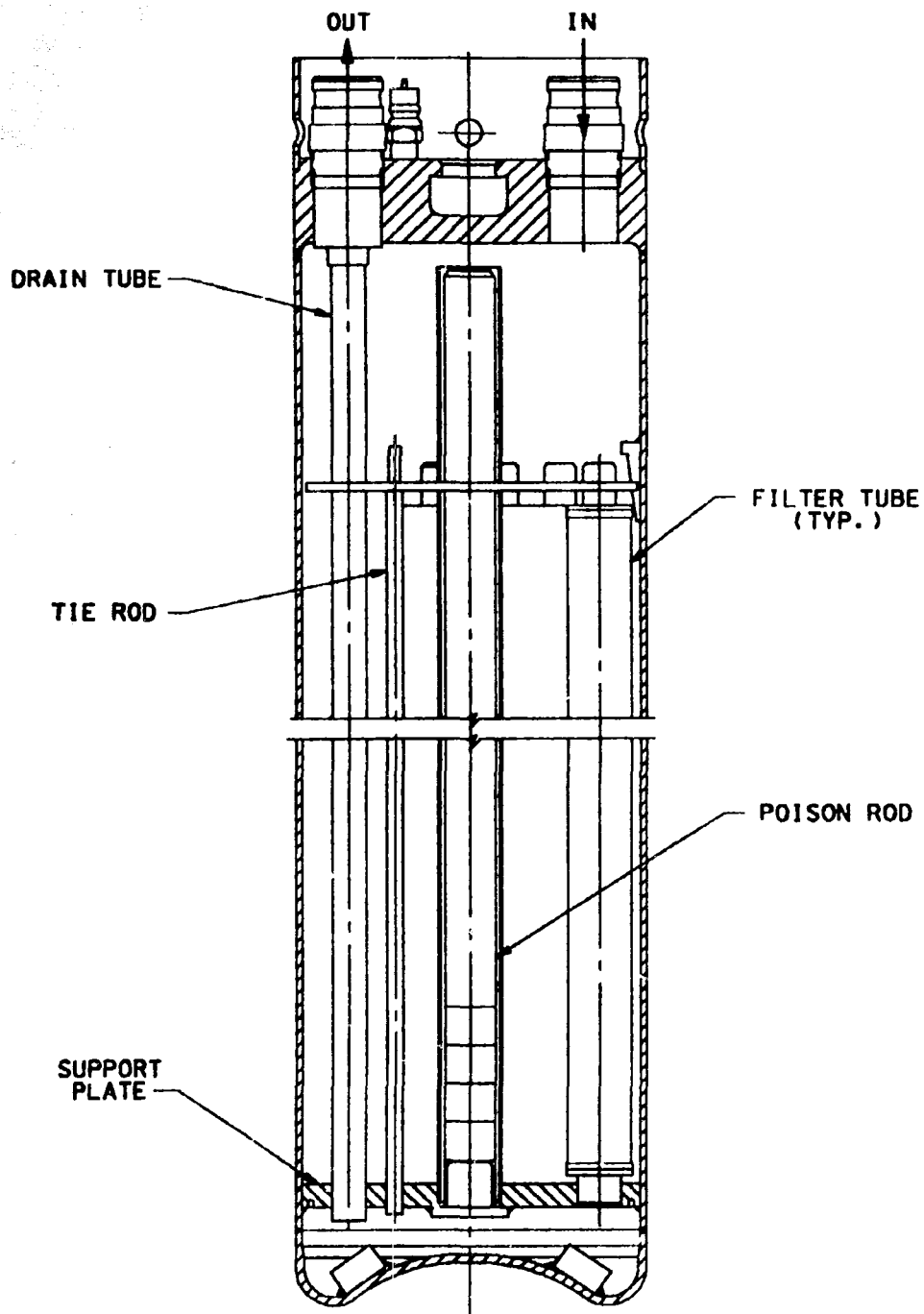


Figure 2-16. Filter canister.

### 3.0 CONTINUING EFFORTS

The defueling tooling covered in this report is capable of removing the debris in the upper section of the core. This tooling can remove the majority of debris located above the hard crust. Bulk core region defueling tooling is being developed to cut up debris that cannot fit into a fuel canister, and to section and remove brittle and ductile hard crust material. It can also be used to remove partial fuel assemblies, cut and remove incore instrumentation, and vacuum limited areas of the lower grid. Finally, additional tooling for lower reactor vessel head and core support assembly defueling will permit the removal of essentially all the fuel and core debris remaining in the reactor vessel.

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## **APPENDIX**

### **TMI-2 DEFUELING SYSTEM DESIGN DESCRIPTION**

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Madison, PA 15663**

## ABSTRACT

This Appendix provides a summary level description of the Three Mile Island Unit 2 (TMI-2) dry defueling system designed for, and with the assistance of the GPU Nuclear Corporation. The system will be operated by GPU Nuclear Corporation. Defueling will take place through the internals indexing fixture (IIF), which is located above the reactor vessel. Defueling equipment will be mounted on and operated from the shielded work platform. Defueling operations will progress from fairly simple pick and place operations and vacuuming up to more complex cutting and other debris removal tasks.

## ACKNOWLEDGMENTS

Talent and skill from a variety of engineering disciplines were necessary to complete defueling tooling preliminary design. These people are among those who made important contributions to the success of the Project and their efforts are gratefully acknowledged:

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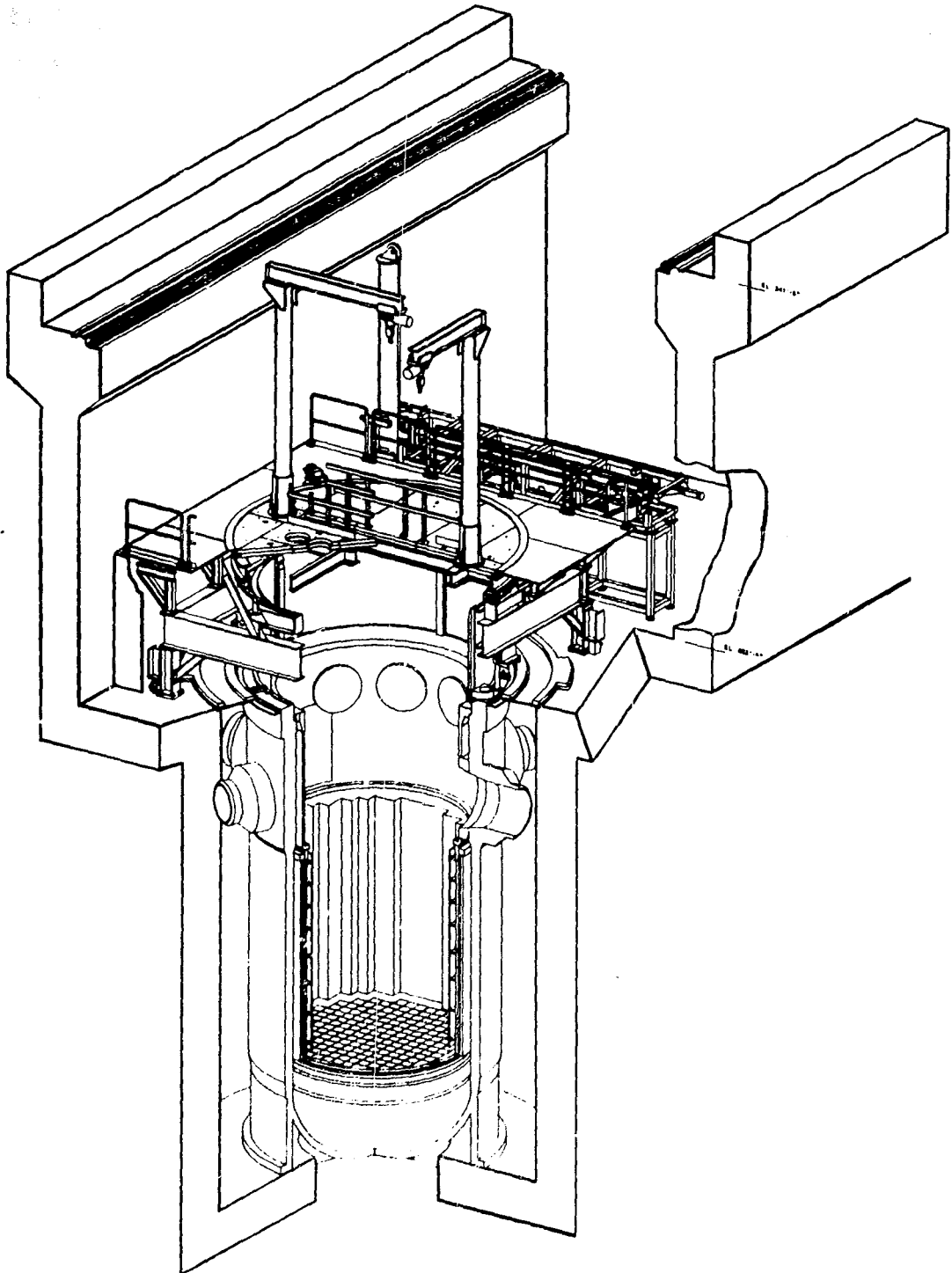
NOTE: Drawing numbers indicated on figures are Westinghouse drawing numbers.

## 1.0 INTRODUCTION

The defueling system, illustrated in Figure A-1, is a system of equipment that will remove the loose debris and core materials from the reactor vessel of the TMI-2 plant. The core materials exist in a variety of shapes and sizes from full fuel assemblies to rubble small enough to be moved by fluid vacuum pumping. Operations will include sizing the core material and loading and preparing canisters for removal from the reactor vessel. All of the operations within the reactor vessel are within the scope of the defueling system while the transfer of canisters will be the responsibility of and described by others. All fuel handling operations and canister loading will take place inside a composite water vessel composed of the reactor vessel, the core support assembly, and the IIF with a modified seal. The defueling water level will be maintained 5 ft above the vessel flange. Operators will operate tools from a shielded work platform mounted directly over the IIF. This dry defueling system has several advantages over the conventional flooded canal approach. They are: (1) long handled tools are shorter and thus more feasible (25 ft versus 45 ft), (2) all canister loading is done in the vessel to confine contamination to a limited area, (3) a smaller volume of water needs to be processed by the defueling water cleanup system (DWCS) and (4) the equipment operators on the shielded work platform perform the defueling operations in a lower background radiation field (as opposed to the radiation field at El. 347'-6").

Figure A-1

Dry Defueling System (Dwg. 1737E60)



## 2.1 Reference System

The operators will be standing on the shielded work platform above the reactor vessel flange. This platform provides shielding so that the contaminated water in the reactor vessel will not be a major exposure source for personnel operating the defueling system tools. The platform is supported from the refueling canal floor by the shielded support structure. Between the shielded work platform and shielded support structure, various lines for water treatment sampling and off-gas ventilation are routed into and out of the reactor vessel. This water treatment and off-gas control piping are stationary and do not impact operation of the shielded work platform.

The shielded work platform has an 18-in. wide slot through which the long handled tools are operated. The tool working slot width and the shielded work platform shielding will limit the radiation fields from the active core and water while operating the long handled tools. The working slot may be covered by plugs of 6-in. thick steel. These plugs are normally removed to gain access to the reactor vessel and to permit lateral movement of the long handled tools to deposit debris in the fuel canisters.

By taking advantage of the shielding, provided by the refueling canal walls and the clean stainless steel liner of the canal, exposure due to other radiation sources is reduced. Thus, general background radiation levels can be relatively low for the personnel in the refueling canal area.

To transfer canisters loaded with fuel fines, debris, and partial fuel assemblies from the reactor vessel, a canister handling trolley is used. This trolley (the responsibility of others) hoists the radioactive canister out of the water, through the shielded work platform, and into the shielded canister transfer device. The loaded canister handling trolley is used to move the canister to the modified fuel transfer system in the deep end of the canal, where the canister is lowered into the transfer system upender.

## 2.2 Core Mapping

The initial defueling process is a core mapping operation to characterize the TMI-2 core to confirm the overall defueling process philosophy and facilitate core removal.

## 2.3 TMI-2 Defueling

Defueling will proceed in two phases. These phases are:

Phase I Removal or rearrangement of debris including end fittings, partial fuel assemblies, spiders, and smaller debris using pick and place methods with low capacity long-handled tools until sufficient space is cleared to install the vacuum system and canister positioning system. Vacuum fine debris and continue pick and place operations until the long-handled tool capabilities have been exceeded.

Phase II Install manual tool positioner and continue defueling operations, including fused debris removal and handling large partial fuel assemblies, until essentially all debris is removed from the interior of the core support structure.

### 2.3.1 Phase I

At the beginning of Phase I, the plenum has been removed from the reactor and placed in a stand in the deep end of the refueling canal. The IIF is in place on the reactor vessel flange. The main structure of the shielded support structure is installed, centered, and leveled and the shielded work platform is in place on the main structure. The platform drive system and the cable management system are installed. The service platform is in place, the north and south service platforms are installed and the fuel handling operations can begin. Phase I operations include:

- Rearrange debris or load into debris buckets using long-handled tools until the canister positioning system can be installed.
- Install the vacuum system and continue to remove or rearrange debris if required.

- Vacuum fines and small debris directly into canisters.
- Rearrange or remove debris to allow access to vacuumable debris.
- Repeat above operations until the manual tool positioner is required.

### 2.3.2 Phase II

Phase II begins with installation of the manual tool positioner to assist long-handled tools. Operations include:

- Pick up debris and load into debris buckets within the reactor vessel cavity. The debris buckets will subsequently be loaded into the fuel canisters.
- Break up fused or bonded core components and transfer to fuel canisters in the canister positioning system.
- Remove partial intact fuel assemblies. These may either be placed in canisters directly, or reduced to a suitable form via the end effectors and then placed in fuel canisters.

Throughout all defueling phases filled fuel, filter, and knockout canisters will be removed from the vessel and transferred to fuel pool A. New canister will be placed in the vessel to continue the defueling operations.



The start of defueling operations is scheduled for the 4th quarter of 1985. The defueling tool systems will support the planned operations as described in Section 2.3. The tool systems include:

- Shielded Work Platform
- Shielded Support Structure
- Vacuum System
- Long Handled Tools
- Control System
- Viewing System
- Canister Positioning System
- Single Canister Support Bracket
- Test Assemblies
- End Effectors
- Tool Positioning System
- Support Tools

The arrangement and interfaces of all defueling equipment are shown in Reference 1. The reactor dimensions are shown in Reference 2. A Defueling System Design Specification (Reference 3) has been written to cover all tooling. All defueling tooling design activities are based on the GPUN Technical Specification (Reference 4). Quality requirements are specified in Reference 5. To assure that a complete tool list is identified, detailed defueling task descriptions have been written (Reference 6).

### 3.1 Shielded Work Platform

The Final Design Report for the Shielded Work Platform (Reference 7) and the Operation and Maintenance Manual for the Shielded Work Platform (Reference 8) contain detailed information on the work platform. A summary tool list is included in Table A-1. The shielded work platform (Figure A-2) provides a shielded work area for the defueling operations, a support for the defueling tools, and openings for removing the canisters. The shielded work

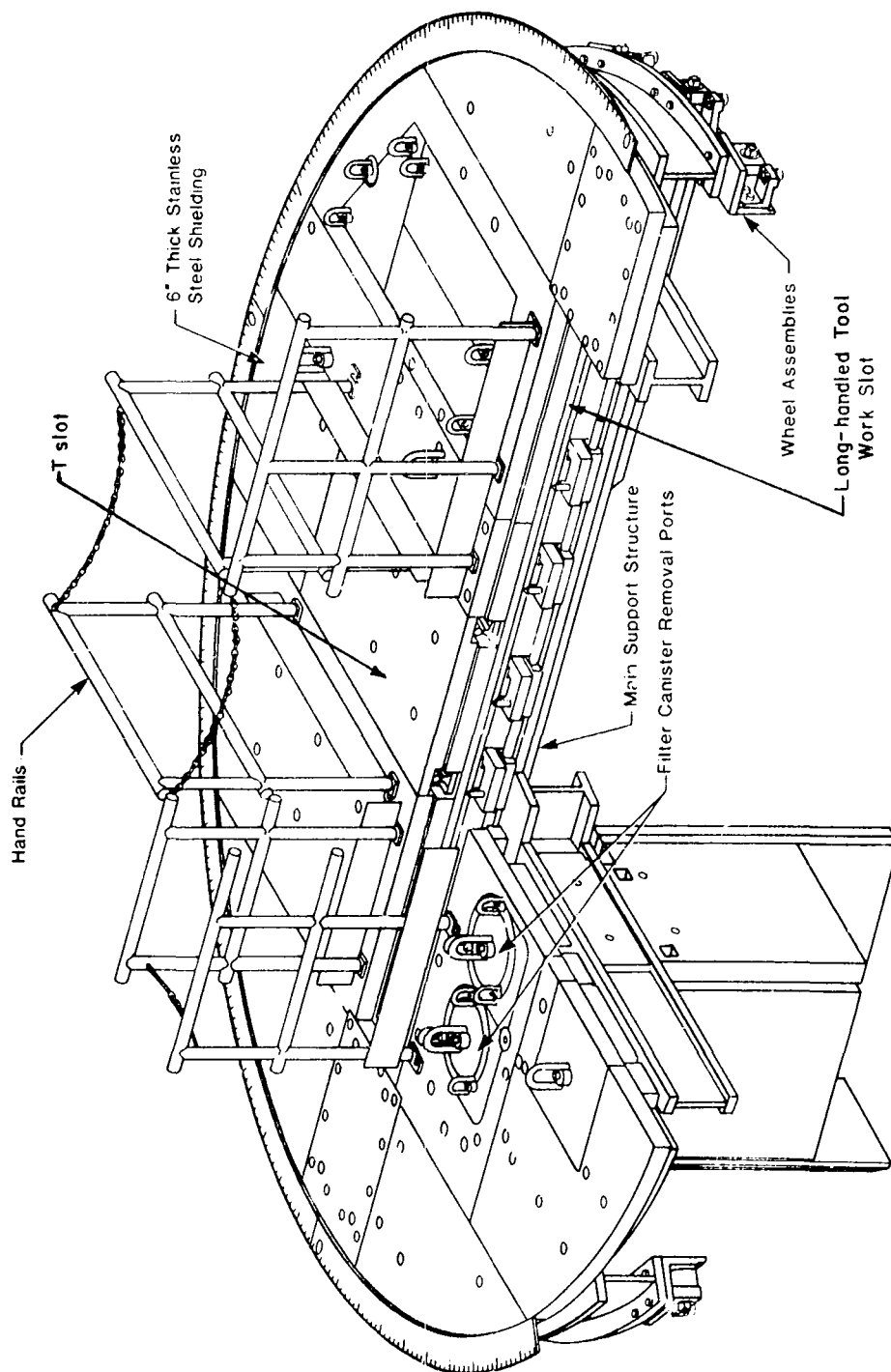
- Main Support Structure
- Long Handled Tool Slot Rail System
- T-Slot Rail System
- Shielding Plates
- Decontamination Spray System
- Roller Assemblies
- Platform Drive System
- Jib Cranes

TABLE A-1 WBS 721 SHIELDED WORK PLATFORM TOOL LIST

<u>Tool/Component</u>	<u>Westinghouse Dwg. No.</u>	<u>GPUN Equip. Ident. No.</u>
Shielded Work Platform	1739E46	DEF-SWP-001 thru 088
Main Support Structure	1739E30	DEF-SWP-001 thru 017
Shielding Plates	1739E30	DEF-SWP-034 thru 063
Cable Drive System	1738E91	DEF-SWP-023 thru 029
Jib Cranes	1739E46	DEF-SWP-076
Brake	1739E48	DEF-SWP-068

The main support structure is constructed of fabricated stainless steel I-beams. These specially made beams are required to meet space constraints and to resist corrosion. The circular main support structure is divided into three beam assemblies to permit entry into containment: two 140° arc segments and one center support structure of two 40° arc segments connected by two parallel straight beams. The straight beams are the main load carriers and form the sides of the long-handled tool slot.

The long-handled tool slot rail system provides linear motion along the tool slot. The rail system consists of two Thomson rails bolted to the two straight I-beams. Twin pillow blocks are installed on these rails and support installed defueling tools. A similar system is provided for the adjacent T-slot.



Surface and vertical shielding are used to reduce the radiation dose rates. Each horizontal surface shielding section is comprised of two 3-in. thick stainless steel plates. Each section rests on the top flanges of the beams in the main support structure. Three ports are provided to remove the two filter canisters in the vacuum system and the fuel or knockout canisters in the canister positioning system. The vertical shielding is located at these three ports to block shine as canisters are removed from the reactor vessel. These 5-in. thick plates extend from the bottom of the surface shielding to about 2 ft below the water level.

The decontamination spray system flushes radioactive debris from the surface of the canister as it is removed from the reactor vessel. The spray system is constructed of stainless steel.

Twenty-two 5.00-in. diameter rollers provide the rotational capability for the shielded work platform. The rollers are mounted on shoulder bolts (axles) pressed into the roller housing. A set of cam followers are mounted on the roller carriers. These smaller rollers provide the restraining force to keep the work platform centered.

The platform drive system (Figure A-3) rotates the shielded work platform 180° in either direction from a nominal position at a speed between 0 and 0.3 r.p.m. Rotation of the shielded work platform is actuated by rotating the drive drum that takes up the cable in one direction and pays out the cable in the other. A servomotor powers the drive drum through a double worm gear reducer. The gear reducer has two ended input shafts; one end for the motor and one end for the manual drive handle.

A manual disc brake secures the shielded work platform in the static position. The index ring on the shielded work platform serves as the disc and also as a manual position indicator. The index ring has degree markings to indicate angular position relative to the indicator on the shielded support structure. The shielded work platform can be pin locked in one position for canister removal.

Two jib cranes are mounted on the shielded work platform to aid the operators in manipulating the long-handled tools in the long-handled tool slot. The maximum head room of the jib cranes above the work platform is 13 ft 6 in. and the capacity is 1 ton.

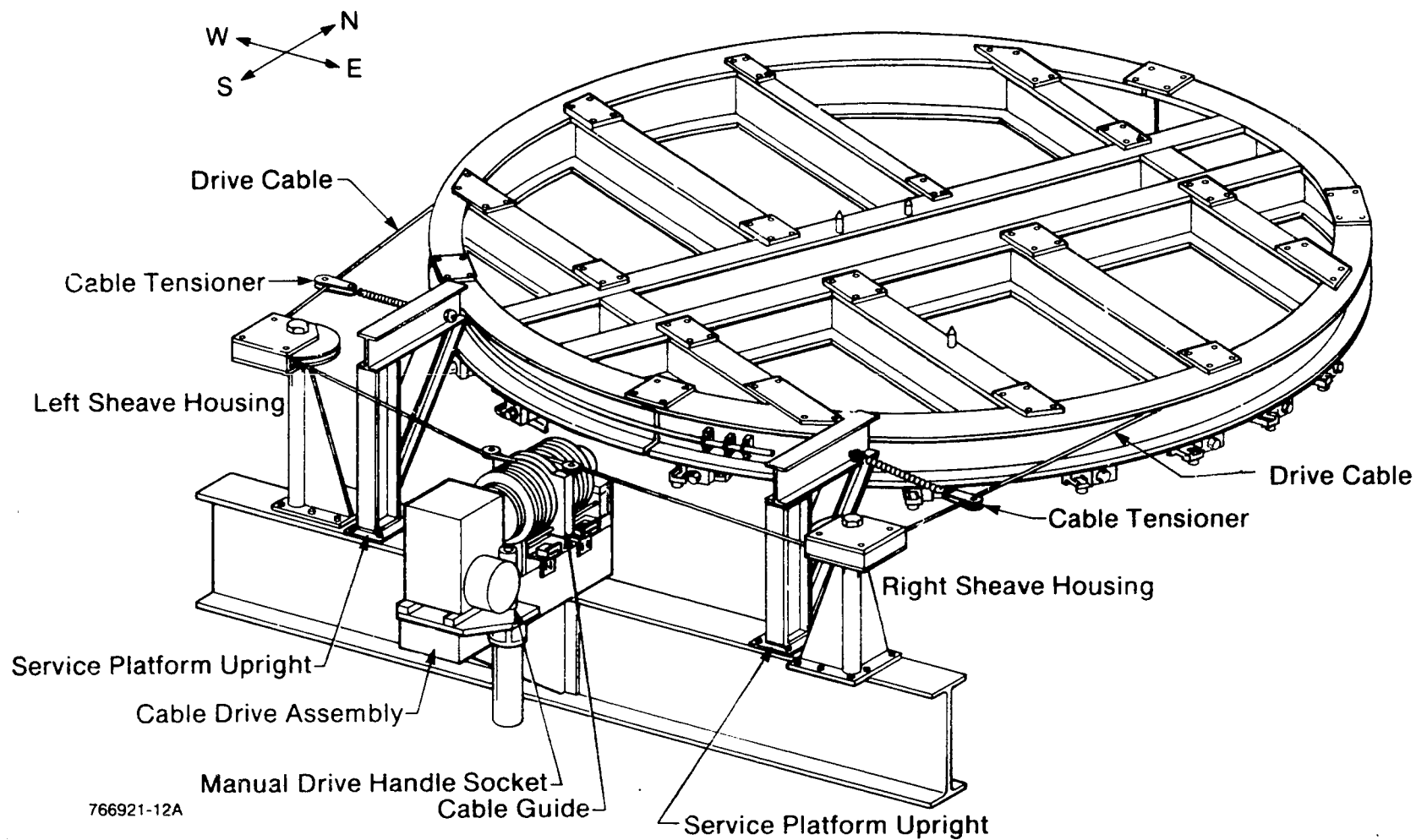


Figure A-3 Shielded Work Platform Drive System (Dwg. 1739E30)

### 3.2 Shielded Support Structure

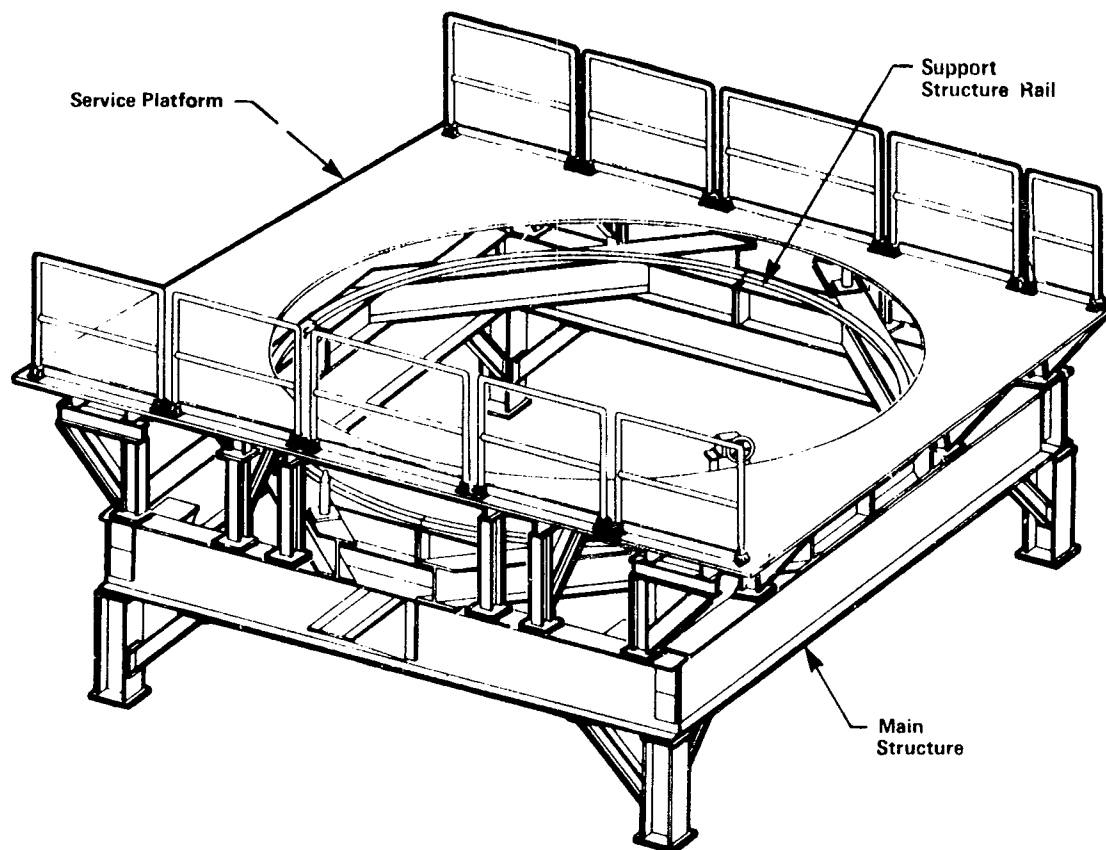
The shielded support structure illustrated in Figure A-4 is a rectangular-shaped beam structure that circumscribes the IIF. This structure is supported on the refueling canal floor and extends upward approximately 7 ft to El. 331'-5". The primary function of the shielded support structure is to support the shielded work platform. The interface to the shielded work platform is a circular rail (203 in. diameter) that is supported by an octagonal beam arrangement. Detailed information on the shielded support structure is provided in the Final Design Report for the Shielded Support Structure (Reference 9) and the Operation and Maintenance Manual for the Shielded Support Structure (Reference 10). A summary tool list is included in Table A-2.

