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REMOTE HANDLING SYSTEMS AT THE BARNWELL NUCLEAR FUEL PLANT -- AN OVERVIEW

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ABSTRACT

Facility design of the Barnwell Nuclear Fuel Plant (BNFP) incorporates a combination of remote and contact-maintenance systems. Several unique concepts were employed in the remote-systems design to assure minimal radiation exposure to personnel and operational efficiency. Extensive checkout has been conducted to assess the performance of underwater handling, sampling, hot cell, and specially shielded transfer equipment. Innovative solutions to remoting deficiencies have been applied to enhance plant operating capability.

1.0 INTRODUCTION

Constructed as a commercial Light Water Reactor (LWR) reprocessing facility, the proceedings on Allied-General Nuclear Services' (AGNS) application for an operating license have been terminated by the Nuclear Regulatory Commission (NRC) due to the Administration's policy on nonproliferation.

Since that time, the AGNS staff, utilizing the plant itself as a unique research and demonstration tool, has been engaged in a variety of contract tasks for the Department of Energy (DOE) in the area of nonproliferation research and development. Primary areas of emphasis include spent fuel handling and storage, demonstration of existing and development of advanced safeguards systems, and development of proliferation-resistant alternate fuel cycles.

The remote systems at the BNFP utilize a combination of proven and unique concepts consistent with maintaining plant throughput and achieving as-low-as-practicable exposure to personnel. Several types of remote handling systems are employed at BNFP to accomplish the desired objective in selected portions of plant systems. Fuel unloading, storage, and transfer is performed underwater. Equipment requiring routine maintenance or mechanical handling is located in two large hot cells with complete remote maintenance capability. Limited remote capabilities for clearing transfer piping pluggage and vessel and/or cell decontamination have been provided in five contact maintenance cells. Specially shielded equipment was fabricated to permit removal for maintenance or replacement of selected contact cell equipment, removal of filters, and other functions. Chemical process operations are monitored in an analytical chemistry hot cell divided into eight compartments, which accommodate sampling and analysis of various process streams which contain radioactive materials.

Extensive testing demonstrated operability of the various remote systems, and allowed for identification of needed improvements or additions. This overview of remote equipment installations and handling techniques is intended to typify AGNS' approach to efficient systems design, and to describe some of the improvements made as a result of the testing.

2.0 UNDERWATER HANDLING SYSTEMS

In the fuel receiving and storage station, underwater handling was selected to accommodate spent fuel storage requirements for shielding, heat removal, and visibility. Several specialty equipment items were designed to safely move fuel through the pool systems. Operator handling is achieved by means of four cranes provided for the special functions of cask handling, fuel unloading, fuel storage canister transport, and fuel storage canister unloading.

2.1 Fuel Handling Cranes

The cask handling crane is an overhead bridge unit equipped with a single trolley and two hoists (Figure 1). The crane movements are pendant controlled from poolside elevation. The 122-tonne main hoist is used for fuel cask movements, including immersion in the unloading pool, while the 22-tonne auxiliary hoist handles closure heads and miscellaneous components. Electrical limit switches restrict bridge and trolley movements, while over the pool area, to that portion of the unloading pool protected by an energy absorption pad. A redundant hoist brake system is employed to reduce the possibility of an accidental cask drop.

Substantial effort was expended in analysis of the cask handling crane system as related to underwater handling. Several improvements have been identified for future implementation. These include radio controls which allow the operator to select the best position for viewing, unrestricted by crane pendants; an extension yoke to eliminate immersion of the block and cables in the contaminated pool water, replacement of the stainless steel cable with lubricated, carbon steel cable for longer life, and a power rotatable hook to upgrade remote positioning capability.

The cask unloading, canister, and canister unloading cranes are utilized to unload and store fuel and to load the conveyor cart for transfer to mechanical processing. Each crane is operated from a suspended catwalk with a pendant control.