TABLE A-2 WBS 711 SHIELDED SUPPORT STRUCTURE TOOL LIST

<u>Tool/Component</u>	<u>Westinghouse Dwg. No.</u>	<u>GPUN Equip. Ident. No.</u>
Shielded Support Structure	1738E76	DEF-SSS-001 thru 100
Main Structure	1738E73	DEF-SSS-001 thru 009
Support Structure Rail	1738E37	DEF-SSS-006-2, 007-02, 008-02, and 009-02
Service Platform	1738E75	DEF-SSS-040 thru 085
Vertical Shielding	1738E82	DEF-SSS-088 thru 093
Piping	1738E80	DEF-SSS-019 thru 033
Off-Gas Seal	1738E74	DEF-SSS-010 thru 014
Alignment Stud	1738E36	DEF-SSS-015 & 016

The shielded support structure also provides a stationary service platform area for tool staging at the shielded work platform elevation. Piping, off-gas seal, and shielding are included in the shielded support structure. The piping includes DWCS, off-gas control system, and bubbler system piping. The off-gas seal will minimize the intake flow area in the

**FIGURE A-4**  
**SHIELDED SUPPORT STRUCTURE (DWG. 1738E76)**



767017-26A

shielded support structure and shielded work platform region. This will ensure the off-gas system is effective in containing fission gases. Shielding plates are located along the north end of the shielded support structure to reduce the radiation levels in operator work areas. The shielded support structure is fabricated using welded and bolted connections so that it can be transported into containment through the personnel hatch.

The shielded support structure is comprised of six major components:

- Main Structure
- Support Structure Rail
- Service Platform
- Vertical Shielding
- Piping
- Off-Gas Seal

The main structure, shown on Figure A-5, is a 17-1/2 ft by 21 ft by 7 ft (height) assembly constructed of ASTM-A36 low carbon steel beams. The main structure is supported on the refueling canal floor by four columns. Located at each of these columns is a leveling jack and shim arrangement to level the shielded support structure. When used with a leveling transit, this system can level the structure to within 1/6 in.

The columns support a rectangular beam structure of W27 beams. This rectangular structure provides support for an octagonal beam array of W14 beams. This beam array supports the circular support structure rail. The support structure rail is a 2-in. high by 3-in. wide bar of 18% nickel maraging steel (200 grade). The bar is age hardened to achieve a Rockwell "C" hardness of 45. The support structure rail is fabricated in four sections and bolted to the main structure. The main structure provides three mounting brackets for the work platform drive system and two removable alignment pins to aid in the installation of the shielded work platform. These pins will be removed after the shielded work platform is installed.



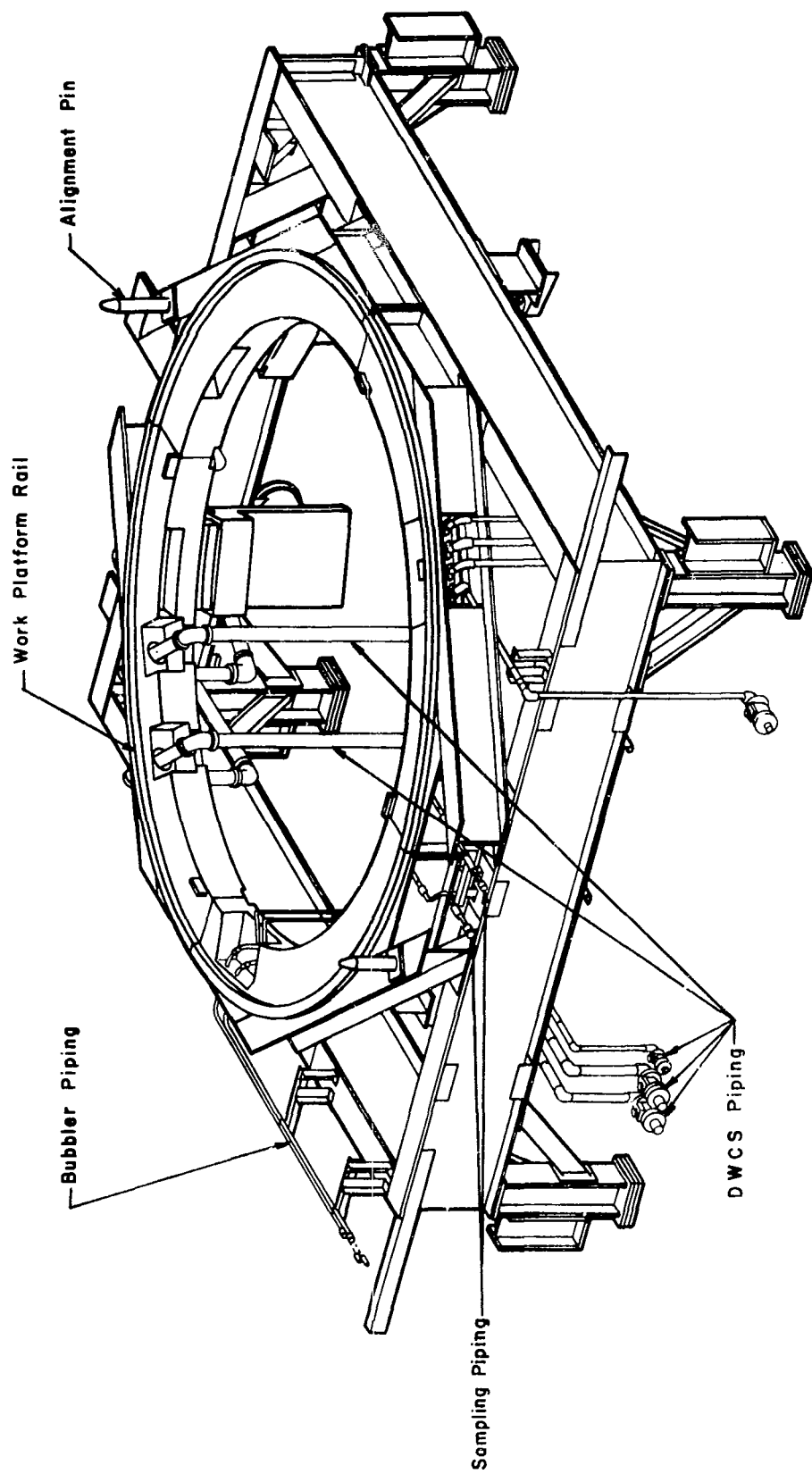


Figure A-5 Main Structure (Dwg. 1738E73)

The service platform is field connected to the main structure. The primary function of the service platform is to provide a staging area for personnel and equipment at the shielded work platform elevation. The service platform deck consists of 3-in. thick carbon steel plates that provide shielding and 1/4-in. thick stainless steel diamond plate decking. Removable handrails are located on the north and south sides of the service platform deck.

A 1-in. diameter pin and an indicator are located at the 0° reference position on the service platform. These will assist in positioning of the shielded work platform in the "jog" mode. A mounting area for the manual brake provided by the shielded work platform is located at the 60° reference position.

The vertical shielding is field connected to the main structure. The vertical shielding consists of 2-in. thick carbon steel plates on the north side of the shielded support structure. They extend from the refueling canal floor to the service platform deck leaving a 1-in. gap between the plates and the canal walls. The plates are butted together at assembly and have a maximum gap of 1/4 in. between the plates. The gap helps to simplify installation and removal of the plates, yet maintains acceptable radiation levels. A spanner beam over the seal plate supports the interior shielding panels. This beam eliminates any loading of the seal plate by transferring the load through the spanner beam to the refueling canal floor.

The off-gas seal minimizes the air flow gaps among the IIF, the shielded support structure, and the shielded work platform. Minimizing the gaps reduces the off-gas blower capacity requirements. The off-gas seal consists of two major components: a rotating upper seal assembly provided by the shielded work platform and a stationary lower seal.

The piping is routed from inside the IIF through the off-gas seal to the DWCS, the off-gas control system, and the bubbler system. Flanged pipe connections are incorporated into the piping designs to facilitate in-containment handling.

At two reactor vessel stud hole locations, stainless steel alignment studs will be installed in the reactor vessel flange to position the shielded support structure. The seal plug bolts at the two locations are removed to install the alignment studs. After the studs are installed, the main structure can be lowered into place.

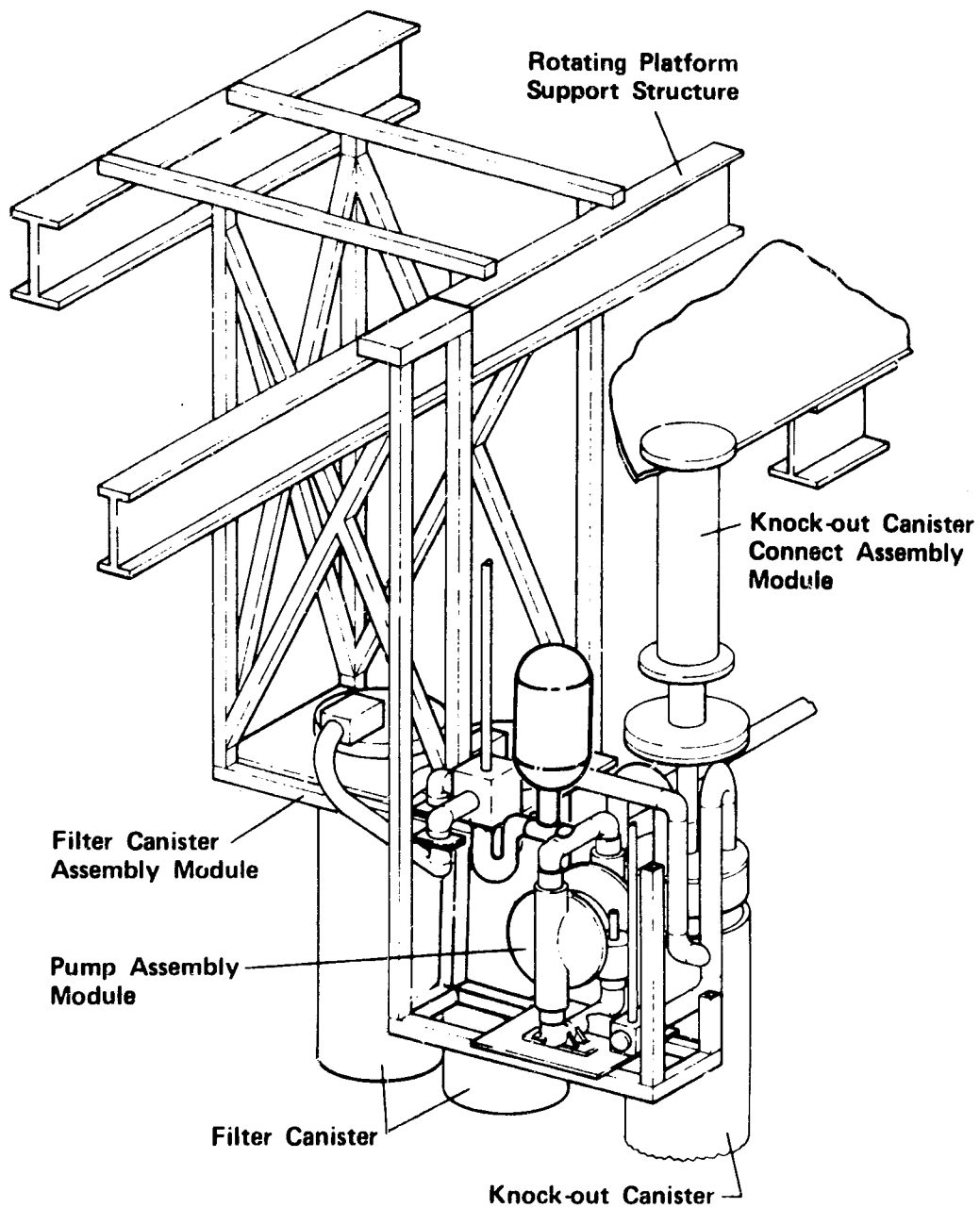
### 3.3 Vacuum System

The vacuum system illustrated in Figure A-6 is used in the TMI dry defueling system to remove debris from the TMI reactor vessel. The vacuum system consists of a long-handled nozzle handling tool, the knockout canister connect assembly module, the pump module, knockout and filter canisters, and the required flexible and stainless steel piping to join the various components into a system. The vacuum system component modules are positioned beneath and supported by the shielded work platform. Controls for the vacuum system are located on the control console. Valve actuators for the vacuum system are located on the work platform. A summary tool list is presented in Table A-3.

TABLE A-3 WBS 412 VACUUM SYSTEM TOOL LIST

<u>Tool/Component</u>	<u>Westinghouse Dwg. No.</u>	<u>GPUN Equip. Ident. No.</u>
Nozzle Assembly Module	1734E56	DEF-VAC-010
Pump Assembly Module	1735E21	DEF-VAC-006
Knockout Canister Connect Assembly Module	1734E56	DEF-VAC-018
Filter Canister Weighing Assembly	1735E62	DEF-VAC-005
Support Tooling:		
Manually Operated Grapple Tool	1735E11	DEF-VAC-002
Hose Handling Tool	1735E06	DEF-VAC-004
Disconnect Tool	1735E31	DEF-VAC-003

**FIGURE A-6**  
**VACUUM SYSTEM (DWG. 1738E56)**



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The vacuuming operation consists of presenting the nozzle to the debris bed, whereby debris is vacuumed up through the nozzle assembly and delivered to the knockout canister where debris larger than 130 microns is trapped. The debris smaller than 130 microns passes through the knockout canister and are delivered to the filter canister where debris as small as 0.5 microns in size are trapped. The effluent from the filter canister is discharged into the reactor vessel. The design of the nozzle end limits the particle size intake to fuel pellet size and under. Thus the debris size range for vacuuming is from fuel pellet size (3/8 in. x 5/8 in.) to 0.5 micron.

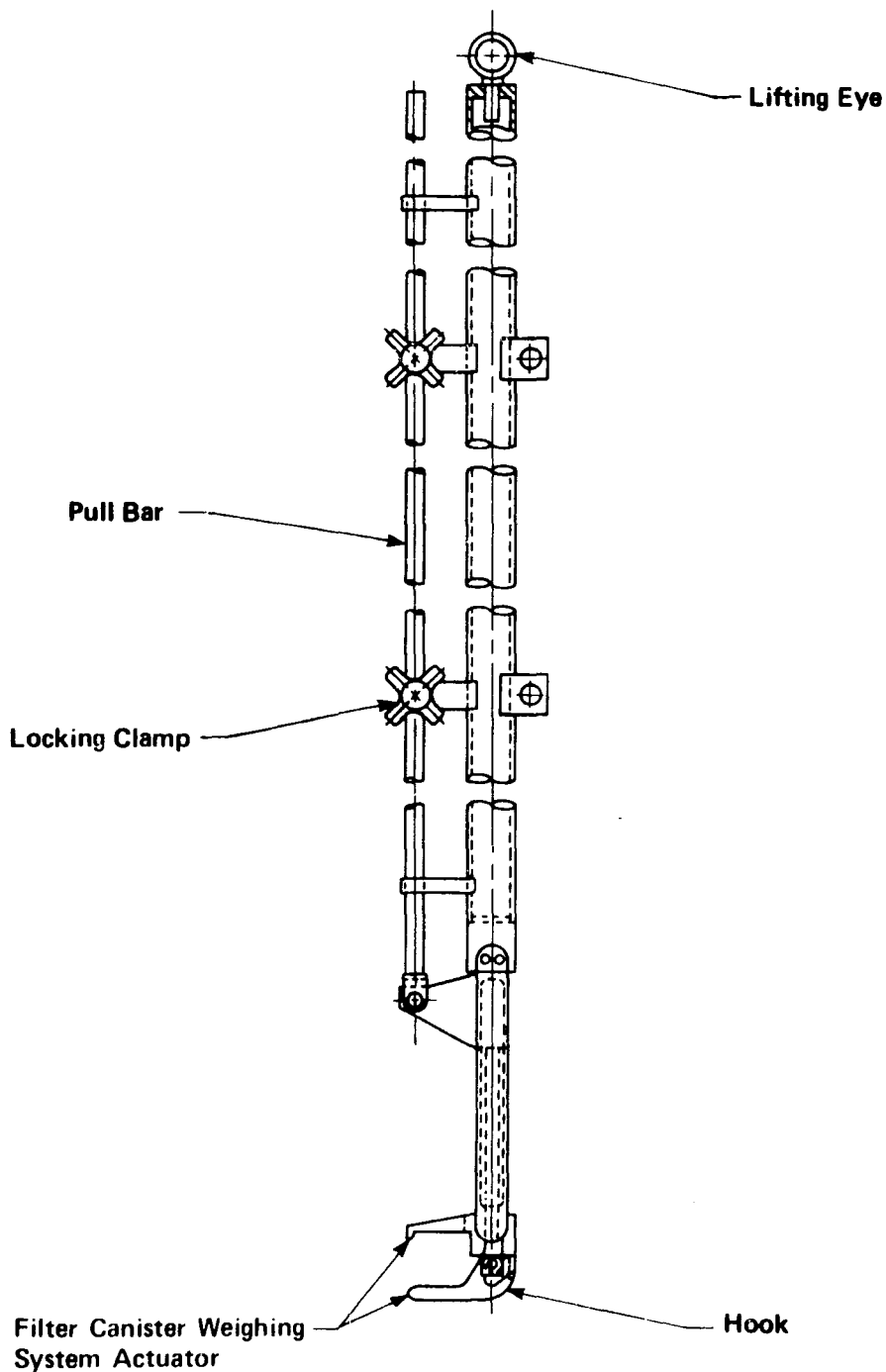
The weight of the knockout canister engaged by the vacuum system is monitored continuously by a load cell in the knockout canister connect assembly module. The signal from this load cell is transmitted to a readout on the control console, where an alarm sounds when a predetermined weight is reached. Filter canisters are weighed continuously and are monitored in a similar manner.

Long-handled tools are used to install, actuate, maintain, or service the vacuum system components and modules. These tools are the manually operated grapple (Figure A-7), the disconnect tool (Figure A-8), the hose handling tool (Figure A-9), the socket wrench (Figure A-10), the hook tool (Figure A-11), quick disconnect coupler (Figure A-12), the hose connection tool (Figure A-13), and the canister grapple connection vacuum tool (Figure A-14). Detailed information on the vacuum system is presented in the Final Design Report for Early Defueling Vacuum System (Reference 11) and the Operation and Maintenance Manual for Early Defueling Vacuum System (Reference 12).

### 3.4 Long-Handled Tools

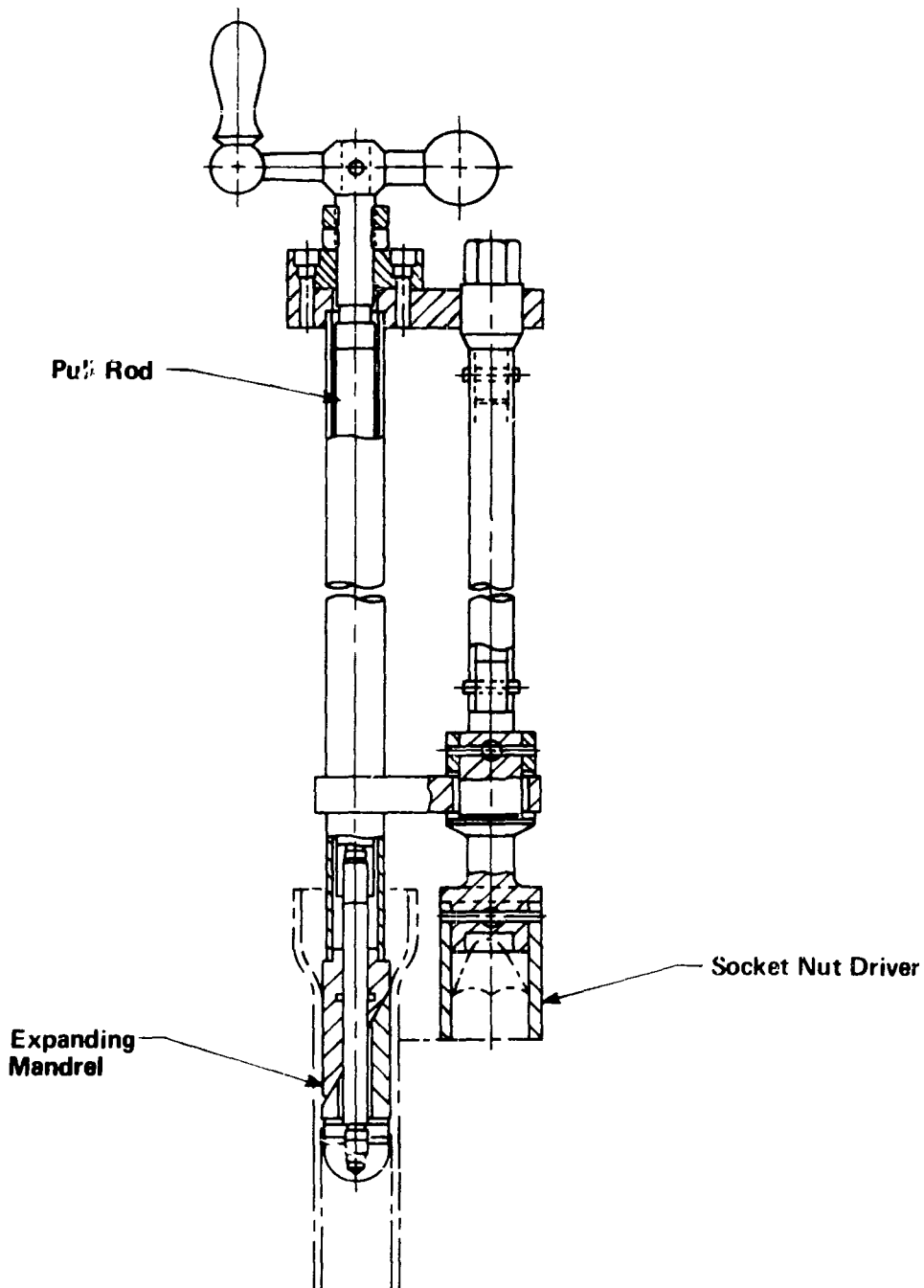
The Final Design Report for the Long Handled Tools is found in Reference 13 and the Operation and Maintenance for Long Handled Tools is found in Reference 14. A summary tool list is presented in Table A-4. The long-handled tools consist of two basic groups; heavy duty tooling and light duty tooling. They will be used for limited pick and place operations and minor cutting of debris. The operator will use the tools through the tool slot in the shielded work platform. The tools will be supported by an overhead crane that also provides vertical and lateral motion.

**FIGURE A-7**  
**MANUALLY OPERATED GRAPPLE TOOL (DWG. 1807E53)**



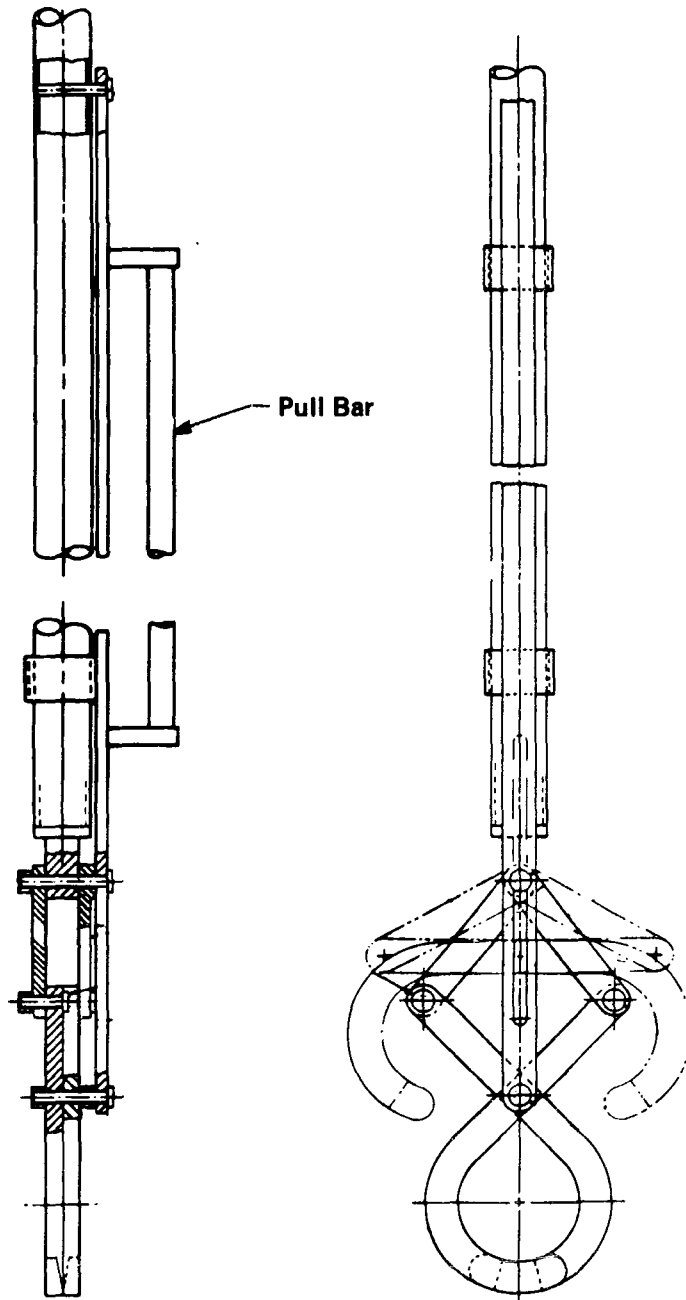
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**FIGURE A-8**  
**DISCONNECT TOOL (DWG. 1735E31)**



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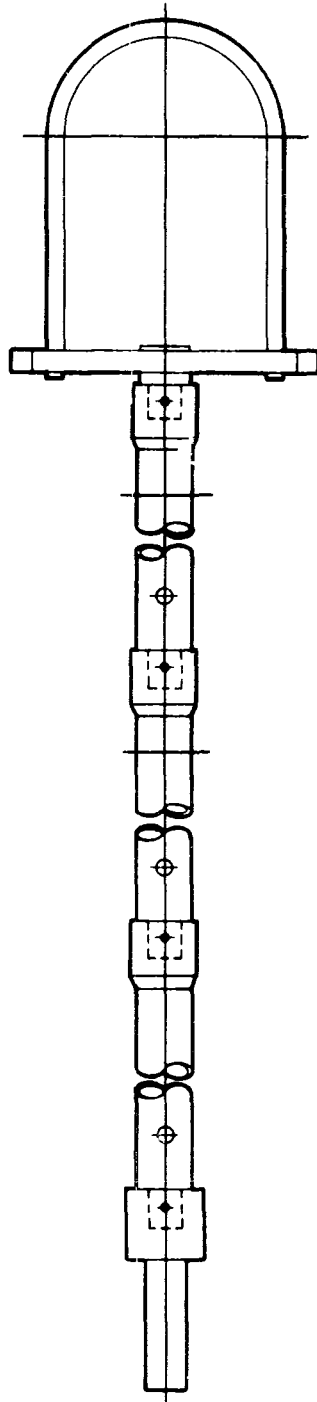
**FIGURE A-9**  
**HOSE HANDLING TOOL (DWG. 1735E06)**



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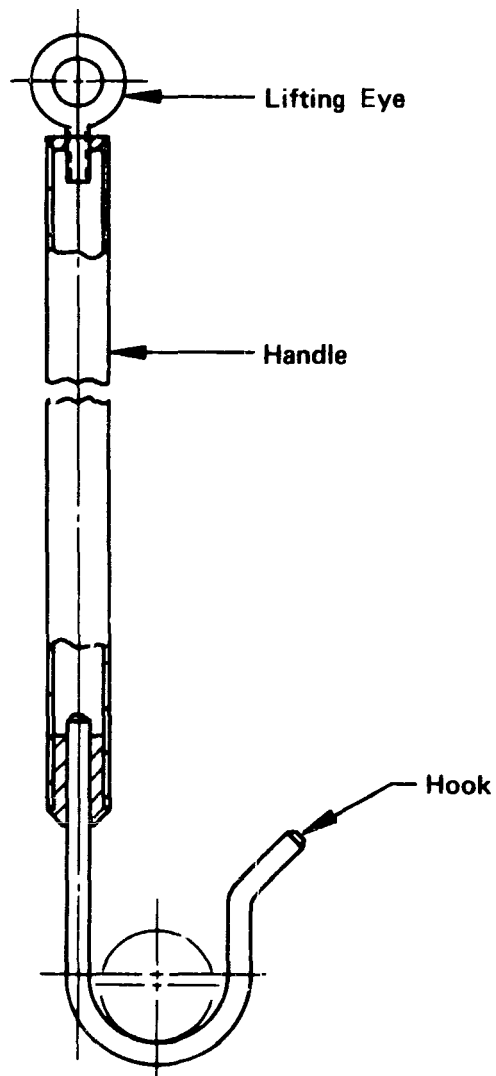


**FIGURE A-10**  
**VACUUM SYSTEM SOCKET WRENCH (DWG. 1808E36)**



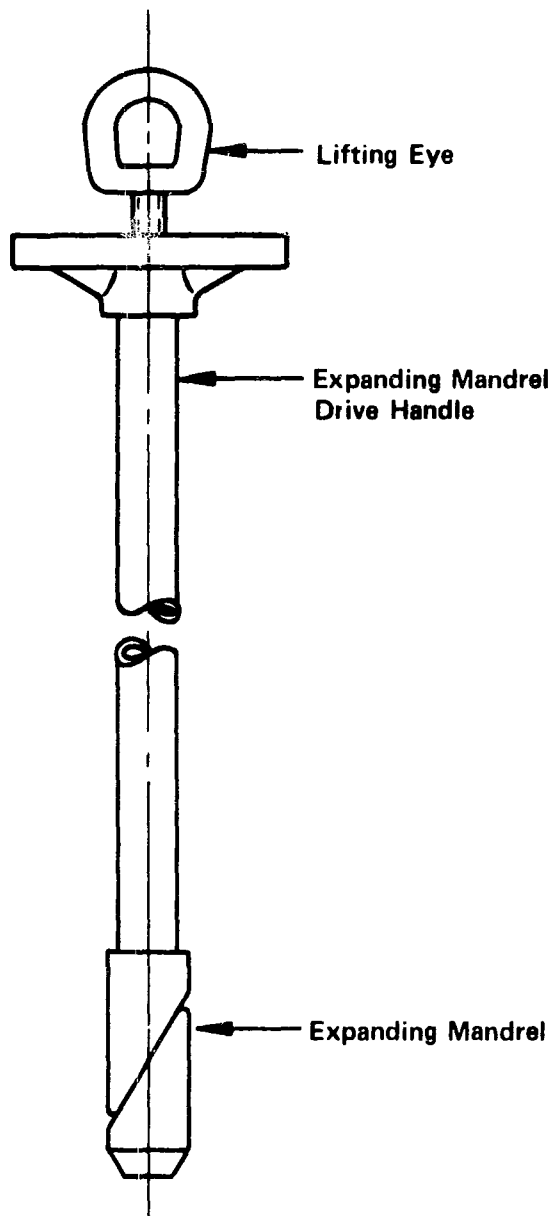
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**FIGURE A-11**  
**VACUUM SYSTEM HOOK TOOL (DWG. 1808E37)**



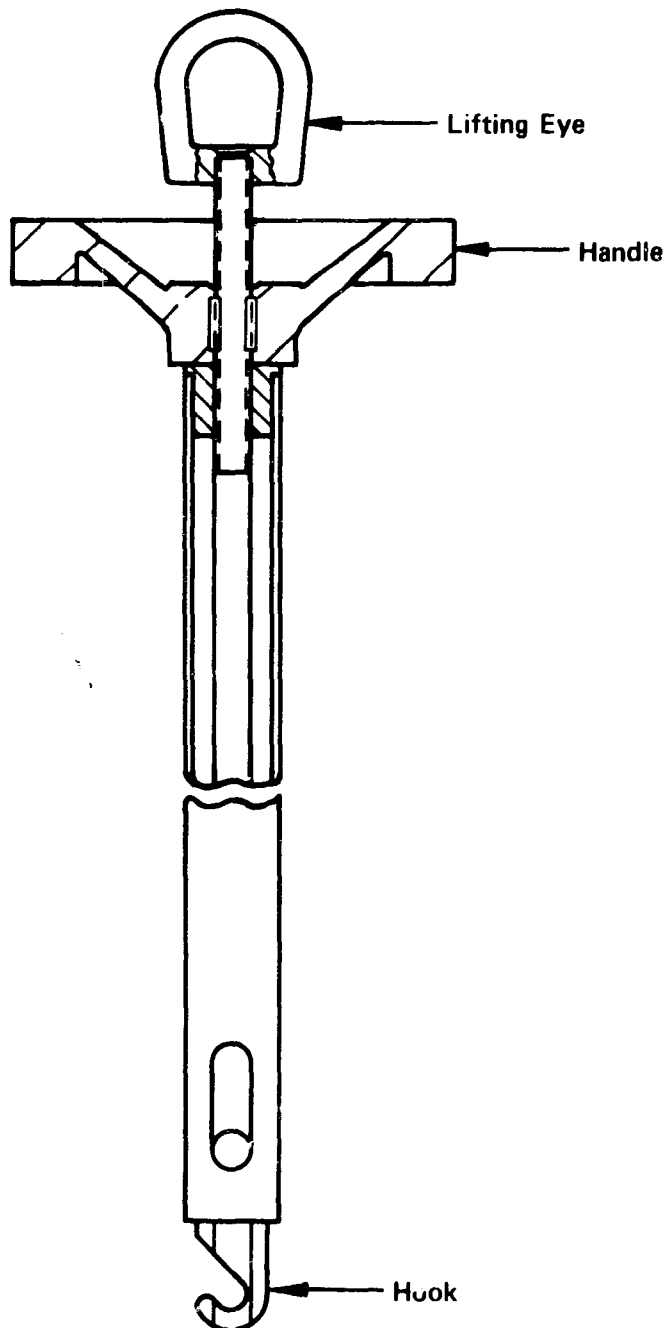
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**FIGURE A-12**  
**QUICK DISCONNECT TOOL (DWG. 1808E39)**



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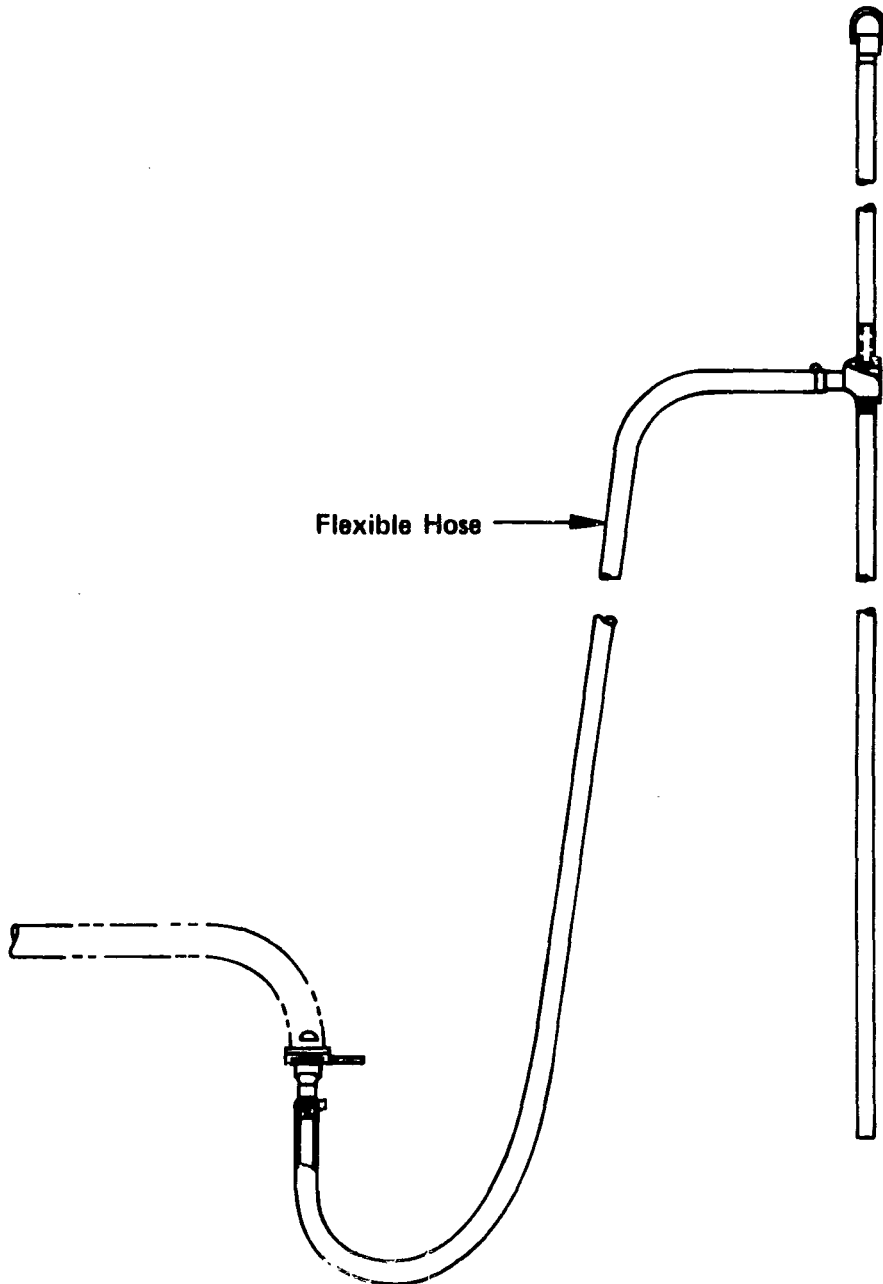
**FIGURE A-13**  
**HOSE CONNECTION TOOL (DWG. 1808E38)**



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Figure A-14

Canister Grapple Connection Vacuum Tool (Dwg. 1807E5&)



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TABLE A-4 WBS 514 LONG-HANDLED TOOLS LIST

<u>Tool/Component</u>	<u>Westinghouse Dwg. No.</u>	<u>GPUN Equip. Ident. No.</u>
End Effector Handling Tool	1773E26	DEF-LHT-109
Three Point Gripper	1773E45	DEF-LHT-104
Four Point Gripper	1773E49	DEF-LHT-105
Grapple	1773E09	DEF-LHT-190 & 191
Single Rod Shears	1775E59 & 1774E53	DEF-LHT-101 & 102
Parting Wedge	1773E28	DEF-LHT-103
Vise Grips	1773E36	DEF-LHT-183 thru 189
Bolt Cutters	1770E41	DEF-LHT-150
Hook Tools	1773E39	DEF-LHT-192 thru 195
Socket Wrench	1773E39	DEF-LHT-116
Disposable Debris Buckets	1778E40 & 1778E51	DEF-LHT-134 & 136
Debris Bucket Handling Tool	1777E79	DEF-LHT-138
Debris Bucket Stands	1778E69 & 1778E70	DEF-LHT-135 & 137
Heavy Duty Tong Tool	1778E36	DEF-LHT-113
Spade Bucket Tool	1778E44	DEF-LHT-148
Clamshell Tool	1780E75	DEF-LHT-108
Partial Fuel Assembly Tool	1778E53	DEF-LHT-145
Heavy Duty Shears	1778E66	DEF-LHT-146
Measuring Probe	1778E50	DEF-LHT-127
Light Duty Tong Tool	1778E42	DEF-LHT-130
End Fitting Loading Tool	1778E49	DEF-LHT-141
Banding Tool	1778E41	DEF-LHT-129
Debris Clamping Station	1773E96	DEF-LHT-151
Debris Bucket Hanger	1773E88	DEF-LHT-152

### 3.4.1 Heavy Duty Tools

End Effector Handling Tool - A long-handled pole or end effector handling tool, illustrated in Figure A-15, is used to position and operate the various end effectors from the shielded work platform. The high pressure lines used to actuate the end effectors run inside the pole to protect them from damage. The pole is designed for a 2,000 lb tension load and a 135 lb lateral load.

All end effectors will be attached to the end effector handling tool using remote bolts and hydraulic quick disconnects. The quick disconnects are commercially available in Type 304 stainless steel, and are modified by removing the self-locking ring portion. The connection is made when the swing bolts are tightened to the mast flange. Locating pins are used to assure that the hydraulic connections are aligned prior to connection.

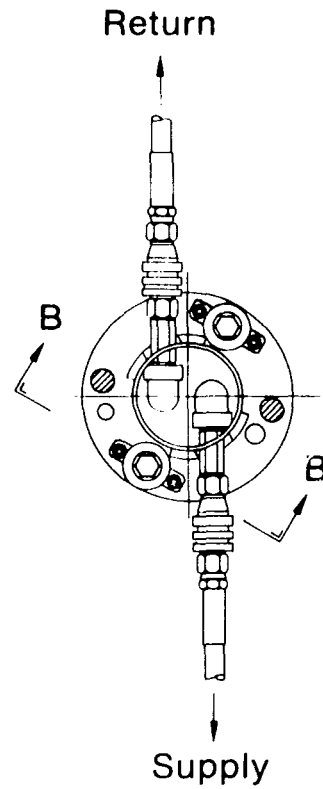
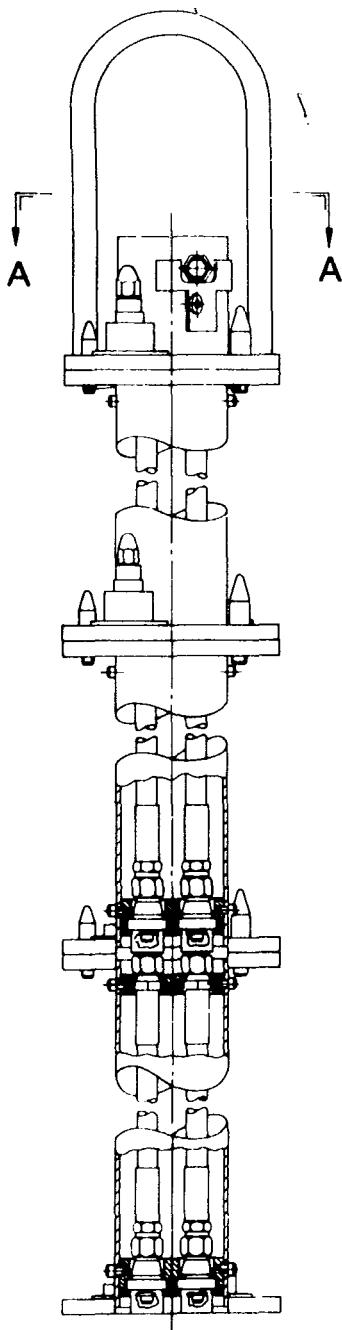
The pole is segmented into a 22 ft section and two 7 ft sections so that it may be used in either a 22, 29, or 36 ft length. The pole sections are attached to each other using remotely connected bolts and quick disconnect hydraulic fittings with the self-locking ring portions removed. Locating pins are used to assure that the hydraulic fittings are aligned prior to connection. The pole sections will have holes drilled in them to reduce buoyancy problems.

The total weight of the long-handled pole with an end effector attached to approximately 270 lb.

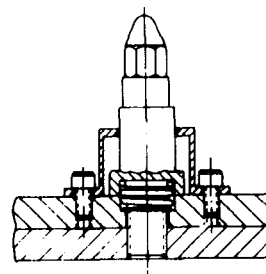
Three Point Gripper - The three point gripper, illustrated in Figure A-16, will pick up small objects from the debris pile. Maximum object size is 5 in. and expected payload is 20 lb.

Four Point Gripper (Staple Puller) - The four point gripper (staple puller), illustrated in Figure A-17, will pick up single, regularly or irregularly-shaped, objects from the debris pile. More than one size will be built with various width jaws for various sized objects. The tool will be effective for handling objects from 1/4-in. diameter to approximately 3.5-in. diameter.

**FIGURE A-15**  
**END EFFECTOR HANDLING TOOL (DWG. 1773E26)**



Section A-A

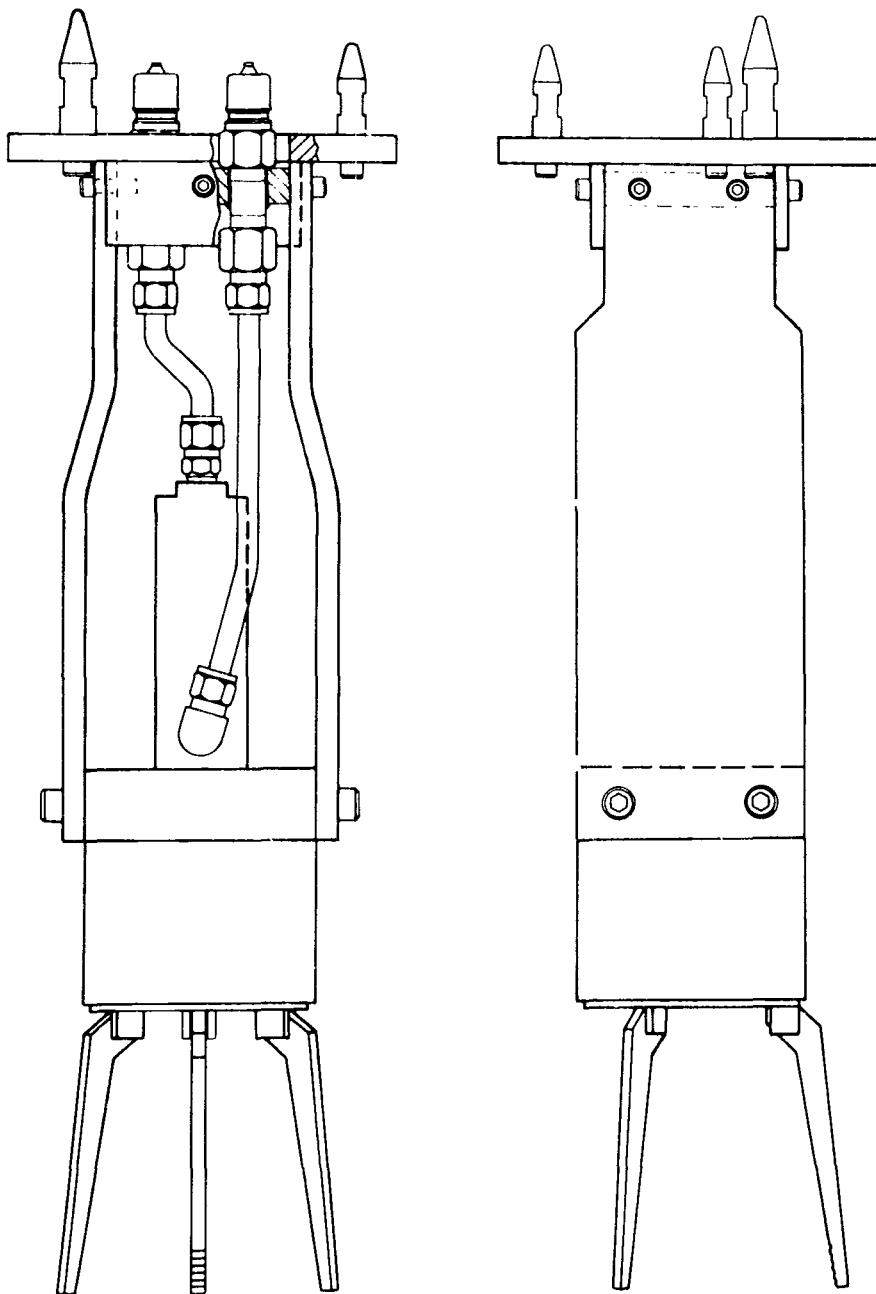


Section B-B

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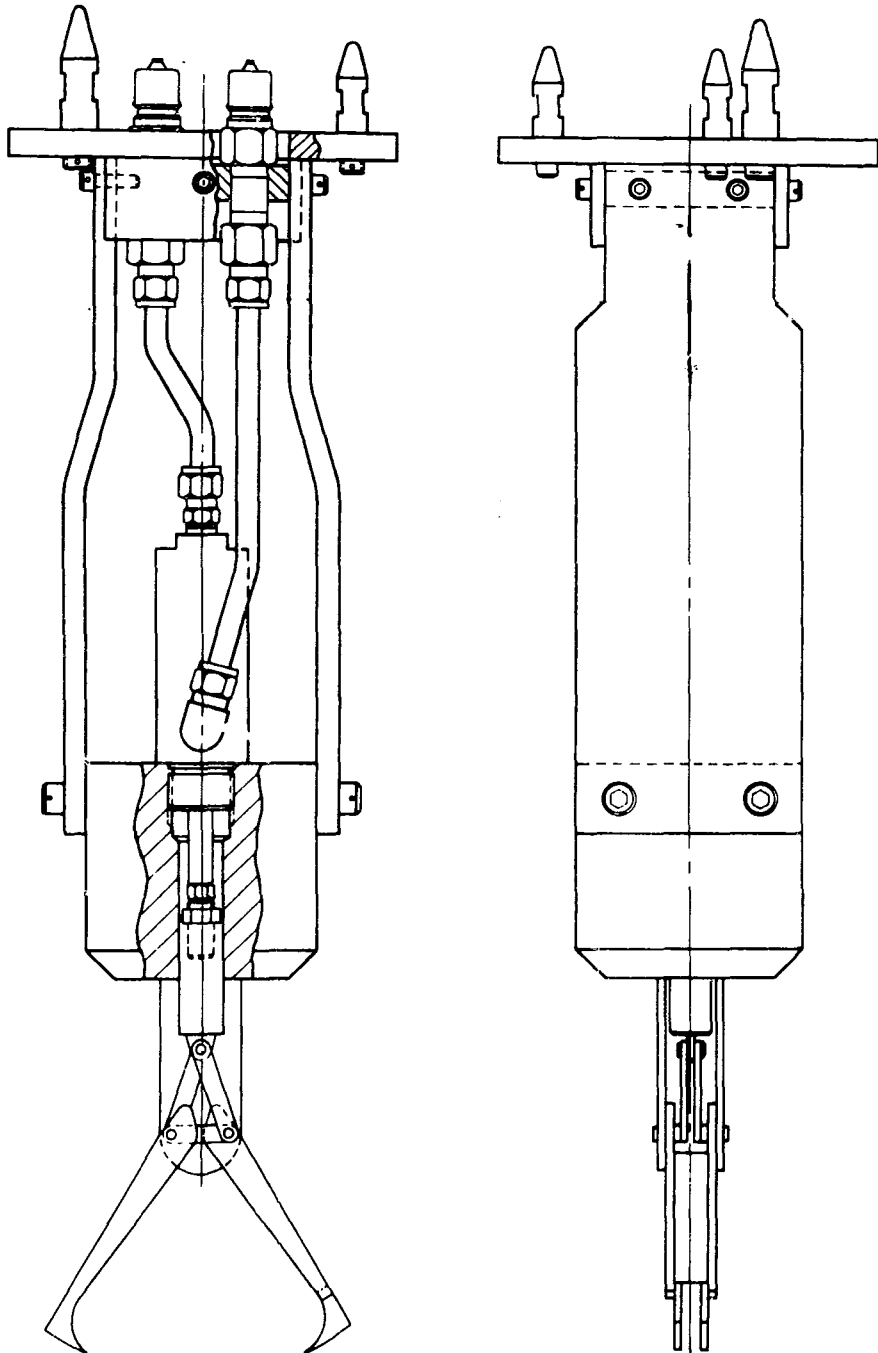


**FIGURE A-16**  
**THREE POINT GRIPPER (DWG. 1773E45)**



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**FIGURE A-17**  
**FOUR POINT GRIPPER (DWG. 1773E49)**



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Grapple - A grapple, illustrated in Figure A-18, will be used to lift irregular pieces, especially end fittings and spiders.

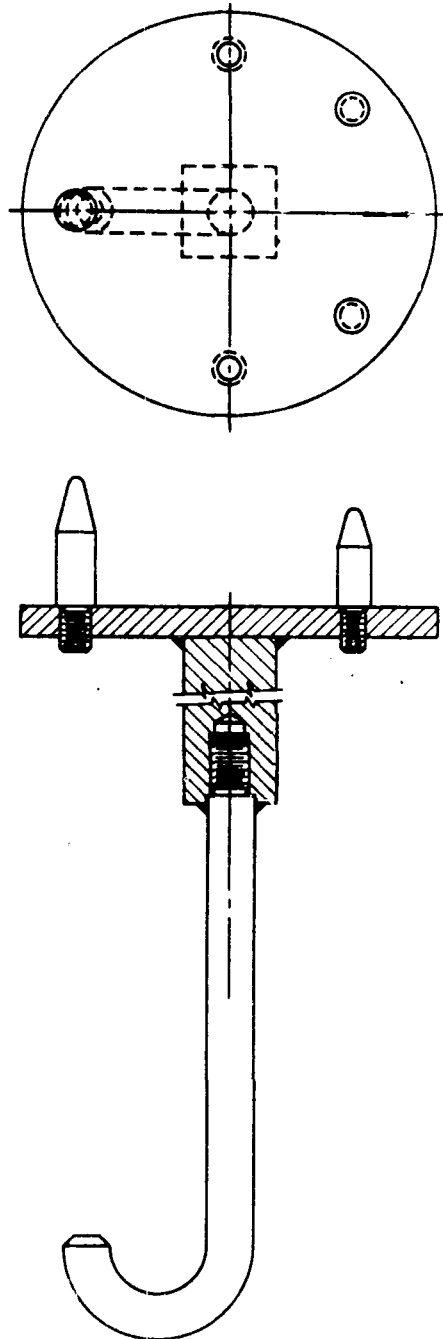
Single Rod Shears (Horizontal and Vertical) - The single rod shears, illustrated in Figure A-19, will be a scissor-type tool made from AISI tool steel capable of cutting one to two fuel rods at one time. The stationary blade can be wedged in between the fuel rods in an assembly. The moving blade is hooked to keep it from slipping away from the assembly. It is powered by a double-acting cylinder and can produce a 5,000 lb shear force at 1500 psi hydraulic pressure. By removing two pins, the blades can be easily removed and replaced. Left and right handed shear blades will be available. The shears incorporate design parameters based on results from the shear proof of principle tests.