The cask unloading crane is a semigantry 9-tonne unit used in conjunction with extension fuel grapples to transfer fuel assemblies from the transport casks to storage canisters. Notable design features include a structural height limitation* to preclude exceeding minimum water shielding requirements, and a hoist overload interlock to stop movement in the event a fuel assembly were to jam.

The canister crane is a 13-tonne bridge crane traversing the unloading, storage, and transfer pools. This is a dedicated unit whose lift mechanism (canister cap) is designed to transfer fuel storage canisters between pools. Multiple speed controls including bridge and trolley inch speed (0.45 meters/minute) enhance close quarters maneuverability.

The canister unloading crane is a 13-tonne overhead bridge crane utilized to transfer individual fuel assemblies with extension grapples from a storage canister to the fuel transfer conveyor.

The physical layout of the pool area cranes is conducive to potential collision problems. A proximity warning system will be incorporated whereby interference of the canister crane with either of the other two units will be prohibited. Also, underwater lamps will be suspended from the crane trolley to provide increased visibility.

*Design feature of the other two units also.

2.2 Rail Cask Lift Yoke

The NL Industries lift yoke is designed for handling of the 10/24 rail cask (Figure 2). Prior to lowering the cask into the unloading pool, the inner head is attached to the lifting yoke by means of wire rope slings. When the yoke is disengaged and raised from the cask, the inner head is removed. Alignment guides are provided to permit reattachment of the yoke to the cask. Operation of the yoke arms is accomplished by action of a pneumatic slave cylinder attachment on each leg. The operator positions an electrical switch to supply air through flexible tubing to the slave cylinders' engage or disengage connection.

2.3 Underwater Television

The underwater television unit facilitates identification of fuel and may be used to determine yoke and grapple positions (Figure 3). The camera is mounted on a remotely operated pan and tilt mechanism which is lowered down the pool wall on a winch-suspended cart. The winch support frame is bracketed to a desired pool wall location. Rheostat-controlled lighting, along with power zoom and focusing, enable the operator to obtain a clear view of the desired object. A high-resolution monitor affords a sharp picture under minimal lighting conditions. Readability of 13-millimeter high dummy fuel numbers has been demonstrated through about 11 meters of water.

2.4 Fuel Grapple

Typical of fuel grapples employed to handle fuel assemblies under water is a 15-meter Babcock and Wilcox grapple (Figure 4). The grapple is suspended from the cask unloading crane and engaged or disengaged from the operating platform by rotating the top nut to the mechanical stops provided. The positions are clearly marked open and close.

During checkout, it was determined this fuel grapple would not release from the fuel assembly when inserted into a canister. The four fingers on the slave end of the grapple were beveled to eliminate interference with the canister fuel slot.

2.5 Canister Cap

The lifting mechanism suspended from the canister crane is known as the canister cap. Two remotely operated hydraulic arms engage trunnions on both sides of a canister. A trolley-mounted reciprocating pneumatic cylinder is connected to a pumping cylinder. The pumping cylinder powers two double-acting hydraulic cylinders mounted on the canister cap. A demineralized water medium eliminates the consequences of a hydraulic fluid spill into the pool. The latching mechanism is spring loaded to the failsafe (engaged) position (Figure 5). In addition, for criticality considerations, integral metal cross bars are spaced to retain fuel assemblies within the canister in the unlikely event of canister drop from a crane failure.

2.6 Fuel Transfer Conveyor

The transfer conveyor consists of a rectangular enclosure affixed to a chain driven cart (Figure 6). Bogey wheels positioned within guide rails provide necessary alignment to traverse the access tunnel which connects the fuel transfer pool and the hot cell. Positioning of the cart for top or bottom end fuel loading to the shear is accomplished by manipulator-controlled cam adjustments in the hot cell. The drive mechanism and travel limit switches are located in the operating area. Hot cell and transfer pool located components, such as the cart and chain, can be repaired or replaced remotely. Addition of a redundant cell end travel limit and drive amperage overload system alleviates the likelihood of chain failure.