Parting Wedge - The hydraulic parting wedge, illustrated in Figure A-20, is used to separate and fracture material. At 2000 psi hydraulic pressure, it can apply a force of 500 lb at the end of its arms. It consists of a single-acting hydraulic cylinder and two 8-in. long spreading arms. The arms can spread open to 7.25 in. When closed, the wedge can fit inside a 1.25 x 2 in. hole. This is a commercially available item that is modified to increase spreading force by reducing the arm length from 14-5/8 in. to 11-5/8 in.

Heavy Duty Tong Tool - The function of the heavy duty tong tool, shown in Figure A-21, is to grasp a partial fuel assembly from two opposite sides and reposition the assembly within the reactor vessel. The tool consists of two sets of opposing lifting tongs that are operated by a double acting hydraulic cylinder. The tong tool is capable of gripping debris up to a 10-in. cross-section. The tool requires a hydraulic supply pressure of 2000 psi.

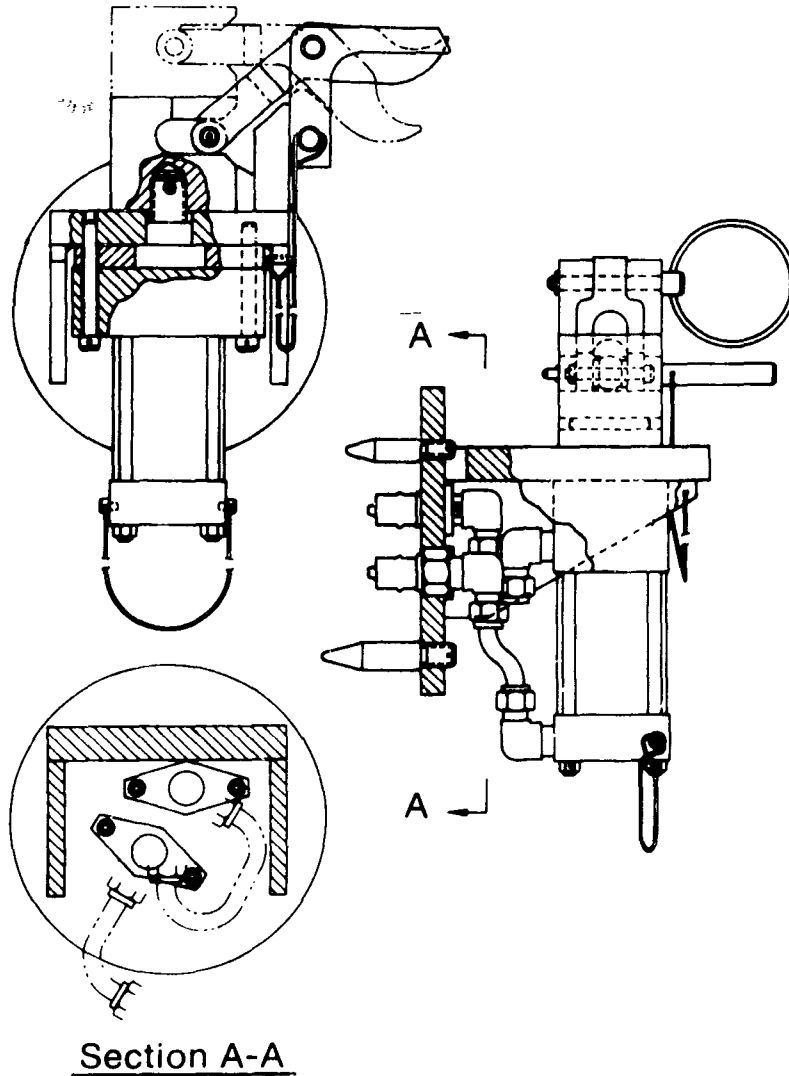
Spade Bucket Tool - The spade bucket tool, shown in Figure A-22, is used for digging into the debris bed and scooping quantities of small to medium-sized debris and loading the debris into a debris bucket. The tool consists of a rigidly mounted vertical plate and a hydraulically-operated bucket. The recommended hydraulic operating pressure for the tool is 500 psi.

**FIGURE A-18**  
**GRAPPLE (DWG. 1773E09)**



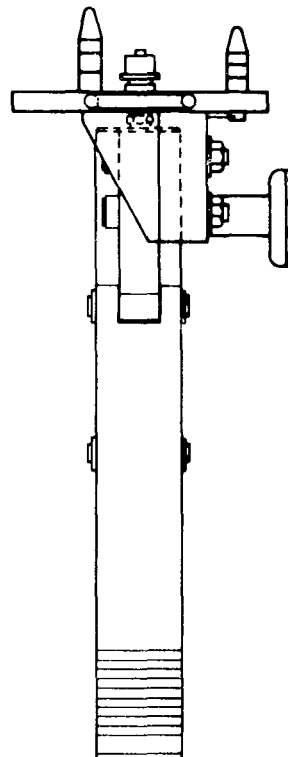
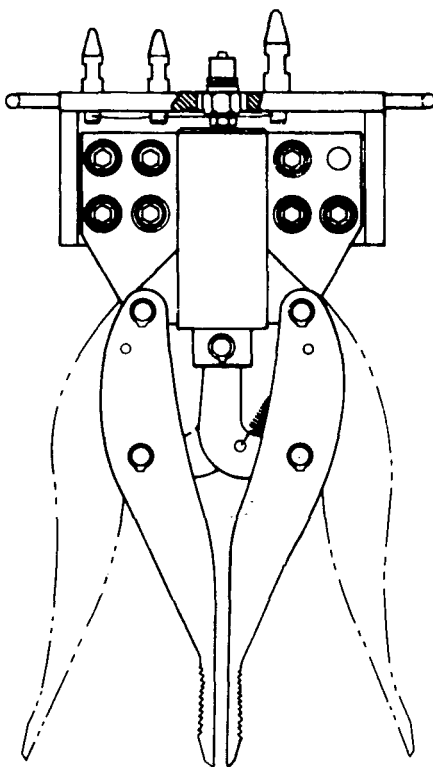
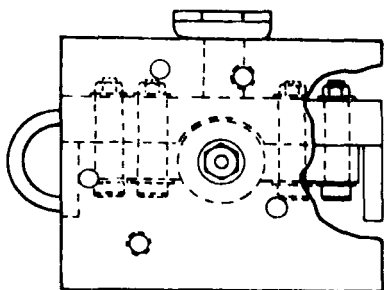
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**FIGURE A-19**  
**HORIZONTAL SINGLE ROD SHEARS (DWG. 1775E50)**



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**FIGURE A-20**  
**PARTING WEDGE (DWG. 1773E28)**



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**FIGURE A-21**  
**HEAVY DUTY TONG TOOL (DWG. 1778E36)**

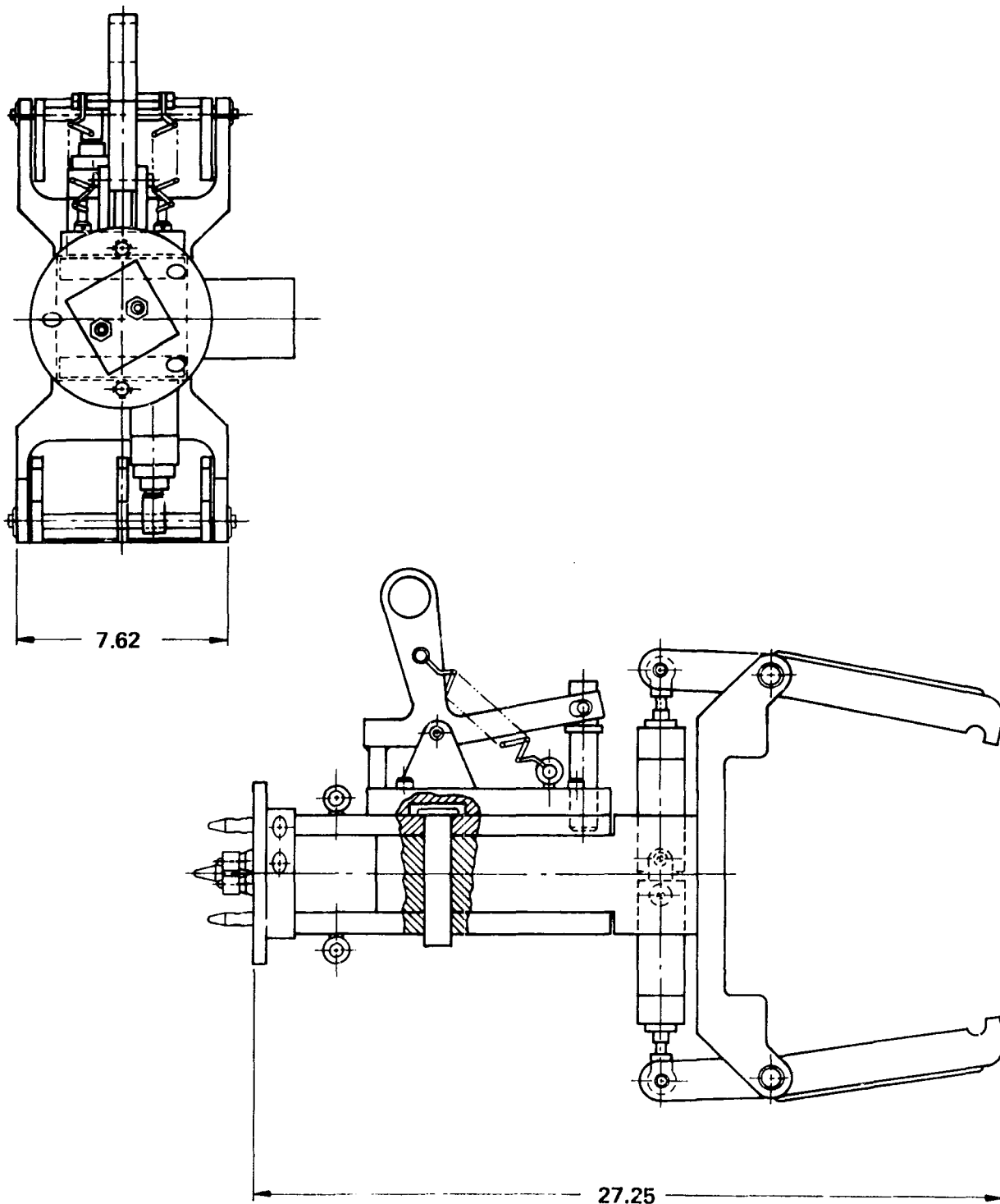
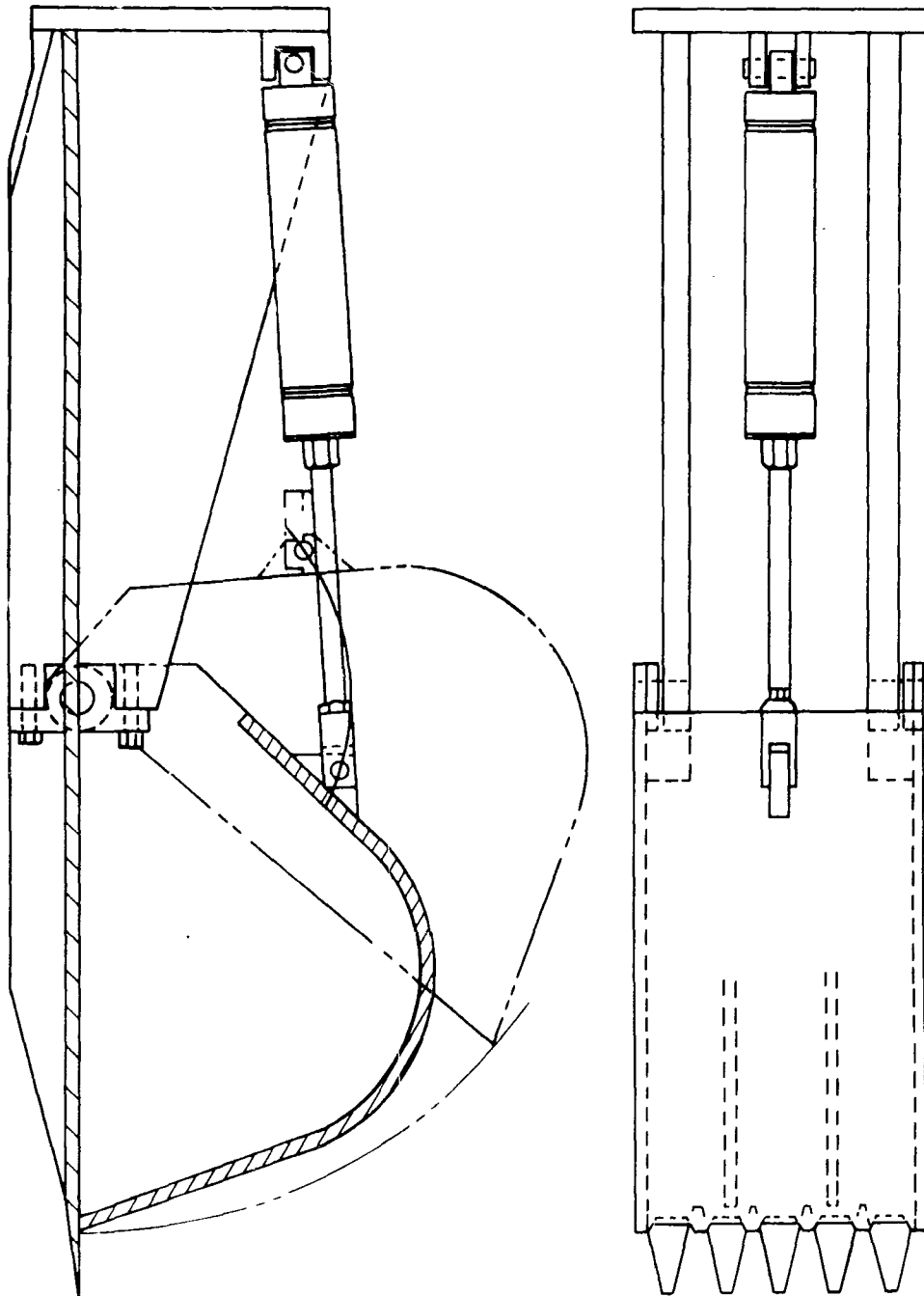


Figure A-22

Spade Bucket Tool (Dwg. 1778E44)





Clamshell Tool - The clamshell tool, as shown in Figure A-23, will be used in a manner similar to the spade bucket tool in areas of the core where access is limited to as little as 6 in. The tool may also be used to loosen compacted or partially fused gravel-type debris. The clamshell tool consists of two opposing triangular-shaped blades operated by a double acting cylinder. The clamshell tool has a vertical lift capacity of 250 lb and is capable of removing approximately 90 in. of debris per operation. The operating hydraulic pressure under normal conditions is 500 psi.

Heavy Duty Shears - The heavy duty shears, as shown in Figure A-24, will be used to remove end fittings from partial/intact fuel assemblies and to cut fuel assemblies into suitably sized portions for insertion into fuel canisters. This tool is comprised of a modified Hurst hydraulic cutter and an end effector mounting plate with quick disconnect hydraulic fittings. The shear blades open to a maximum gap of 6.5 in. Therefore, several cuts will be required to completely sever an intact fuel assembly.

Figure A-23

Clamshell Tool (Dwg. 1780E75)

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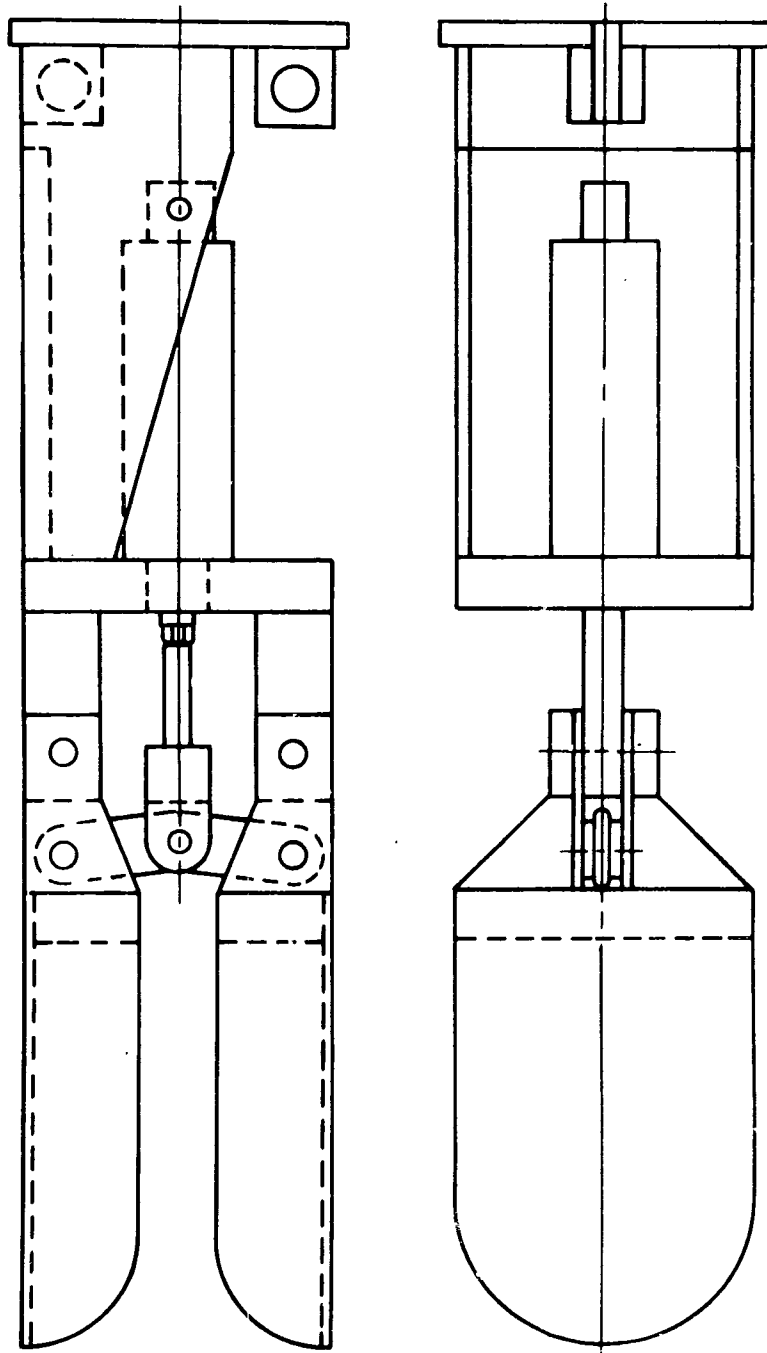
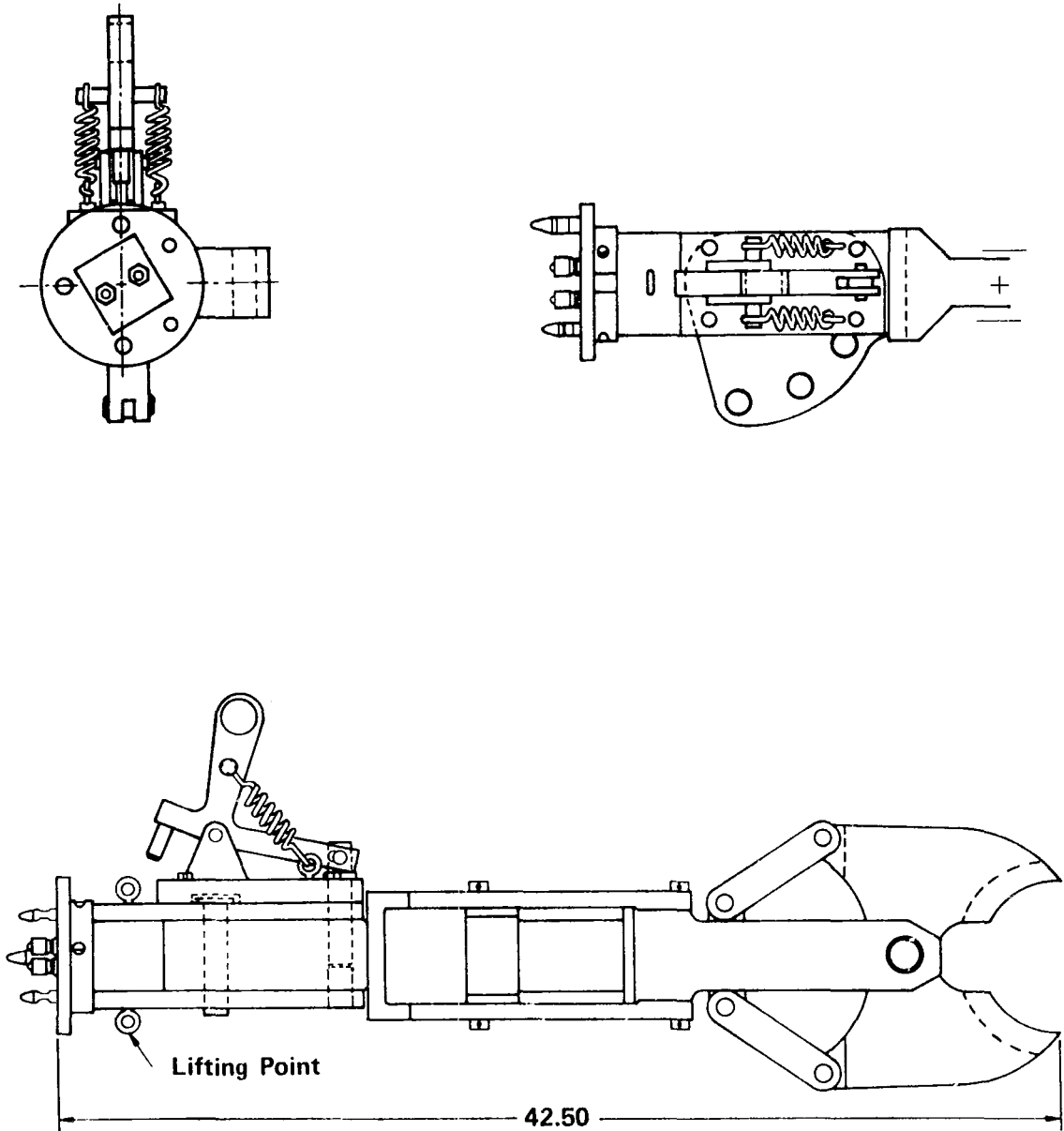


FIGURE A-24  
HEAVY DUTY SHEARS (DWG. 1778E66)



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### 3.4.2 Lightweight tools

The light weight tools will be mounted on aluminum conduit coupled together in sections. These tools can be manually operated with or without using the crane and have been found to be very useful in unstructured underwater operations.

Vise Grips - Several configurations and types of remotely operated vise grips, illustrated in Figure A-25, will be used for various operations. All use a double-acting cylinder. Vertically and horizontally oriented vise grips with standard, needle nose, and tube gripper ends are provided for defueling operations.

Bolt Cutters - The bolt cutters, illustrated in Figure A-26, will be used for various light duty cutting operations. Interchangeable cutting heads are available. These tools will be capable of cutting horizontally and vertically. The cutting force is expected to be in the 1500-lb to 1800-lb range.

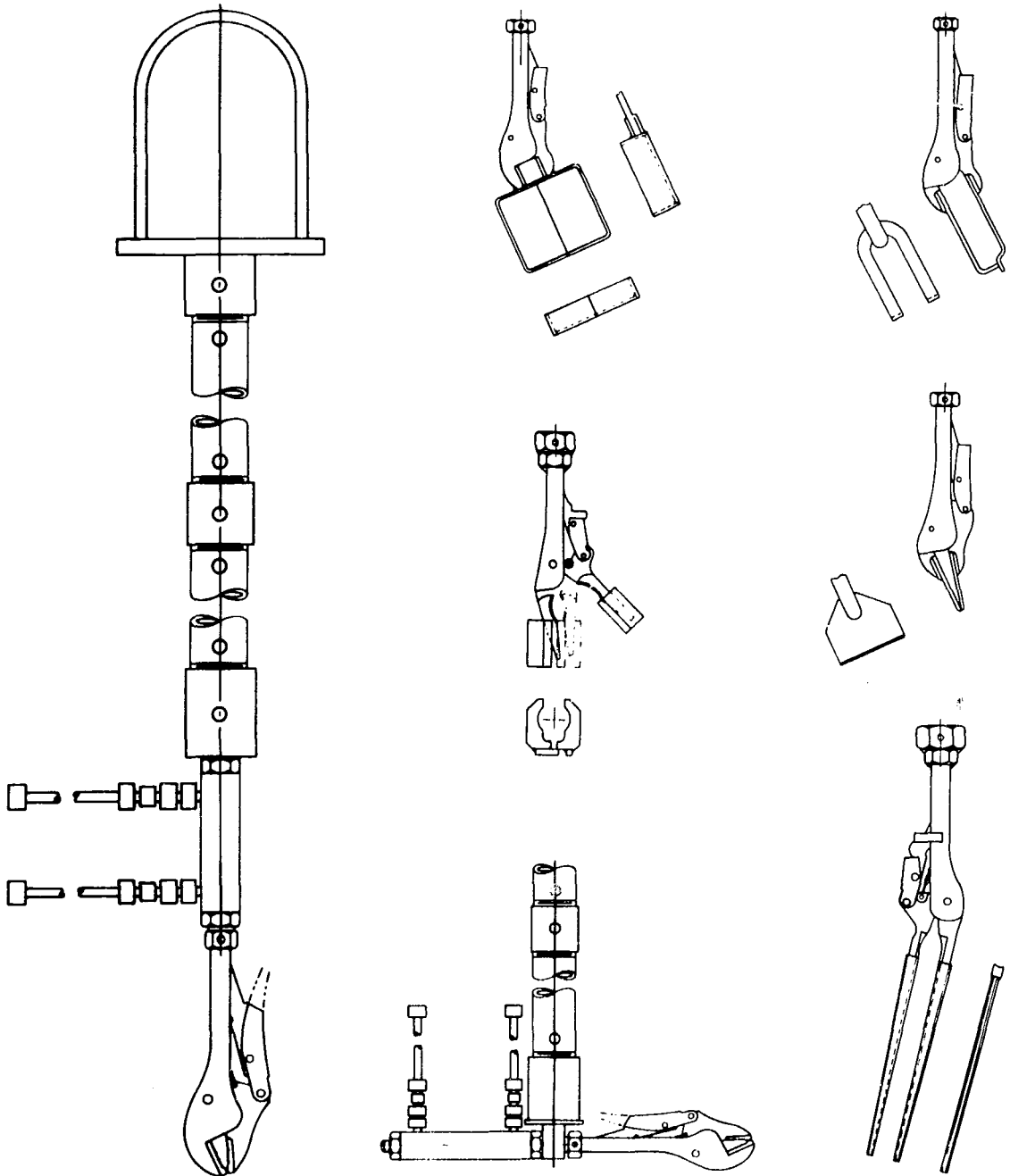
Hook Tools - Various size hook tools, similar to the one illustrated in Figure A-27, will be used to lift and move debris, hoses, and cables. Capacity is 50 lb.

Socket Wrench - The socket wrench, illustrated in Figure A-28, is a long-handled tool used to connect and disconnect end effectors and end effector handling tool pole sections.

Measuring Probe - The measuring probe, shown in Figure A-29, will be used to determine the overall lengths of partial fuel assemblies prior to cutting operations. The probe consists of a 15-ft scale that is stamped to an aluminum pole section.

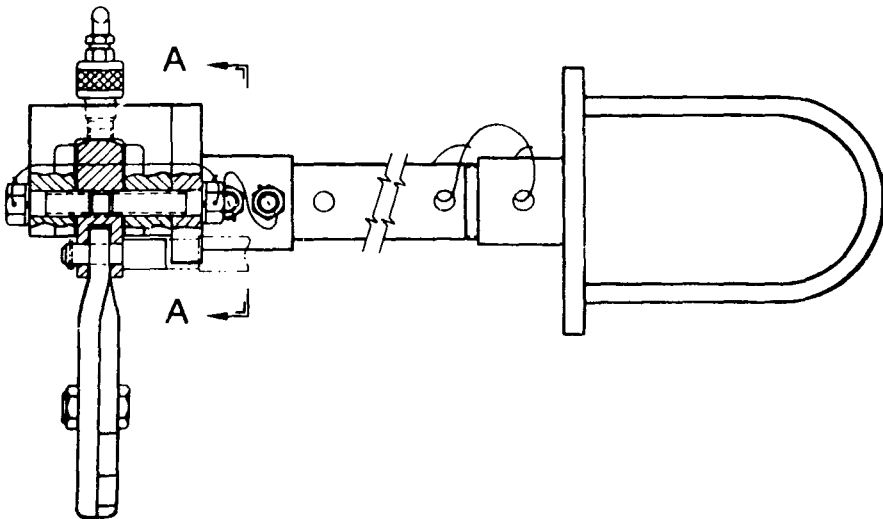
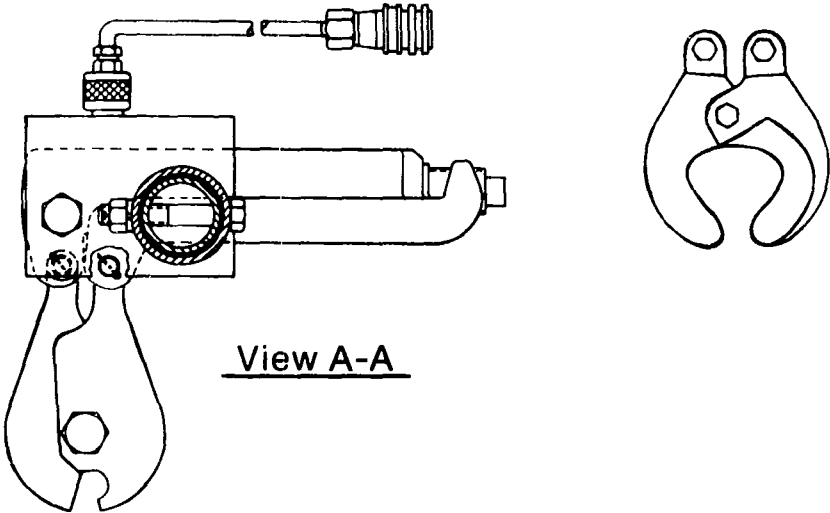
Light Duty Tong Tool - The light duty tong tool, shown in Figure A-30, will be used to reposition and deposit debris up to 100 lbs into debris buckets.

**FIGURE A-25**  
**WISE GRIPS (DWG. 1773E36)**



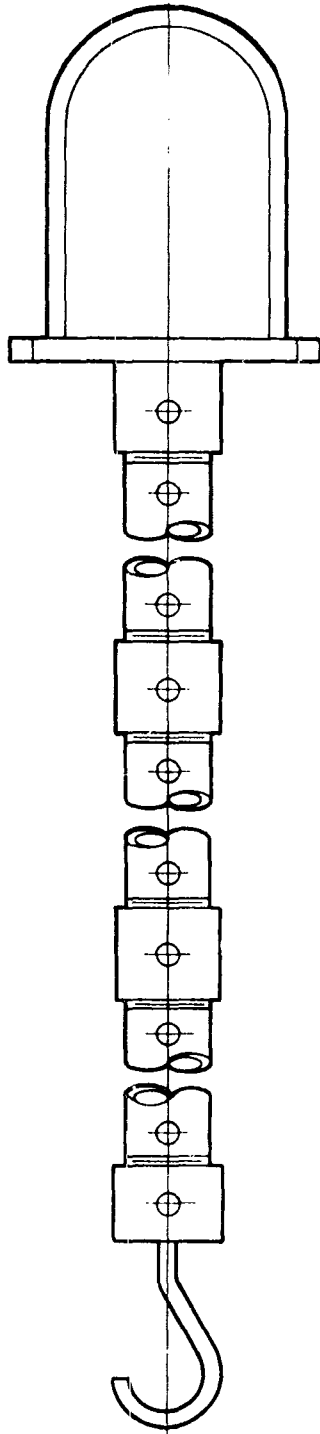
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**FIGURE A-26**  
**BOLT CUTTERS (DWG. 1770E41)**



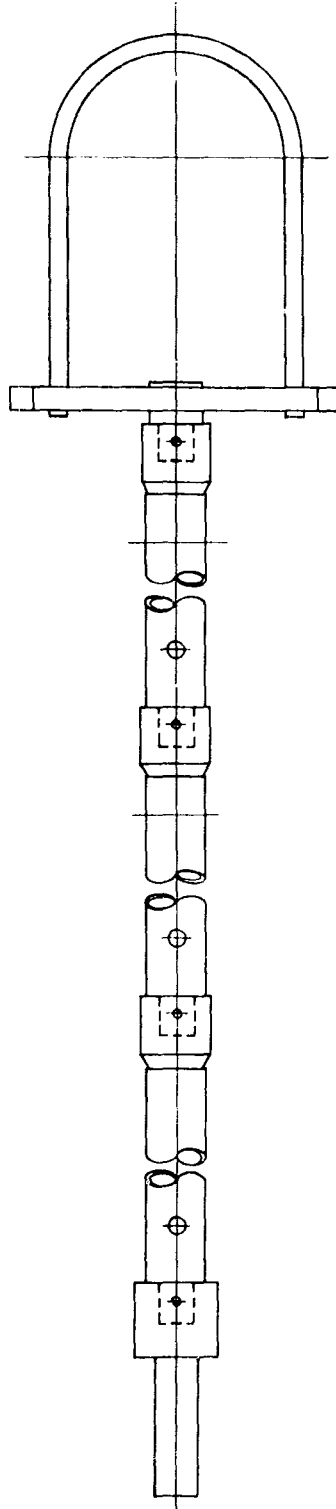
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**FIGURE A-27**  
**HOOK TOOLS (DWG. 1773E49)**



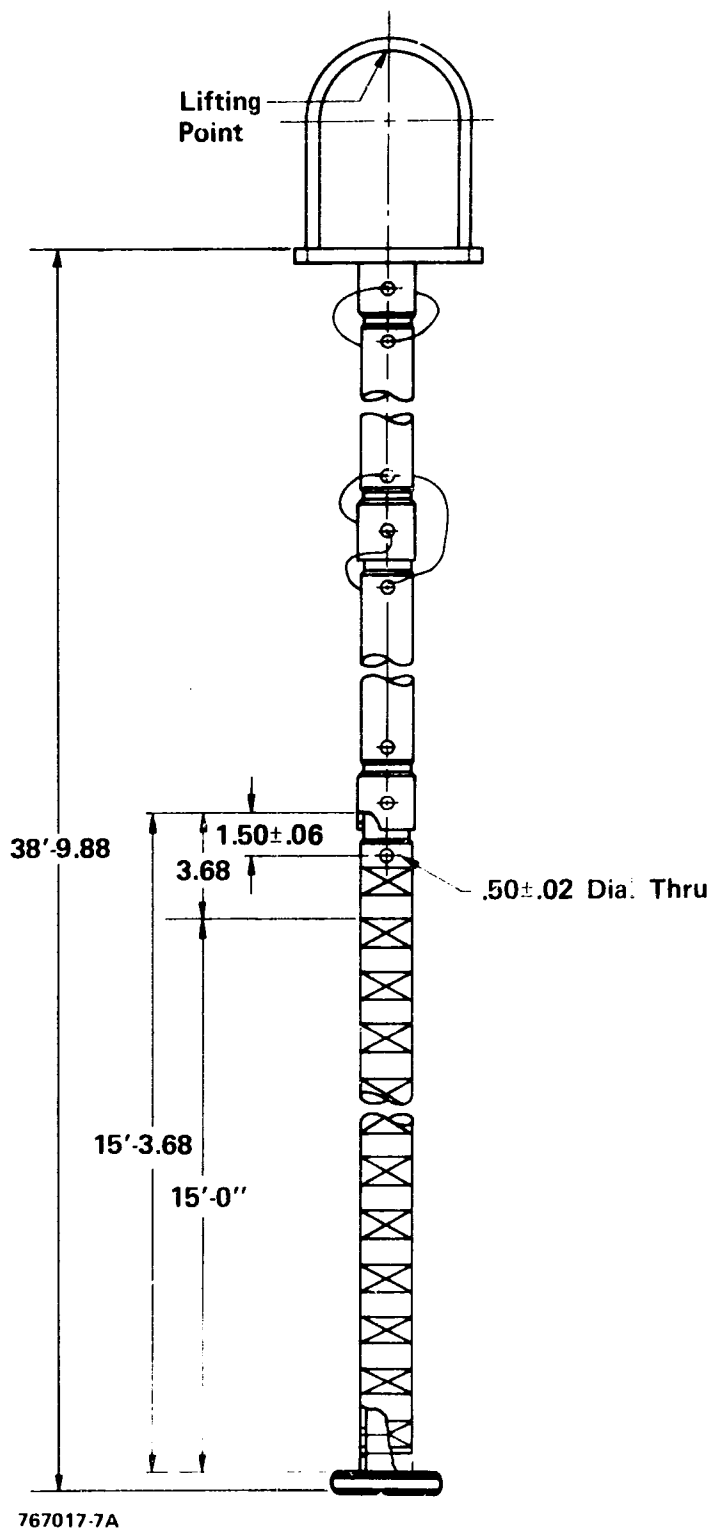
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**Figure A-28**  
**Socket Wrench (Dwg. 1773E39)**

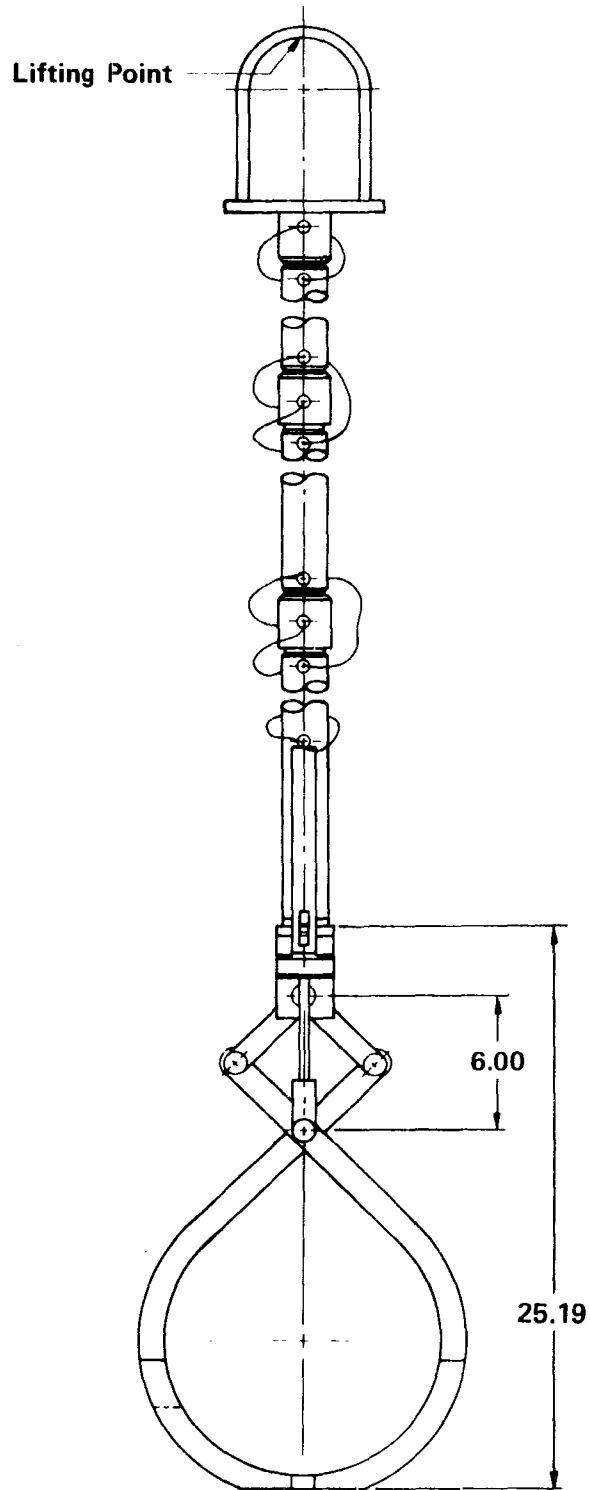




**FIGURE A-29**  
**MEASURING PROBE (DWG. 1778E50)**



**FIGURE A-30**  
**LIGHT DUTY TONG TOOL (DWG. 1778E42)**



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End Fitting Loading Tool - This tool, shown in Figure A-31, has provisions for alignment of the short length end fitting relative to the inside width of the fuel canister. The tool is capable of lifting up to 2000 lbs.

Banding Tool - The banding tool, shown in Figure A-32, consists of pivot-mounted, commercially available crimping and tensioning devices. The crimping and cut-off functions will be actuated by a 2000-psi hydraulic cylinder. Band tensioning function will be actuated by a 500-psi hydraulic rotary stepper motor. This tool is used for banding fuel assemblies prior to shearing.

Handrail Hydraulic Panel - The handrail hydraulic panel, as shown in Figure A-33, will be used as an intermediate hydraulic control location for the banding tool and the debris clamping station. This panel will include high pressure and low pressure banding tool crimping cylinder controls, banding tool tensioner rotary stepper controls, and a pressure regulator and gauge for operation of the debris clamping station. The panel will receive a 2000-psi hydraulic supply from the local service panel. The handrail hydraulic panel will be mounted on the long-handled tool slot handrail.

Debris Bucket Handling Tool - This tool, as shown in Figure A-34, is designed to engage the lifting tabs on a debris bucket, deposit the debris bucket directly into a fuel canister and, finally, disengage from the bucket.

#### 3.4.3 Long-Handled Tool Support Equipment

The support equipment for long-handled tools includes the debris buckets and associated equipment. The buckets will be loaded in the lower core region and then transferred into fuel canisters.

Disposable Debris Buckets - Two types of disposable debris buckets (Figure A-35) will be provided: top loading debris buckets and side loading debris buckets. Both types are constructed of 300 series stainless steel sheet and are designed to fit into the fuel canisters. The top loading debris bucket is loaded in the vertical position. Lifting tabs are mounted on the sides for stacking inside the fuel canister.

FIGURE A-31  
END FITTING LOADING TOOL (DWG. 1778E49)

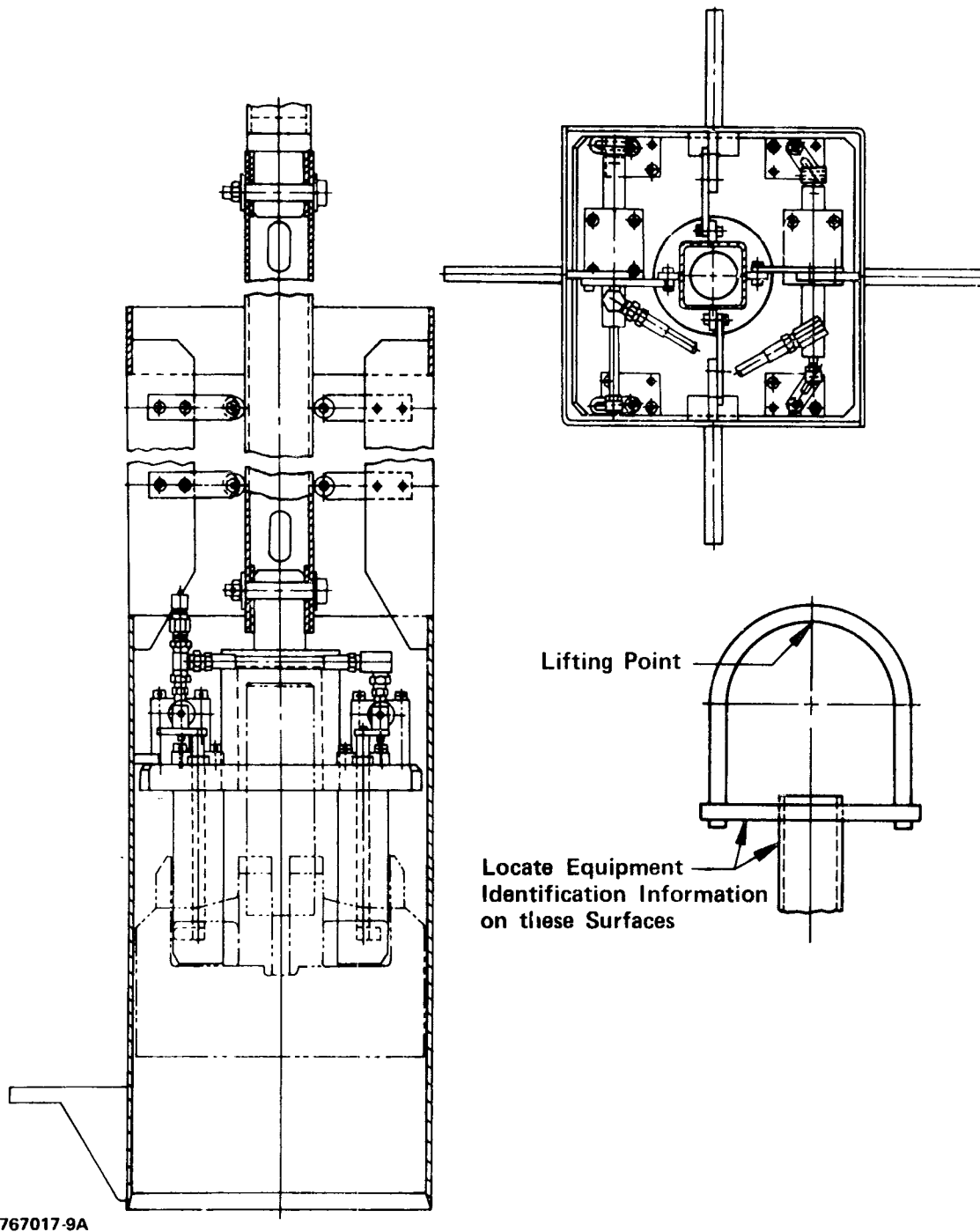
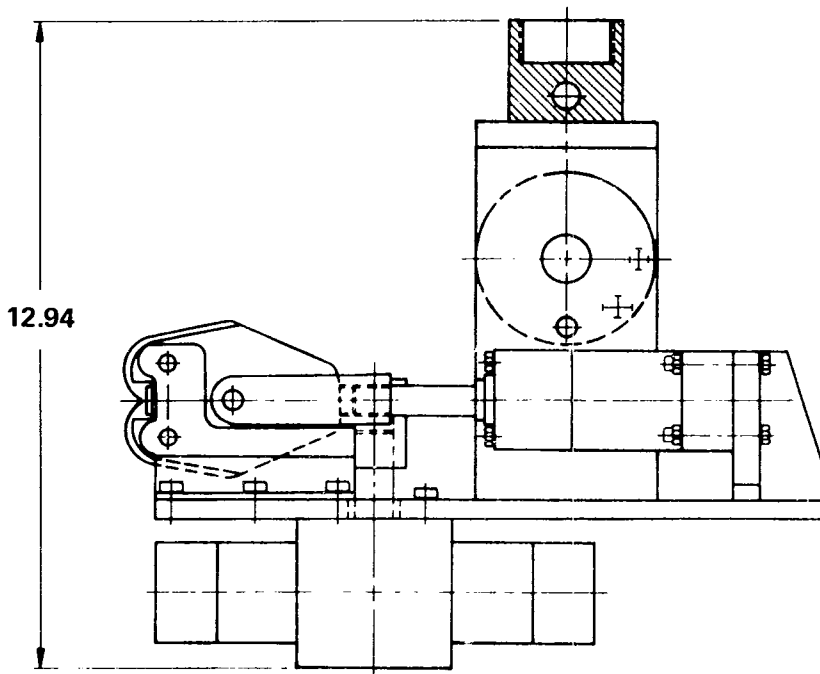
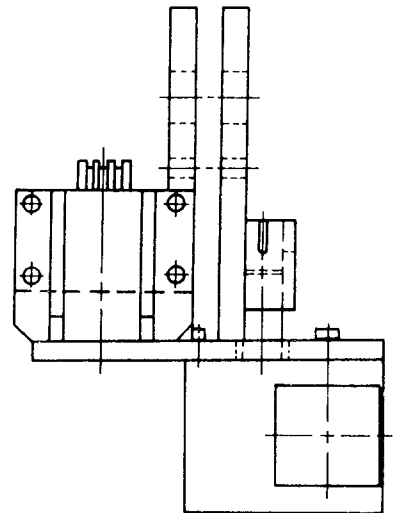
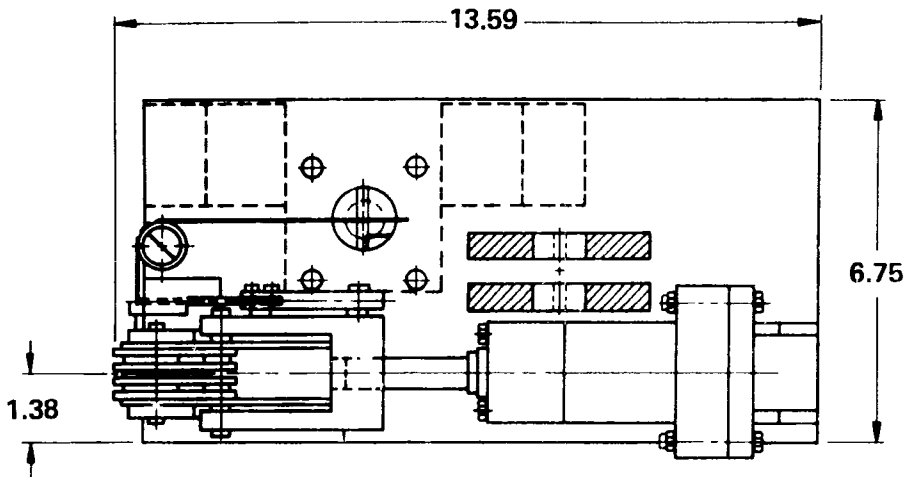


FIGURE A-32  
BANDING TOOL (DWG. 1778E41)



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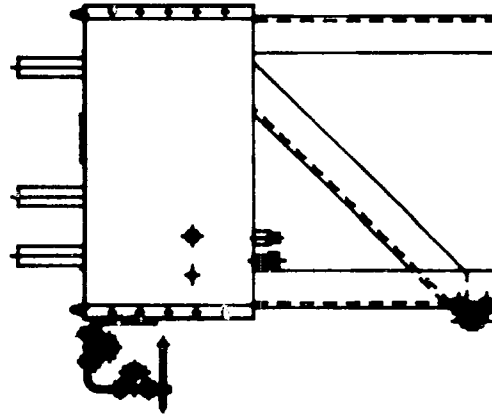
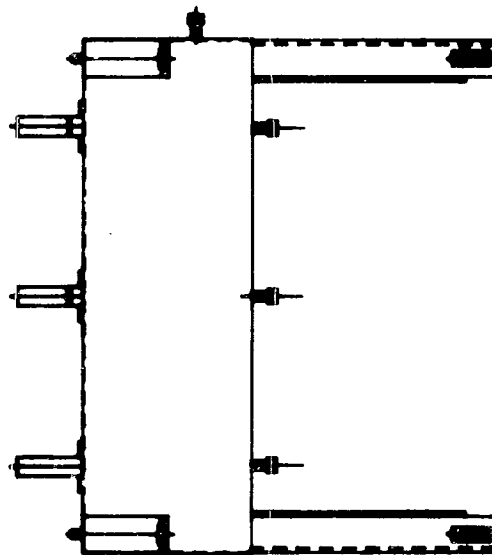
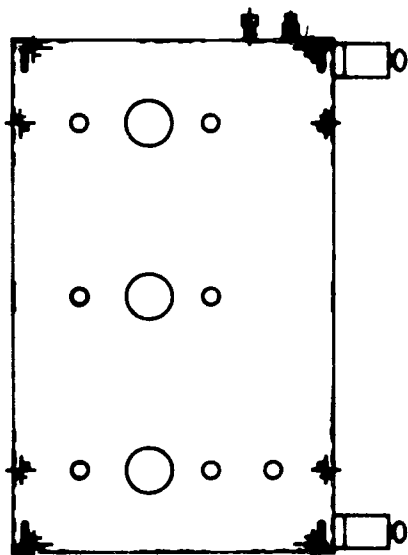
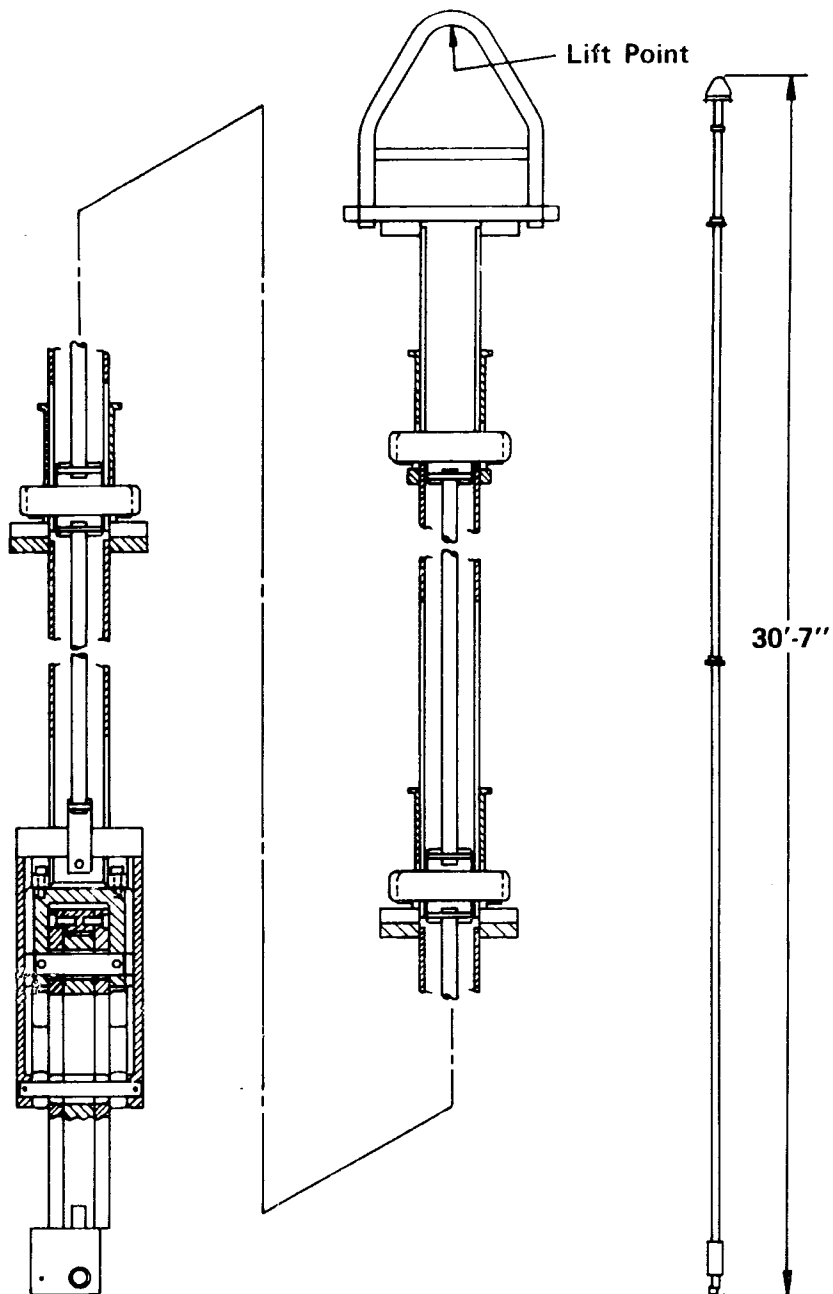


FIGURE A-33  
HANDRAIL HYDRAULIC PANEL

**FIGURE A-34**  
**DEBRIS BUCKET HANDLING TOOL (DWG. 1778E79)**



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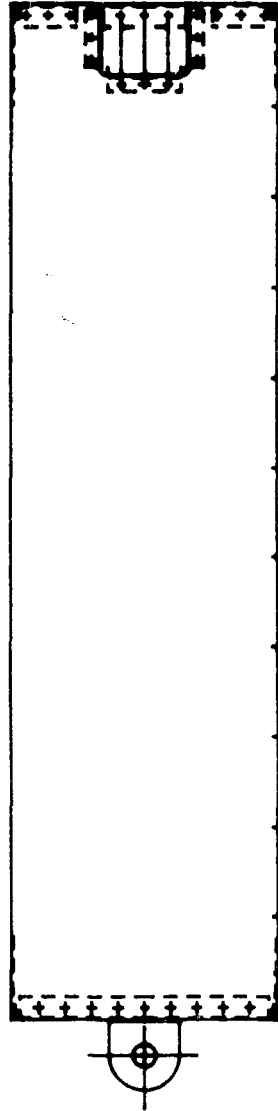
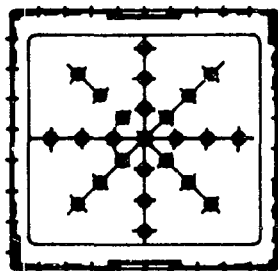


FIGURE A-35  
DISPOSABLE DEBRIS BUCKET



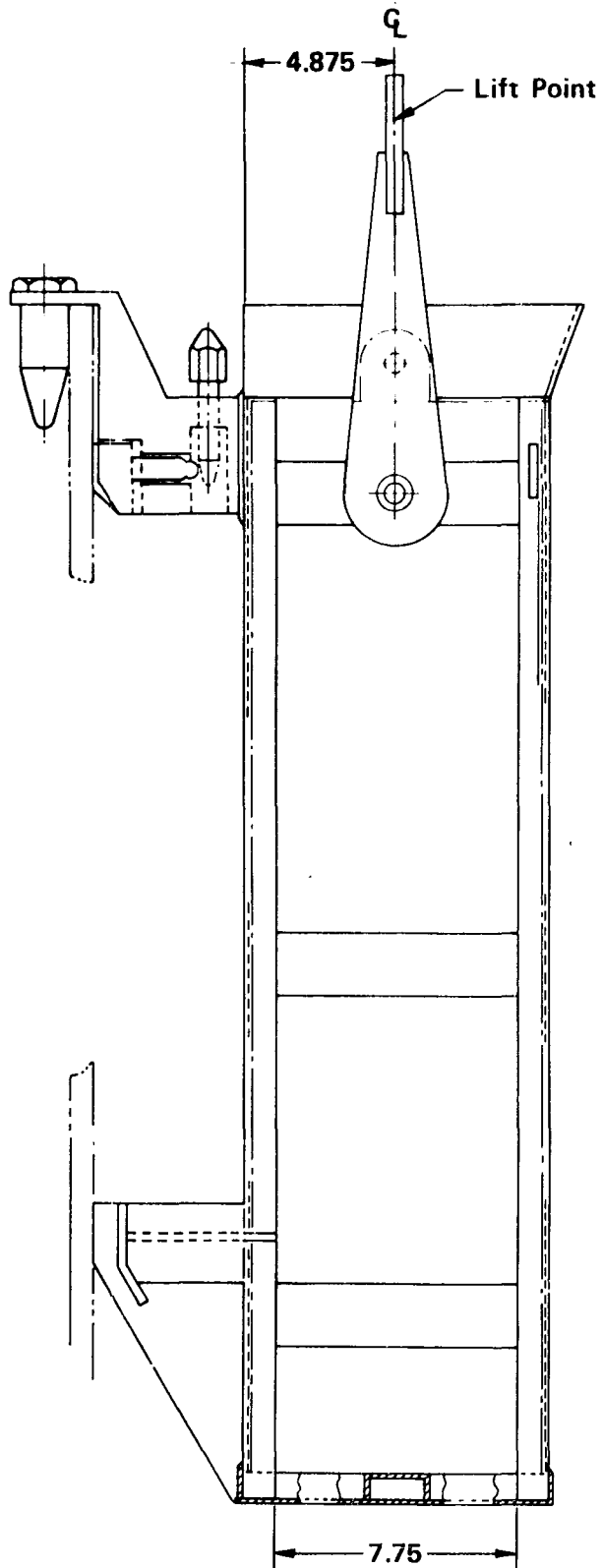
The disposable side loading debris bucket is loaded in the horizontal position and has a hinged lid on the side that latches closed to prevent accidental spillage. Lifting tabs, located on one end of the bucket, allow the bucket to be transferred from the horizontal position to the vertical for stacking inside the fuel canister. Canister loading has been optimized by selecting bucket lengths and by resting the protruding lifting tabs into the bottom of the stacked buckets, thereby eliminating empty spaces.

Top Loading and Side Loading Debris Bucket Stands - The debris stands, as shown in Figures A-36 and A-37 are used for temporary storage of the top loading and side loading debris buckets while the buckets are being filled. The stands are provided with a clamp mount that is designed for mounting of the stand on a core support assembly baffle plate. The clamp mount is operated by a 1.0-in. light duty socket tool. The top loading debris stand includes a three-sided stainless steel funnel at the top to assist in directing debris into the bucket. Both debris stand designs include a pivoting ball assembly that may be used in conjunction with a hook tool or grapple for stand installation and removal. When not in use, the ball may be pivoted out of the way for debris bucket insertion and removal. Both stands are designed to hold a nominal load of 400 lb.

Debris Clamping Station -The debris clamping station, shown in Figure A-38, will be used to clamp and hold fuel assembly end fittings, spiders, partial or complete fuel assemblies while performing cutting, banding, or other long-handled tool operations. This debris clamping station is designed to be mounted on the 18-in. long-handled tool slot and can hold debris both in the horizontal and vertical directions.

Work Platform Debris Bucket Hanger - The work platform debris bucket hanger, shown in Figure A-39, will be provided for temporary storage of the top loading or side loading debris buckets while the buckets are being filled during early defueling operations when easy access is available. This device will provide the capability of positioning the debris bucket at various elevations ranging from 18 ft to 30 ft below the shielded work platform deck. In addition, the double pivot design of the hanger will allow for positioning a debris bucket adjacent to ongoing defueling activities in virtually any area in the core support assembly below the two shielded work platform tool slots.

**FIGURE A-36**  
**DEBRIS BUCKET STAND (DWG. 1778E69 & 1778E70)**



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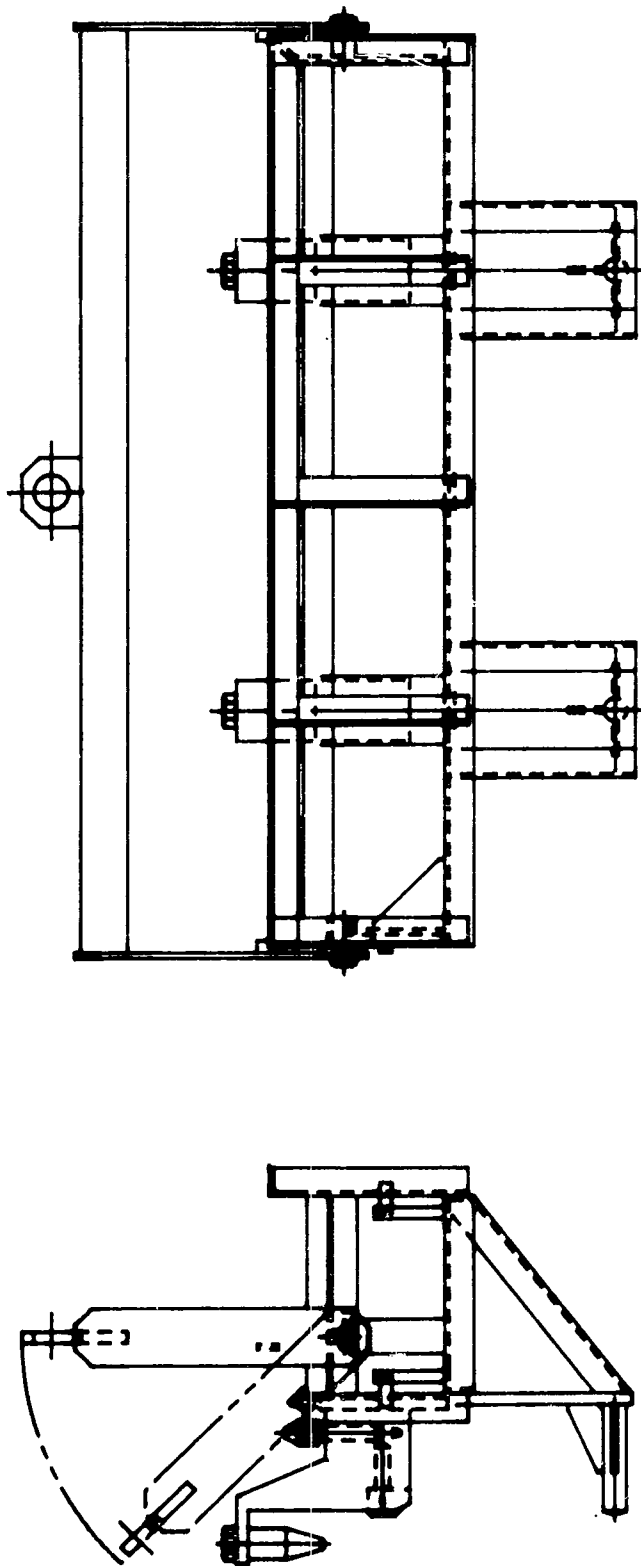
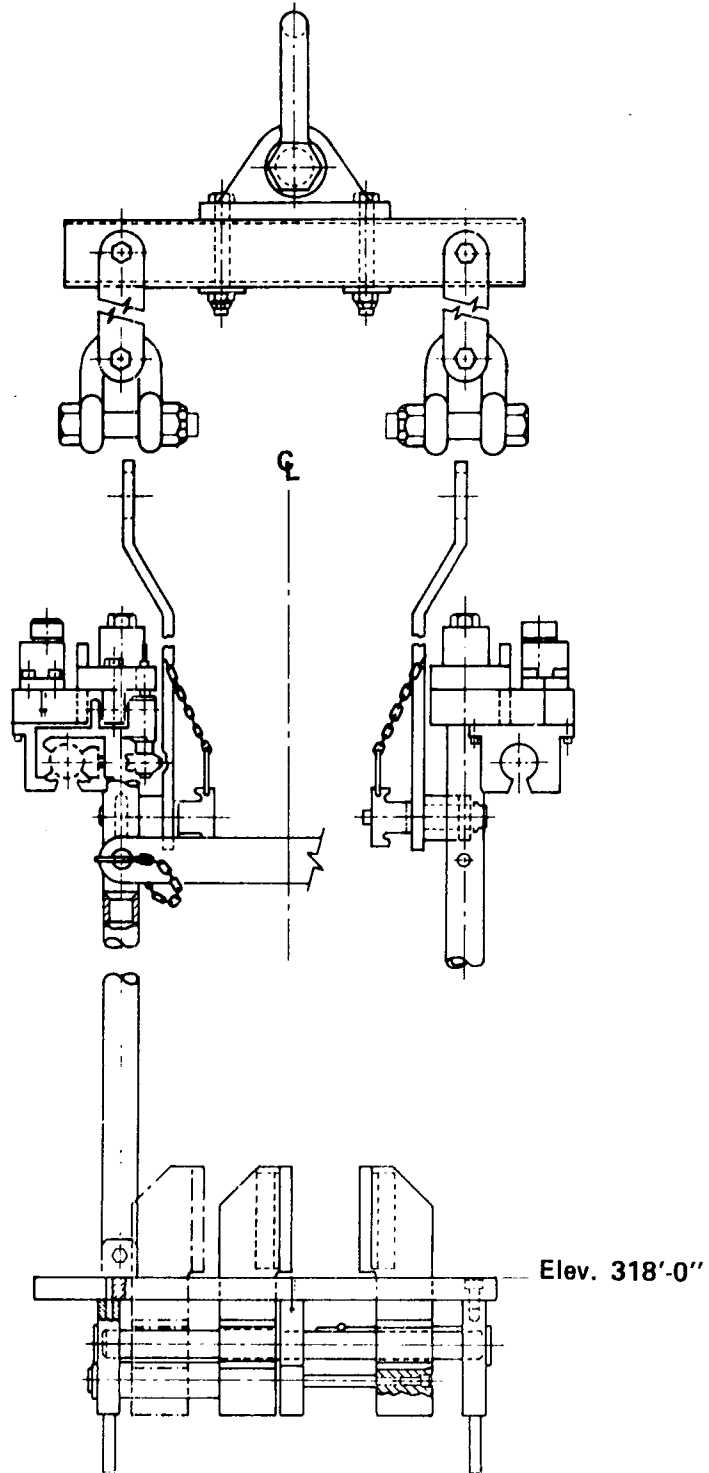


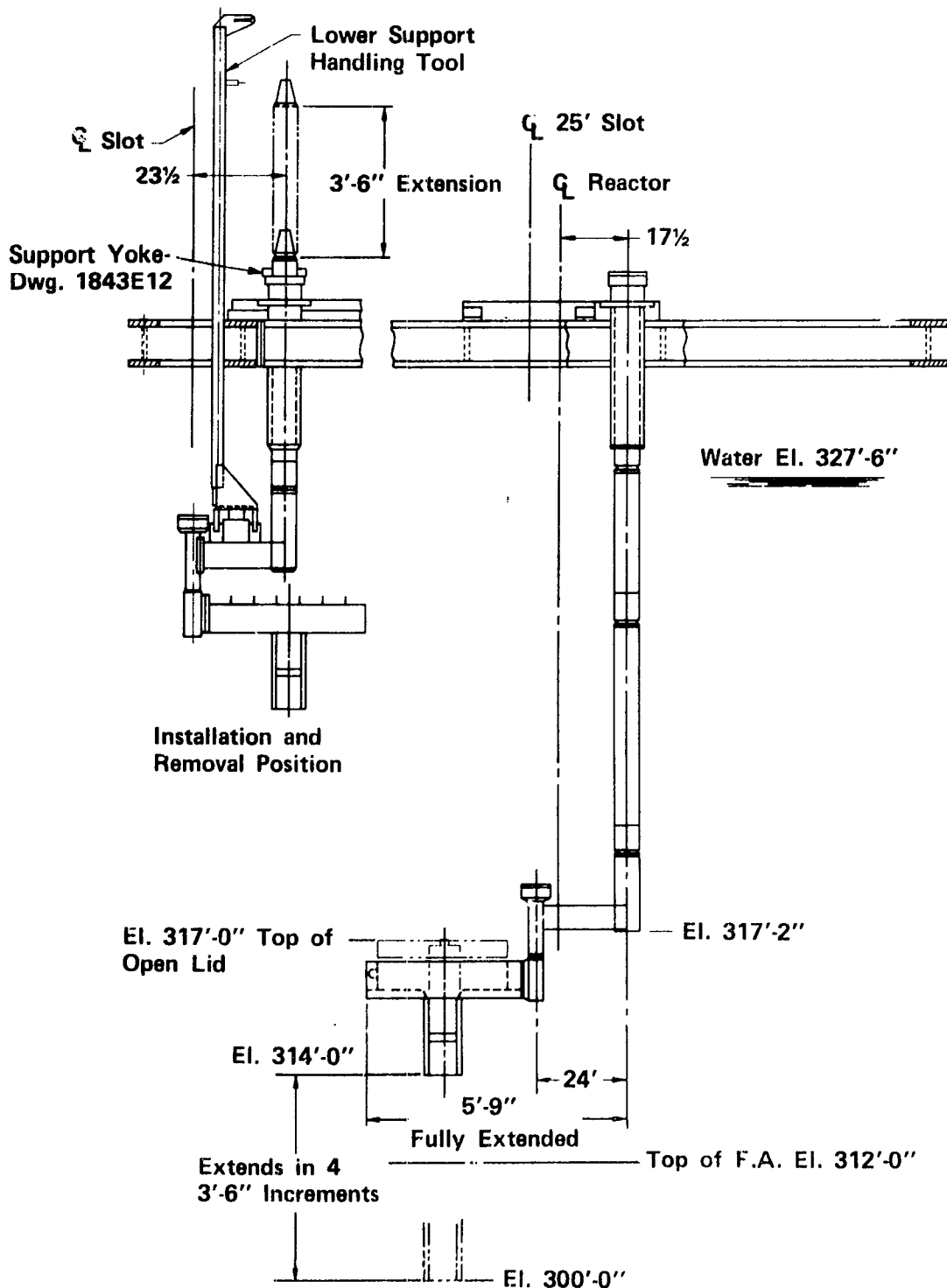
FIGURE A-37  
SIDE LOADING DEBRIS STAND

**FIGURE A-38**  
**DEBRIS CLAMPING STATION (DWG. 1773E96)**



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**FIGURE A-39**  
**WORK PLATFORM DEBRIS BUCKET HANGER (DWG. 1773E88)**



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When not in use, the debris bucket may be pivoted away from the tool slots and under the work deck for storage. The debris bucket hanger also provides a means of transferring debris between the two tool slots in the shielded work platform. The debris bucket hanger consists of a support post, vertical extension support tubes (central pivot), a radial arm, an outer pivot, and a debris bucket tray.

The initial hanger configuration consists of one 72.0-in. extension section and two 42.0-in. extension sections. Torque tool lengths of 42.0 in. and 62.5 in. are required. The vertical support tube may be extended as necessary as defueling operations progress, by the addition of 42.0-in. extension sections. No removal of shielding plates is required to perform this operation. A lower support handling tool and support yoke tool are required to install the debris bucket hanger.

### 3.5 Control System

The control system consists of the electrical, hydraulic, and air distribution systems for the defueling equipment. The control system is made up of the following:

- Electrical Power Distribution System
- Control Console
- Hydraulic System
- Cable Management System

The control system supports all defueling phases.

The piping and instrumentation drawing (P&ID) General Arrangement for the Control System is shown in Figure A-40. The figure depicts the flow of electrical, hydraulic, and pneumatic power from the GPUN site-supplied services. The figure shows schematically all the cable routing to the various tools or instrumentation. The required site supplied services are:

Electrical:    480V, 30, 60A (General)  
                  480V, 30, 60A (Hydraulic)  
                  120V, 10, 20A (Vacuum)

Air:            100 SCFM at 90 psi

### FIGURE A-40



**A-60**

Additional information on the control system is presented in the Final Design Report for the Control System (Reference 15), the Operation and Maintenance (O&M) Manual for TMI-2 Dry Defueling Cable Management System (Reference 16), the O&M Manual for TMI-2 Dry Defueling Control System - Electrical (Reference 17), and O&M Manual for TMI-2 Dry Defueling Hydraulic System (Reference 18). A summary tool list is provided in Table A-5.

TABLE A-5 WBS 561, 564 CONTROL SYSTEM TOOL LIST

<u>Tool/Component</u>	<u>Westinghouse Dwg. No.</u>	<u>GPUN Equip. Ident. No.</u>
Control System	1738E48	DEF-CTL-100 thru 907
Control Console	1738E41	DEF-CTL-300
Cable Management	1739E85	DEF-CMS-001 thru 019
Power Distribution Center	1739E01	DEF-CTL-100 & 200
Hydraulic Power Supply	1740E10	DEF-CTL-500
Local Service Panel	1739E82	DEF-CTL-800
Lighting Control Box	1738E85	DEF-CTL-600 & 601

### 3.3.1 Electrical Power Distribution Center

The electric power distribution center consists of a NEMA Type 12 enclosure and a 30 kVA, 480V-208Y/120V power transformer. All the switch gear to power the various loads is mounted on a 78-in. high x 32-in. wide internal steel panel inside the enclosure. The electrical power distribution center enclosure assembly is shown in Figure A-41.

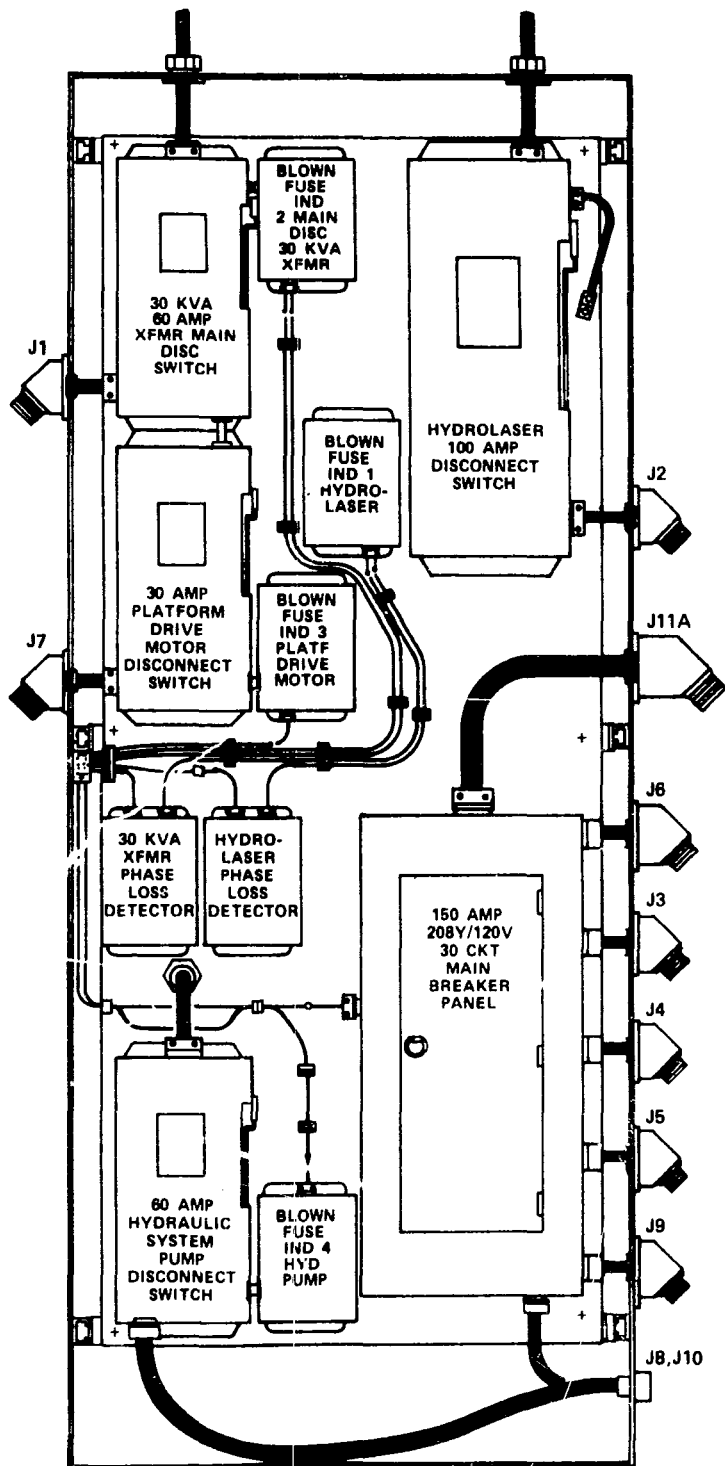
The enclosure dimensions are 90 in. high x 36 in. wide x 24 in. deep and includes a front access hinged door. The total weight of the electrical power distribution center enclosure when completely wired is approximately 600 lb. The total weight of the 30 kVA power transformer is approximately 450 lb.

The main power distribution components housed in the enclosure are:

- 30 kVA Transformer Primary Disconnect Switch, 480V, 60A, 3 pole
- Hydrolaser Disconnect Switch, 480V, 100A, 3 pole



**FIGURE A-41**  
**ELECTRICAL POWER DISTRIBUTION CENTER (DWG. 1739E01)**



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- Platform Drive Motor Disconnect Switch, 480V, 30A, 3 pole
- Hydraulic Power Supply Disconnect Switch, 480V, 60A, 3 pole
- 30 Circuit 208Y/120V Distribution Panel

The 30 circuit distribution panel supplies 120V single phase power to the various loads as follows:

- Video Lighting Control Box #1 (3 circuits - 20A)
- Video Lighting Control Box #2 (3 circuits - 20A)
- Viewing System Cabinet A (1 circuit - 20A)
- Viewing System Cabinet A (1 circuit - 20A)
- Control Console (4 circuits - 15A)
- Work Platform Auxiliary ac outlets (3 circuits - 20A)

Three circuits of 208V, 3 phase power, are also available should the need arise in the future. All 120V circuits are provided with ground fault interruptors.

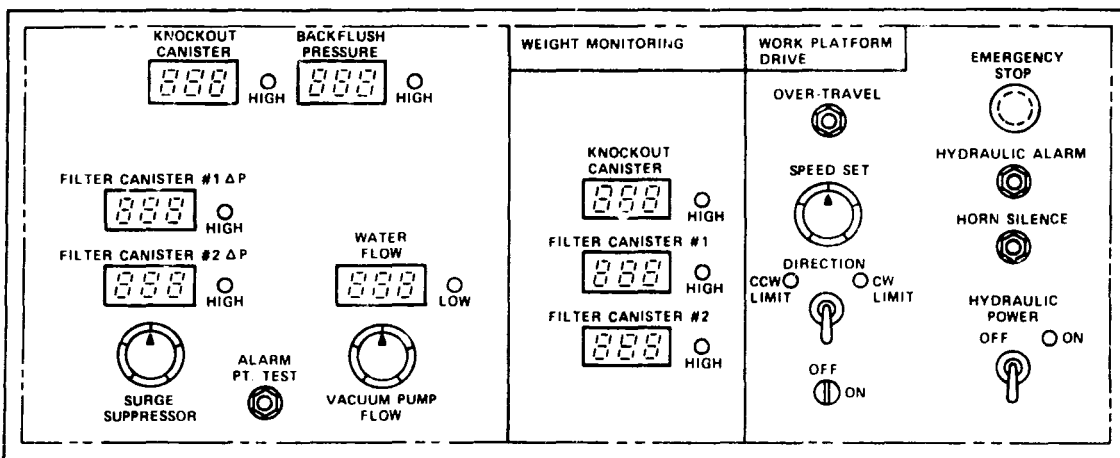
### 3.5.2 Control Console

The control console contains the electronics for control and monitoring of the tooling systems for the TMI-2 defueling project. The assembly is enclosed within a Hoffman box with the dimensions 50 in. high x 48 in. wide x 23 in. deep. Monitoring and control for the vacuum system, shielded work platform, and the hydraulic power supply is provided from the control console.

The control console is shown in Figure A-42. This panel contains the LED readouts, control knobs, push buttons, alarms, and switches that are the operator interface. Each display is clearly marked to indicate its purpose. The switches have an engraved layover to indicate the switch position.

An EMERGENCY STOP switch is located in the upper right corner of the panel. This switch has a red mushroom head and is used to disconnect power from the shielded work platform drive and hydraulic power supply. The EMERGENCY STOP switch will not affect vacuum system monitoring or the weighing system used to monitor canister weight.

**FIGURE A-42**  
**MAIN CONTROL CONSOLE (DWG. 1738E41)**



The electrical power distribution center will provide the 120 vac and 480 vac service necessary at the control console. The two power cable assemblies, designated cables 6A and 7A, enter the control console on the left side and are wired directly to terminal blocks.

The vacuum system monitoring and controls are contained within the control console. Below is a description of the transmitters used on the vacuum system. This description is necessary to understand the control console components used for the vacuum system. There are eight process transmitters as follows:

- Four differential pressure transmitters for monitoring the pressure drop across the individual filter canisters, the knockout canister, and the knockout canister during the backflush cycle.
- One flowmeter mounted on the intake line of the vacuum system.
- Three load cells for monitoring the weight of each canister that the vacuum system can access.

Control of the vacuum pump and surge suppressor is provided by the knobs so labeled on the control console panel. The knobs turn single turn rotary potentiometers with a 1000 ohm resistance. The wiper of each potentiometer is wired to a plug in the signal conditioning unit. The signal conditioner provides a 4-20 mA output signal that is linearly proportional to the wiper resistance. These signals control the electro-pneumatic converters housed in junction box 1.

The shielded work platform drive is controlled from the control console. Housed within the control console is the servo amplifier, drive transformer, signal conditioner, and choke necessary for the drive. The shielded work platform drive system is a standard dc servo-motor system, which is speed controlled.

### 3.5.3 Hydraulic System

The hydraulic system consists of the hydraulic power supply, the local service panel, and interconnecting hoses. The hydraulic power supply will provide and control high pressure hydraulic fluid used in the operation of

long-handled tools and end effectors from the shielded work platform. The hydraulic power supply provides the hydraulic power through the cable management system to the local service panel. The long-handled tools are plugged into and operated from the local service panel.

The hydraulic power supply, shown in Figure A-43, includes the hydraulic pump and the associated motor and motor starter, reservoir, accumulator, drip pans, inlet filter, pressure filter, return line filter, hydraulic fluid level switch, temperature switch, pressure relief valve, air bleed valve, and pressure gauge. The motor is a 30 hp, 480V, 3 phase electrical motor on a 60A supply circuit from the electrical power distribution center. The fluid reservoir is 220 gallon capacity, which is sized for system cooling rather than the operating system volume.

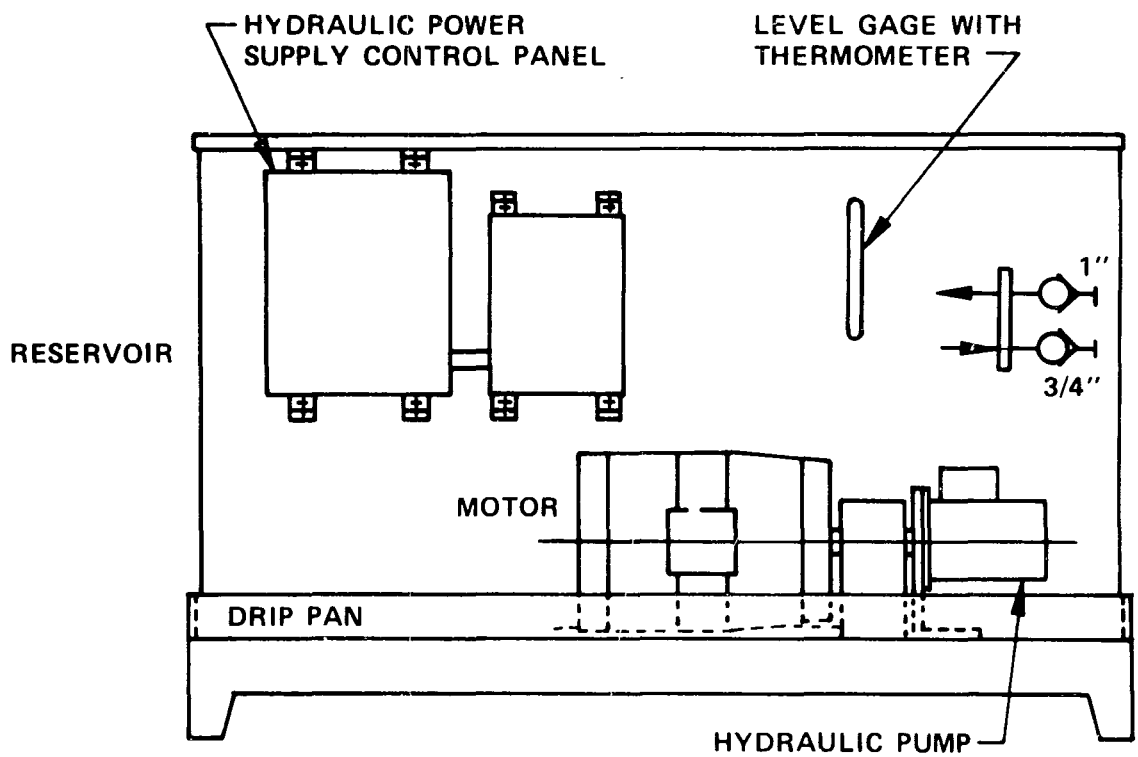
The local service panel, shown in Figure A-44, provides the necessary services on the shielded work platform for the operation of the defueling equipment. The local service panel houses the electrical, pneumatic, and hydraulic connections from the cable management system and the necessary switching for proper operation.

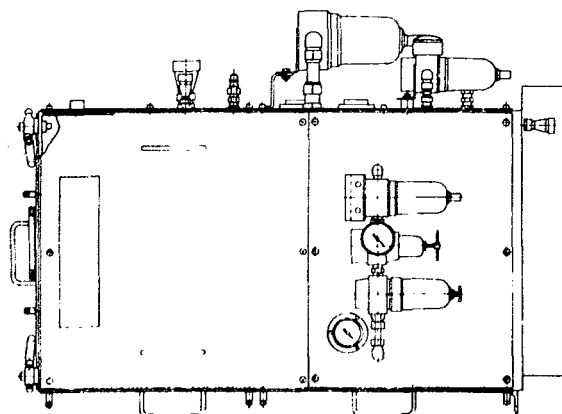
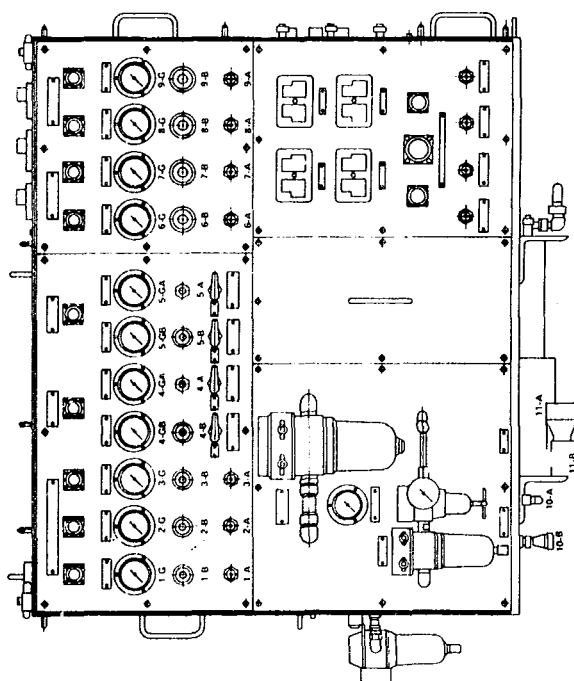
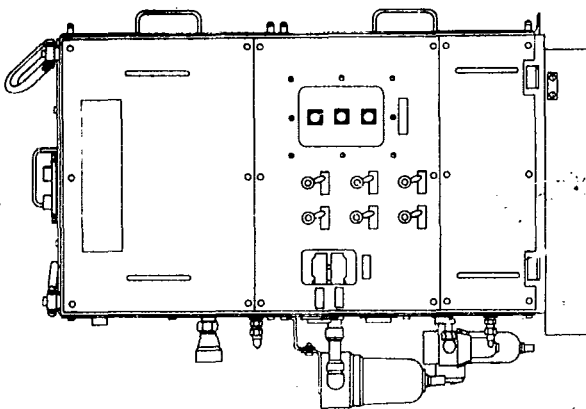
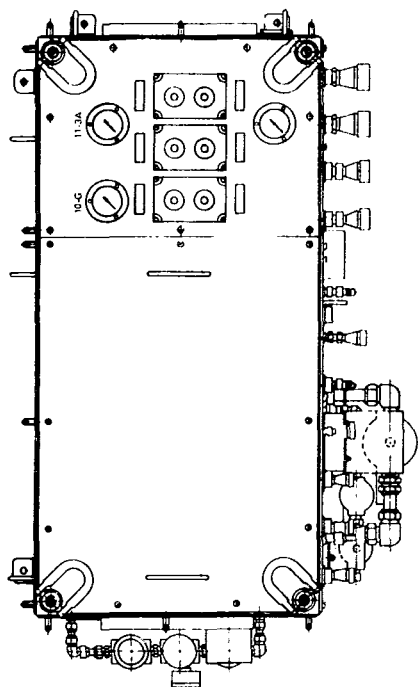
The main air line and electrical cables routed through the cable management system are terminated at the local service panel with quick disconnect couplings. The air input is branched off to four circuits; vacuum system, air-operated service tools, ROSA, and hydraulic booster pump.

The local service panel provides eight electrical outlets through two 120V, 20A, 10 circuits. Standard receptacles mounted in a water-tight enclosure with caps are used for these outlets.

The viewing system uses the local service panel to provide local plug-in terminations for three Rees cameras. These terminations are the standard camera connectors into which the operator can plug a Rees camera. Also provided on the local service panel are standard coaxial taps that are wired back into the plenum assembly removal (PAR) video system.

FIGURE A-43  
HYDRAULIC POWER SUPPLY (DWG. 1740E10)





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The hydraulic portion of the local service panel will be used to supply hydraulic fluid at the required operating pressures and flow rates for operation of the defueling end effectors, light-weight tools, and the vacuum system knock-out canister gripper and upper lift cylinder.

The hydraulic portion of the local service panel consists of hydraulic pressure controls, directional control valves, flow control devices, pressure switches, and an air-operated hydraulic booster pump. This equipment is divided into eleven distinct hydraulic supply circuits as follows:

<u>Circuit No.</u>	<u>Hydraulic Pressure Supplied (psi)</u>	<u>Max. Flow Limit (gpm)</u>
1	500	5.0
2	500	5.0
3	2000	5.0
4	70/130	5.0
5	70/130	5.0
6	4000	0.43
7	4000	0.43
8	2000	16.0
9	2000	16.0
10	200	5.0
11	100 & 2000	5.0

All eleven supply circuits receive hydraulic fluid at 2000 psi from the hydraulic power supply (via a main supply hose routed through the cable management system) through a common 2000 psi supply header. Circuits 8 and 9 are supplied directly from the hydraulic power supply at 16.0 gpm maximum. Two pressure flow controls in the branch lines of the header restrict the maximum 2000 psi supply flow to the remaining nine circuits to 5.0 gpm.

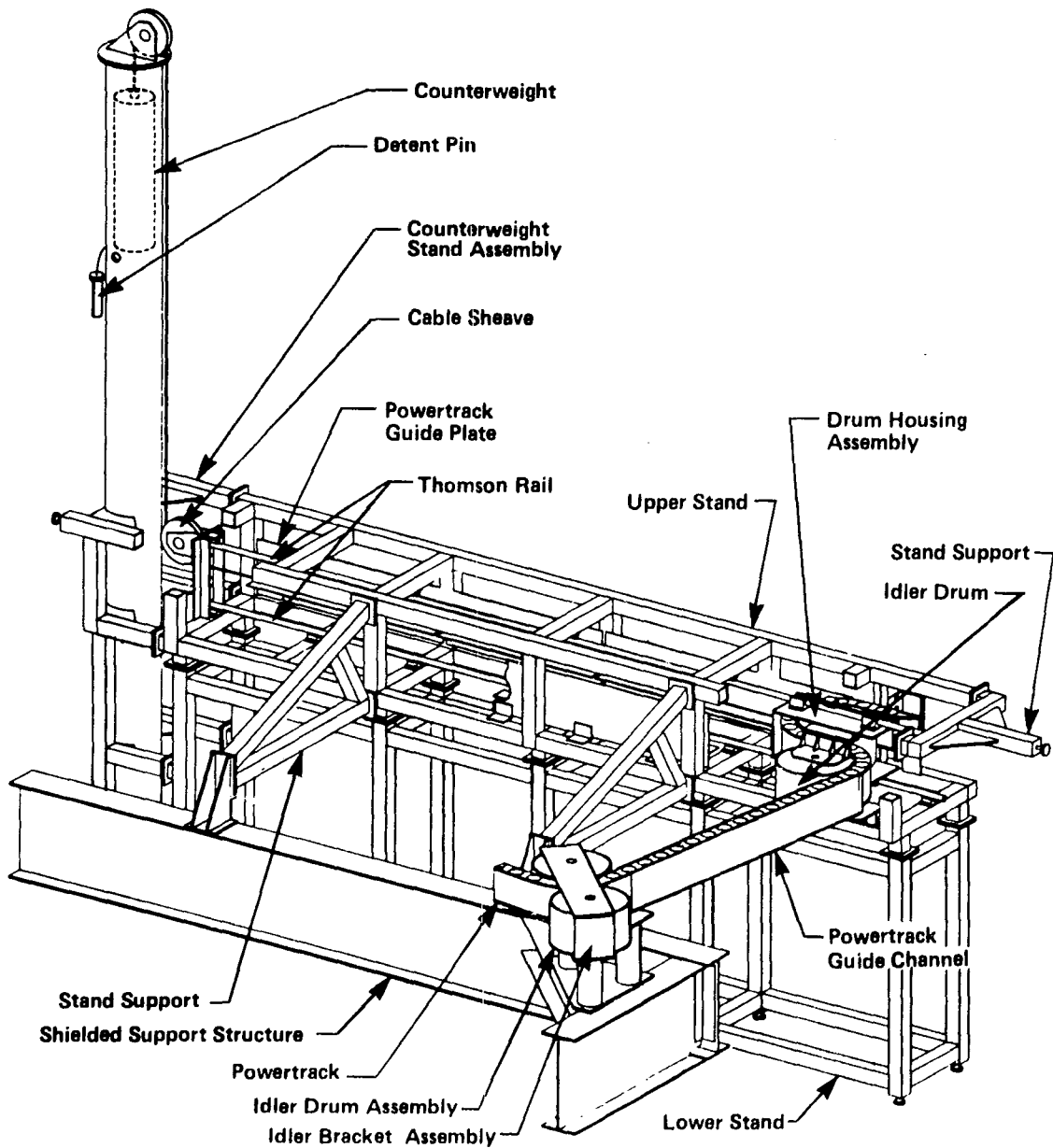
#### 3.5.4 Cable Management System

The cable management system, shown in Figures A-45, routes and manages cable and hose assemblies onto the shielded work platform. The cable management system is comprised of:

- Powertrack Guide Stand Assembly
- Counterweight Stand
- Idler Bracket Assembly



**FIGURE A-45**  
**CABLE MANAGEMENT SYSTEM (DWG. 1739E85)**



767017-22A

- Powertrack Assembly
- Powertrack Carrier Tray
- Powertrack Installation Stand

The cables and hoses are housed in a powertrack assembly that is fixed at each end. The hoses and cables are quick-connected to a manifold panel located on the powertrack guide stand assembly on one end and to the local service panel mounted on the shielded work platform at the other end. As the shielded work platform rotates, the powertrack assembly wraps around the main structure of the shielded work platform. The total take-up travel required for  $\pm 190^\circ$  rotation of the shielded work platform is 30 ft. To accommodate this movement, the powertrack assembly is threaded through a takeup drum that has 15-ft. travel capacity and is designed to take up and let out the powertrack in a fashion similar to a block and tackle arrangement. The drum housing is attached, by a cable, to a counterweight that keeps the powertrack taut.

### 3.6 Viewing System

The viewing system will be used to support all defueling activities. The operations to be viewed during this phase include vacuuming, pick and place, and canister removal and installation in the reactor core. The viewing system can be divided into subsystems that correspond to the operations to be viewed or the type of video equipment being used. These subsystems are as follows:

- PAR Video Equipment
- PAR System Camera Handling Tools
- General Reactor Vessel Lighting System
- Vacuum Nozzle Viewing Equipment
- Instrumentation and Controls

The equipment needed for the TMI-2 Viewing System includes:

- Radiation Resistant, Waterproof Cameras
- Camera Control Units and Cabling
- Waterproof Lights
- Light Control Units and Cabling
- Camera Positioning Tools
- Video Monitors and Recorders

Westinghouse will use the plenum assembly removal (PAR) video inspection system to the fullest extent possible in the viewing system. The PAR system is supplied by GPUN and is currently being used at the TMI-2 site.

The PAR system has two basic subsystems:

- Video Equipment
- Camera Handling Tools

The video equipment includes cameras, lights, controls, cables, and monitors. The camera handling tools position the cameras so that the operators can remotely view the reactor vessel core. The viewing system will use the video equipment and the camera handling tools. In addition to the PAR system, a general reactor lighting system, and clamps for vacuum nozzle viewing have been added to complete the equipment necessary to view defueling operations.

#### 3.6.1 PAR Video Equipment

The PAR video equipment can be divided into two different categories: 1) the in-containment equipment and 2) the coordination center equipment. The in-containment equipment primarily acquires the information and provides immediate monitoring and control of the video equipment by the operator manipulating the tools. The coordination center provides control for monitoring and recording operations from outside the reactor building.

#### 3.6.2 PAR System Camera Handling Tools

The PAR camera handling tool assembly consists of a camera handling tool end, winch assembly, camera cable, Rees R93 camera, and a tool handle. With this setup, the operator can remotely position the camera in predefined locations. These camera handling tools will be used for general surveillance, maintenance, and canister viewing.

### 3.6.3 General Reactor Vessel Lighting System

The purpose of the general reactor vessel lighting system is to provide general background lighting under the work platform during defueling operations. All of the components of this system are designed to operate in the borated water of the reactor vessel.

The system is comprised of four lighting poles or positioners. Three 1000 watt pencil lights are mounted on each pole. The poles are mounted approximately 90 degrees apart on the off-gas seal. The light positioners consist of two 1.00 in. schedule 10 stainless steel pipe sections. The sections are bolted together at two mating blind flanges. Both ends of the poles are sealed. The bottom end of each positioner has a stainless steel sphere. The purpose of the sphere is twofold: 1) to offset the positioner from the periphery of the reactor vessel which, in turn, will protect the lights from ~~the~~ the side during installation and defueling operations and 2) to ease installation by providing a rounded edge for the pole to ride on as it is being lowered against the vessel wall.

### 3.6.4 Vacuum Nozzle Viewing Equipment

The purpose of the vacuum nozzle viewing tool is to position a Rees R93 camera near the vacuum nozzle so that a closeup view of the vacuum nozzle can be obtained during vacuuming. The camera and light are secured to the vacuum nozzle positioner using stainless steel clamps. A stainless steel guard for the camera is also provided to protect the camera and lens while still maintaining a compact assembly.

### 3.6.5 Instrumentation and Controls

The viewing system will utilize the PAR equipment with the addition of two Hoffman boxes containing the variacs for the general reactor vessel lights. The PAR equipment is located on El. 331' 6", in a cabinet with the dimensions 22 in. x 22 in. x 47 in. This cabinet contains the camera control units and local video monitors. This system is tied into the coordination center. Power for the cabinets will be provided by the power distribution

system. The entire system will consist of five camera control units, six 15-in. monitors, and an audio base repeater station for communication with the coordination center. The camera control units include three Rees R93 and two Diamond ST-5 units. These units provide all focus and iris control for the cameras. The output signals to the coordination center will come directly from the video monitors. Also provided on the work platform will be three 15-in. monitors that may be attached to the tool slot safety rail. These monitors will be portable and are meant to be used in conjunction with the long-handled tools.

Detailed information on the viewing system is provided in the Viewing System Final Design Report (Reference 19) and the O&M Manual for the Viewing System (Reference 20). A summary tool list for the viewing system is provided in Table A-6.

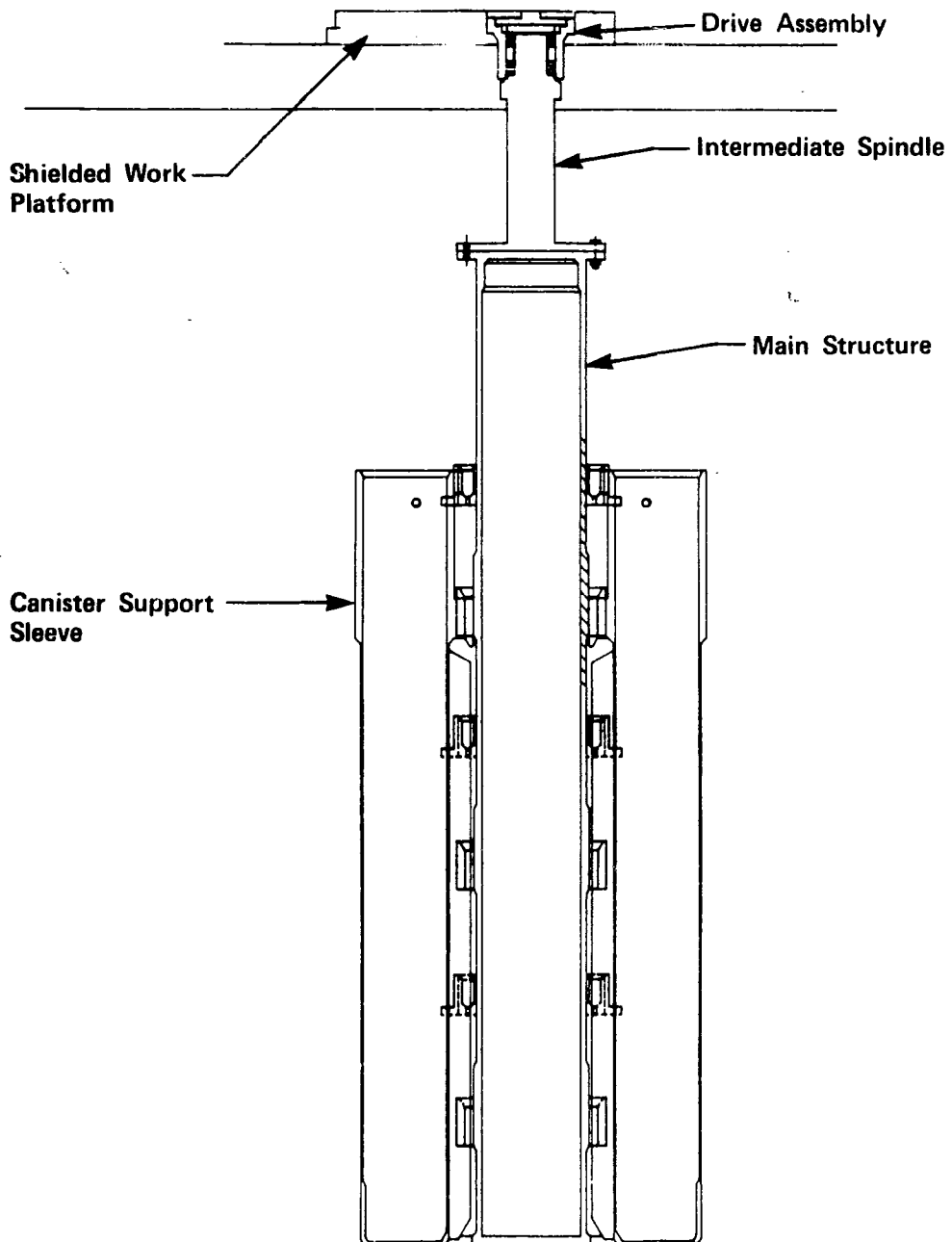
TABLE A-6 WBS 612 VIEWING SYSTEM TOOL LIST

<u>Tool/Component</u>	<u>Westinghouse Dwg. No.</u>	<u>GPUN Equip. Ident. No.</u>
Fuel Canister Monitoring Camera Positioning Tool	Not Supplied by <u>W</u>	---
Portable Camera Positioning Tool	Not Supplied by <u>W</u>	---
Maint. Camera Positioning Tool	Not Supplied by <u>W</u>	---
Vacuum Nozzle Camera Positioning Tool	1735E68	DEF-VEW-005
Reactor Vessel Core Lighting Positioning Tool	1735E41	DEF-VEW-001 thru 004

### 3.7 Canister Positioning System

The canister positioning system (CPS), illustrated in Figure A-46, has five canister holding positions, a means for lowering canister positions, a rotational drive unit, a CPS rotational position measuring device, a removable center access location, an integral shielded support structure, and various tools to facilitate operation. The CPS is mounted to the shielded work platform. The instrumentation for the CPS is located on the control console.

**Figure A-46**  
**Canister Positioning System (Dwg. 1735E81)**



The CPS supports fuel and knockout canisters at elevations 324 ft-11 in, 321 ft, and 317 ft. Canister elevation 1 provides approximately 4 in. of clearance between the bottom of the CPS and the top of the core. Canister elevation 2 allows fuel debris up to 2 ft in length to be placed in a fuel canister while maintaining 4 ft of water above the debris. Canister elevation 3 permits loading fuel debris up to 5 ft in length.

The major components of the CPS are as follows:

- Canister Support Sleeve
- Fuel Canister Seal Cover
- Main Structure
- Sleeve Locking Device
- Intermediate Spindle
- Drive Assembly

Detailed information on the CPS is presented in the Final Design Report for the Canister Positioning System (Reference 21) the O&M Manual for the Canister Positioning System (Reference 22), the Final Design Report for the Single Canister Positioning Bracket (Reference 23), and the O&M Manual for Single Canister Positioning Bracket (Reference 24). A summary tool list is provided in Table A-7.

Table A-7 WBS 742 CANISTER POSITIONING SYSTEM TOOL LIST

<u>Tool/Component</u>	<u>Westinghouse Dwg. No.</u>	<u>GPUN Equip. Ident. No.</u>
Canister Positioning System	1735E81	---
Canister Support Sleeve	1735E71	DEF-CPS-002
Main Structure	1735E70	DEF-CPS-001
Sleeve Locking Device	1735E83	DEF-CPS-003
Intermediate Spindle	1807E02	DEF-CPS-004
Drive Assembly	1807E03	DEF-CPS-005
Ancillary Tools:		
Sleeve Handling Tool	1735E78	DEF-CPS-006
Fuel Canister Seal Cover	1735E86	DEF-CPS-007

<u>Tool/Component</u>	<u>Westinghouse Dwg. No.</u>	<u>GPUN Equip. Ident. No.</u>
Knockout Canister	1735E87	DEF-CPS-008
Indexing Sleeve Cover/ Indexing Sleeve Handling Tool	1735E88	DEF-CPS-010
Single Canister Support Bracket	1807E48	DEF-SCB-001
Plug Handling Tool	1808E04	DEF-CPS-011
Maintenance Lift Fixture	1808E15	DEF-CPS-012
Drive Assembly Maintenance Fixture	1807E65	DEF-CPS-013

### 3.7.1 Canister Support Sleeve

The individual canisters are held in support sleeves shown in Figure A-47 equally spaced on a 1 ft-11 in. radius. When the canister is loaded into the sleeve, either a fuel canister seal cover or a knockout canister index sleeve (depending on canister type) will be installed on the canister. These items maintain the rotational orientation of the canister within the sleeve, as well as performing other functions described in the following sections.

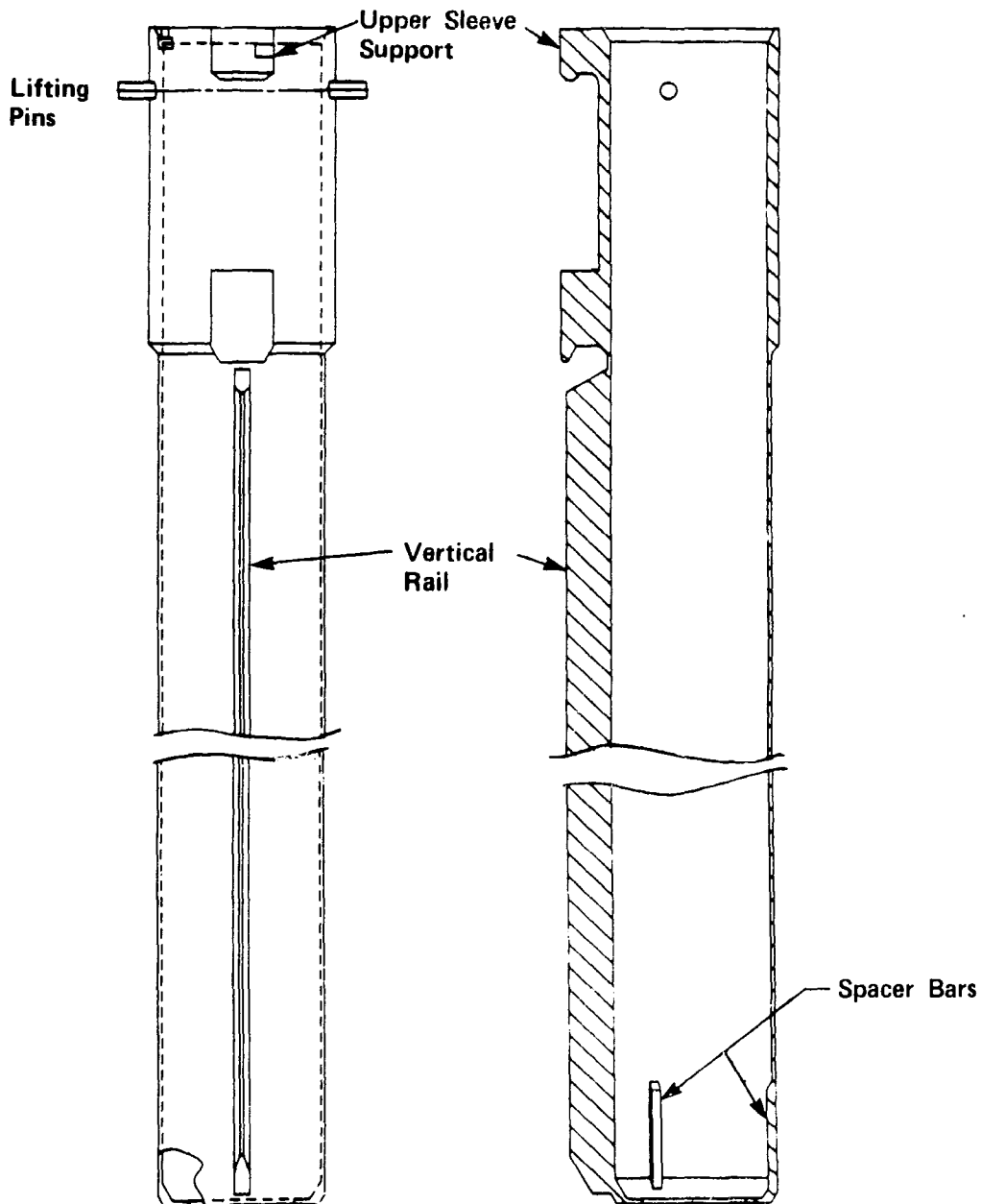
To change canister elevation, the sleeve handling tool illustrated in Figure A-48 will capture the two lifting pins on the canister sleeves and lift the sleeve. This lifting point is off center so that the bottom of the sleeve will tilt and contact the curved surface on the bottom of the CPS. The sleeve is raised until the support lugs clear their rests. It is then lowered into the next resting position and the sleeve handling tool is detached from the sleeve. The sleeve can now be locked in place.

### 3.7.2 Fuel Canister Seal Cover

The fuel canister seal cover is required to protect the sealing surface on the fuel canisters. The cover design includes two vented locating holes, two lifting pins, two orientation slots, and a conical top opening. The cover is placed on top of fuel canisters using the canister handling tools.



**FIGURE A-47**  
**CANISTER SUPPORT SLEEVE ELEVATION (DWG. 1735E81)**



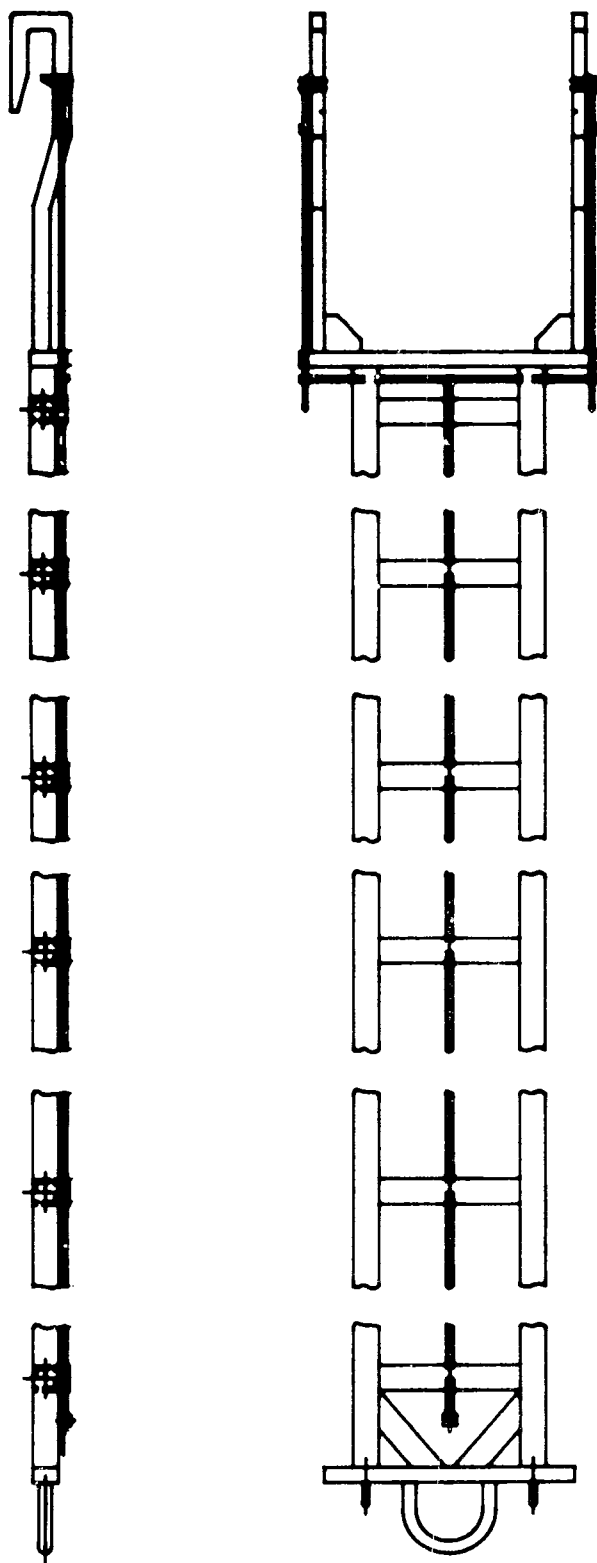


FIGURE A-48  
SLEEVE HANDLING TOOL

### 3.7.3 Main Structure

The main structure is a 20-in. diameter cylindrical spindle with a series of sleeve supports, sleeve guide plates, and position locating devices attached to it. The structure is modular to facilitate entry to containment.

### 3.7.4 Sleeve Locking Device

The sleeve locking device is illustrated in Figure A-49. Its purpose is to lock the canister support sleeves to the CPS at the various elevations. The device consists of an actuation nut, a spindle, three spindle collars, three locking bars, and a spring. The spindle is attached to the CPS main structure through the 1.87-in. diameter holes in the sleeve guide plates. There is a lock bar at each of the canister elevations. The device is operated by a long-handled socket tool.

The sleeve locking device is used once a canister support sleeve is in position. The socket tool is engaged on the nut and rotated clockwise. This swings a locking bar into the groove in the side of the upper sleeve support and then into the groove in the canister support sleeve upper lug. This keys the canister support sleeve to the sleeve support.

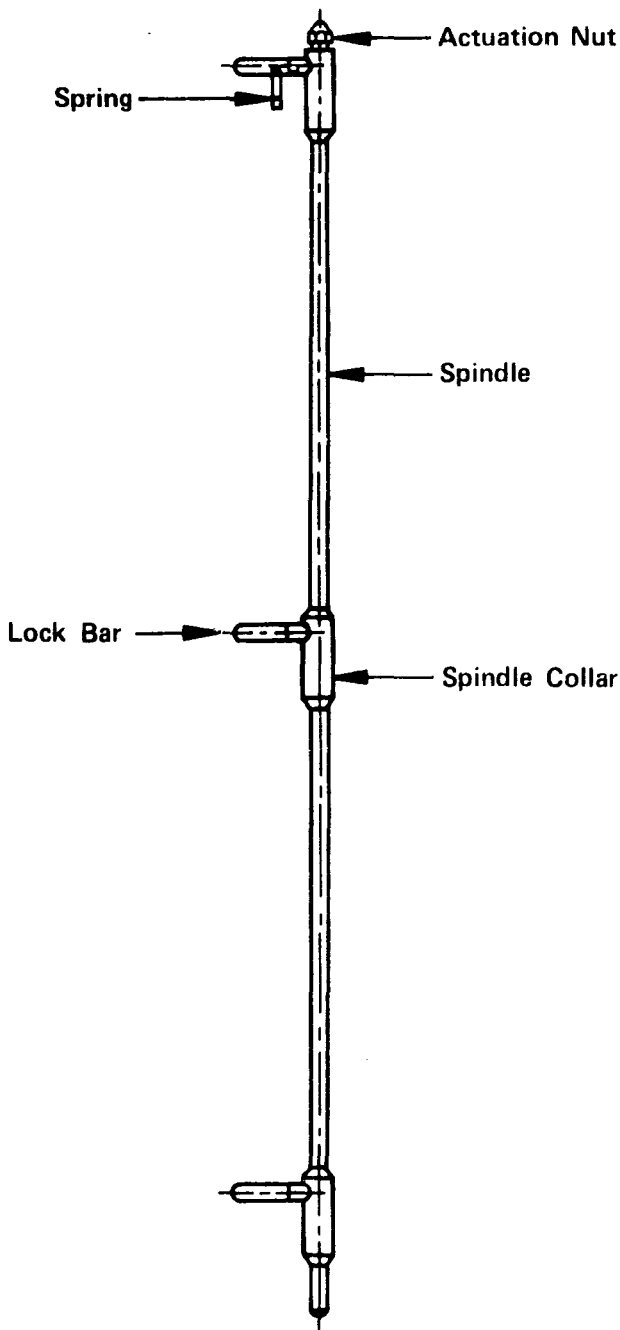
### 3.7.5 Intermediate Spindle

The CPS main structure is attached to the bearing spindle through the hollow intermediate spindle. Two alignment pins are located on each side of the intermediate spindle to assure that the CPS is assembled in the proper orientation. The purpose of the intermediate spindle is to enable the drive assembly to be replaced without removing the entire CPS system from the shielded work platform.

### 3.7.6 Drive Assembly

The CPS is mounted to the rotating shielded work platform through the drive assembly. This is the hardware on which the CPS rotates and through which rotational position is controlled. The unit is designed to be rotated by a standard 3/4-in. square drive wrench. The design torque required to rotate the CPS is about 500 in.-lbs.

**FIGURE A-49**  
**SLEEVE LOCKING DEVICE (DWG. 1735E81)**



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### 3.7.7 Single Canister Support Bracket

The single canister support bracket is illustrated in Figure A-50. The fuel canister is held in a support sleeve that interfaces with the Thomson rail system in the long-handled tool slot. This arrangement allows the canister to be positioned at any of the following three elevations within the core region.

El. 324'-11"

El. 320'-0"

El. 317'-0"

An extension for the single canister support bracket allows each of the above elevations to be lowered 6 ft.

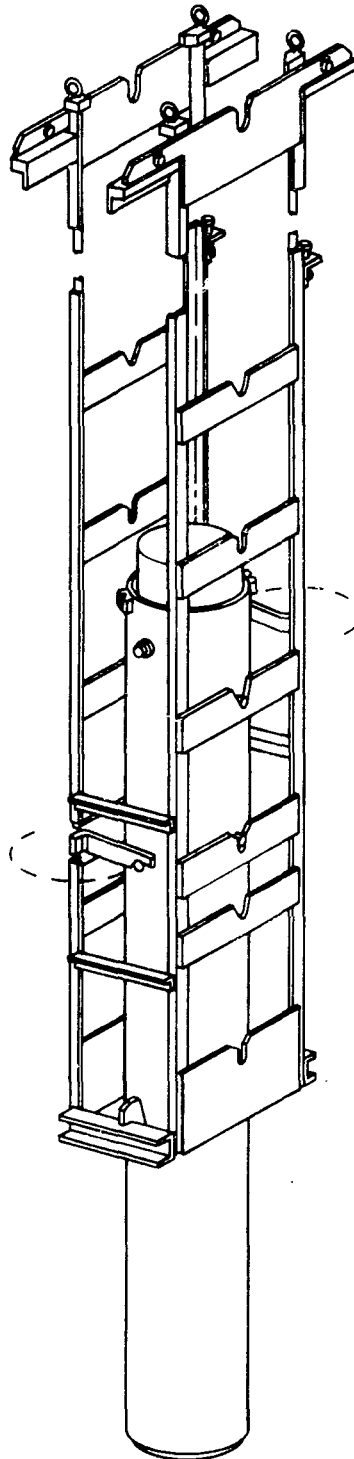
## 3.8 Test Assemblies

The Final Design Report for the test assemblies that support the vacuum system, viewing system, and canister positioning system is found in Reference 25. The qualification test support structure is a bolted carbon steel structure designed to simulate part of the shielded work platform and the reactor vessel. Major areas included are all the access openings between the shielded work platform beams and the 85-in. reactor clear radius.

## 3.9 End Effectors

The Final Design Report for the end effectors is found in Reference 25. A summary tool list is provided in Table A-8. To minimize the size of tools required and the space for storage on the tool racks, several end effectors will be supplied. These end effectors will accomplish gripping, cutting, lifting, positioning, moving, etc. of debris as required for defueling. The end effectors were conceptualized for use with long-handled tools and the manual tool positioner. A common design coupler will be used for attachment of an end effector to each tool.

Figure A-50  
SINGLE CANISTER SUPPORT BRACKET



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TABLE A-8 WBS 524 END EFFECTORS TOOL LIST

<u>Tool/Component</u>	<u>Westinghouse Dwg. No.</u>	<u>GPUN Equip. Ident. No.</u>
Impact Chisel	1768E84	DEF-EEF-216
Hydraulic Abrasive Saw	1768E82	DEF-EEF-208
Cutting Jet	2032379	N/A

### 3.9.1 Impact Chisel

The impact chisel, shown in Figure A-51, will be used to fracture or bore holes into fused core material. It utilizes a commercially available hammer chisel that provides up to 2000 impacts per minute and a drill rotation rate up to 3.5 RPM. It operates on Union Carbide UCON WS-34 hydraulic fluid supplied via the control system hydraulic power system.

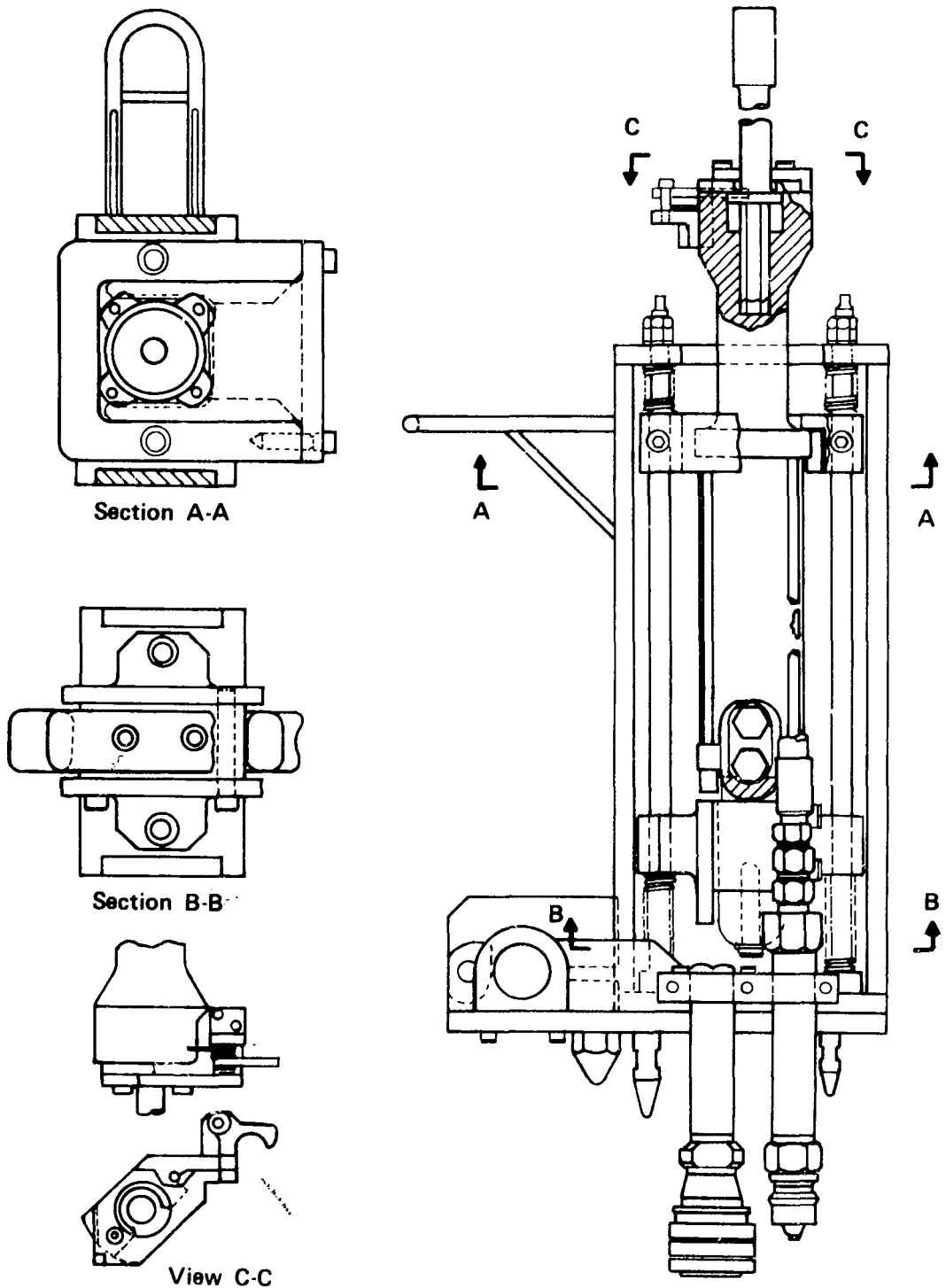
### 3.9.2 Abrasive Saw

The abrasive saw, shown in Figure A-52, will be used to cut fused material or other debris. It requires the same hydraulic power supply as the impact chisel. It can make a 2-in. deep cut with an 8-in. diameter cutting wheel or a 3-in. deep cut with a 10-in. diameter cutting wheel.

### 3.9.3 Cutting Jet (Hydrolaser)

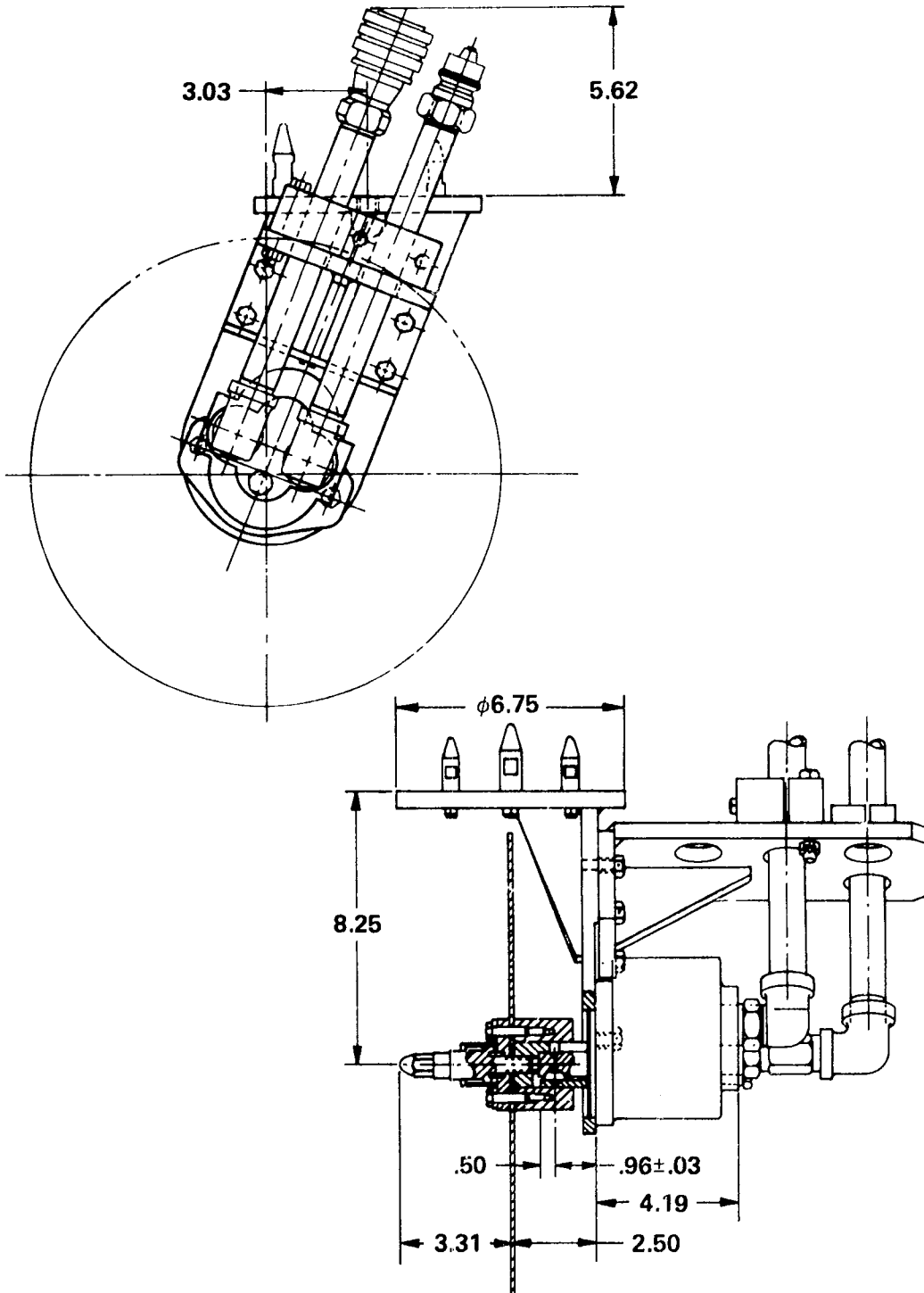
The high pressure cutting jet can be used to cut various kinds of debris. It develops its cutting action by entraining abrasive grit in a 35,000-psi water stream to abrade the piece being cut. The system includes a hopper for the abrasive, a high pressure pump, and a mixing block. The mixing block contains the water orifice and a replaceable tungsten carbide nozzle.

FIGURE A-51  
IMPACT CHISEL (DWG. 1839E45)





**FIGURE A-52**  
**ABRASIVE SAW (DWG. 1839E47)**



767017-18A

Access to all regions within the core support assembly is provided during bulk defueling operations via rotation of the shielded work platform and travel of the manual tool positioner carriage along the work platform tool slot rails. Travel or rotation of the positioner may be limited by other equipment within the slot, such as the fuel canisters. The manual tool positioner includes a post supported by a carriage that in turn can be supported within either of the long-handled tool slots of the shielded work platform. Tools are mounted on a lateral positioner located at the bottom of the post. The manual tool positioner vertical and rotational movements are actuated via two handwheel assemblies that are mounted at the top of the post. The lateral positioner, which is mounted at the lower end of the post, will hold and deliver the end effectors for cutting, drilling, chiseling, etc. The lateral positioner can be serviced or detached remotely using long-handled tools.

The manual tool positioner provides four degrees of freedom to the end effectors:

- 14 ft-6 in. of vertical travel via the telescoping tube section of the post.
- 12.0 in. of lateral positioning via extension and retraction of the lateral positioner combined with carriage travel on the tool slot rail system.
- 360° rotation around the post axis.
- 360° rotation (wrist action) around the lateral positioner rod axis to facilitate angular positioning of the end effectors with selectable stop limits each 90°.

Detailed information on the tool positioning system is provided in Reference 27. A summary tool list is provided in Table A-9.

<u>Tool/Component</u>	<u>Westinghouse Dwg. No.</u>	<u>GPUN Equip. Ident. No.</u>
Manual Tool Positioner	1770E73	N/A
Carriage	1770E74	
Post	1770E73	
Tool Mounting	1770E89	

## REFERENCES

1. Westinghouse Drawing 1737E60, Rev. 2, TMI-2 Defueling Interface Control Drawing
2. Westinghouse Drawing 1737E78, CP-5, TMI-2 Dry Defueling Reactor Internal Dimensions
3. Westinghouse Report, WTSD-TME-037, Rev. 0, TMI-2 Defueling System Design Specification
4. Technical Specification 15737-2-R200B(Q), Rev. 1, Technical Specification for Fuel Removal and Fines/Debris Vacuum System
5. Westinghouse Report, WTSD-TME-018, Rev. 0, WTSD Quality Assurance Program Plan for Fuel Removal and Fines/Debris Vacuum System
6. Westinghouse Report, WTSD-TME-051, Rev. 0, Task Description for TMI-2 Defueling Tools
7. Westinghouse Report, WTSD-TME--054, Rev. 1, Final Design Report for Shielded Work Platform (WBT-721)
8. Westinghouse Report, WTSD-TME-089, Rev. 0, Operation & Maintenance Manual for the Shielded Work Platform (WBS-721)
9. Westinghouse Report, WTSD-TME-053, Rev. 1, Final Design Report for Shielded Support Structure (WBS-711)
10. Westinghouse Report, WTSD-TME-086, Rev. 0, Operation & Maintenance Manual for TMI-2 Dry Defueling Shielded Support Structure (WBS-711)
11. Westinghouse Report, TMI-AD-84-032, Rev. 1, TMI-2 Early Defueling Fines/Debris Vacuum System Final Design Report (WBS-412)
12. Westinghouse Report, TMI-AD-85-010, Rev. 0, TMI-2 Early Defueling Fines/Debris Vacuum System Operation & Maintenance Manual (WBS-412)
13. Westinghouse Report, SAE-SEP-DR-27(84), Rev. 2, Final Design Report for Long Handled Tools (WBS-514)
14. Westinghouse Report, SAE-SEP-MM-37, Rev. 1, Operation & Maintenance Manual for Long Handled Tools (WBS-514)
15. Westinghouse Report, WTSD-TME-055, Rev. 1, Final Design Report for Control System (WBS-561, 564)
16. Westinghouse Report, WTSD-TME-091, Rev. 0, Operation & Maintenance Manual for TMI-2 Dry Defueling Cable Management System (WBS-561)
17. Westinghouse Report, WTSD-TME-092, Rev. 0, Operation & Maintenance Manual for TMI-2 Dry Defueling Control System - Electrical (WBS-561)

18. Westinghouse Report, WTSD-TME-099, Rev. 0, Operation & Maintenance Manual for TMI-2 Dry Defueling Hydraulic System (WBS-561)
19. Westinghouse Report, TMI-AD-84-042, Rev. 1, Viewing System Final Design Report (WBS-612)
20. Westinghouse Report, TMI-AD-85-038, Rev. 0, General Reactor Vessel Lighting System Operation & Maintenance Manual (WBS-612)
21. Westinghouse Report, TMI-AD-84-045, Rev. 1, TMI-2 Defueling Canister Positioning System Final Design Report (WBS-742)
22. Westinghouse Report, TMI-AD-85-057, Rev. 0, TMI-2 Early Defueling Canister Positioning System Operation & Maintenance Manual (WBS-742)
23. Westinghouse Report, TMI-AD-85-001, Rev. 0, TMI-2 Defueling Single Canister Support Bracket Final Design Report (WBS-742)
24. Westinghouse Report, TMI-AD-85-046, Rev. 0, Single Canister Support Bracket Operation & Maintenance Manual (WBS-742)
25. Westinghouse Report, TMI-AD-84-1075, TMI-2 Early Defueling Qualification Test Support Structure Final Design Review Package
26. Westinghouse Report, SAE-SEP-DR-46 (85), Rev. 0, Final Design Report for Bulk Defueling Equipment for Defueling of GPUN TMI-2 Nuclear Power Station
27. Westinghouse Report, SAE-SEP-DR-45 (85), Rev. 1, Final Design Review Report for Manual Tool Positioner for Bulk Defueling of GPUN TMI-2 Nuclear Power Station (WBS-544)