Note: Modifications to the transfer conveyor and remote hot cell equipment are more completely described in a previous paper.(1)

3.0 REMOTABLE HOT CELL EQUIPMENT

All of the process equipment located in the remote hot cells is designed for remote maintenance (Figure 7). Strategically positioned master-slave manipulators, in conjunction with in-cell cranes and power manipulators, allow for maintainability. Varying capacities are available as best suited to the weight of the component to be handled. Viewing for these remote operations is either through lead-glass radiation windows or via closed-circuit television.

A crane room separated from the hot cell by a movable shield door allows for contact maintenance of the cranes. Initial decontamination may be conducted with a master-slave manipulator from the viewing window using high-pressure sprays. Small tool accessories can be cleaned in an ultrasonic bath located in the cell.

The hot cell operating environment and the effects of decontamination tend to aggravate crane and power manipulator electrical problems. Installation of plug-in type electrical junction boxes will minimize maintenance exposure during repair proceedings. Another problem area, cross-winding of crane cables caused by momentary slack conditions during remoting operations, was resolved by installation of special cable retainers. These are designed to retain the cables in the grooves, thus reducing the likelihood of kinking.

In-cell vessels are mounted on self-aligning supports to permit removal for repair or replacement. Clearances were increased in some instances by machining pins or mating slots to preclude potential binding. Service connections are accomplished by means of pipe jumpers affixed to the vessel and wall penetration nozzles with "Hanford" connectors. Large pipe connections employ nozzle flanges with threaded holes mated to the jumper flange containing spring-loaded captive bolts.

Improvements to remote vessels and piping systems include strengthening of wall nozzles and pipe jumper frames to withstand crane forces in the event of jamming. Flange connection bolts are subject to cross threading or bending; therefore, a remotable stud design was developed to eliminate the requirement to screw the bolts into place.

A second hot cell containing similar remote handling equipment (cranes, manipulators, etc.) accommodates cladding hulls packaging and high-level trash handling (Figure 8). A container designed for interim storage retrieval is used for transfer to waste burial.

A transfer cart, utilized for transfer of equipment between hot cells has been installed. This device was designed to require minimum maintenance by virtue of a cable and pulley arrangement operated by the cell crane hoist.

4.0 CONTACT MAINTENANCE CELL REMOTE SYSTEMS

Contact cell vessels will require extensive decontamination to permit entry for maintenance. Decontamination solutions from a cold area pumping station are routed to internal jet sprays. Exterior decontamination may be performed by pressurizing the cell spray header; multiturret nozzles discharge solution throughout the cell.

Prior experience with pluggage of piping associated with air lift systems led to the development of remotely activated freeze plugs (Figure 9). Typically located downstream of the air lift tie-in point, a vented pipe jacket serves as a collection vessel for liquid nitrogen introduced through connecting piping in the operating gallery. When the liquid in the pipe is frozen, pressure is applied to the air lift leg to force the obstruction back into the sending vessel. About 50 of the freeze plugs have been installed on potential problem piping loops.

5.0 SPECIAL EQUIPMENT

Several special equipment items were designed and fabricated to serve specific remote handling functions. These include the hulls transfer cask, centrifuge/contactor cask, filter disposal cask, and waste tank diverter.

5.1 Hulls Transfer Cask

The hulls transfer cask is a 54-tonne shielded container utilized primarily for transport of spent fuel cladding hulls containers to an interim burial site. An additional component allows the removal and replacement of the electrocell internals. The electrocell is mounted in the ceiling of one of the contact cells.

The cask consists of five major assemblies: cask body, hoist assembly, extension piece (for electrocell), control console, and trailer. The cask unit is transported on a heavy duty low-boy trailer designed to handle the 54-tonne load (Figure 10). Motive force for the trailer is supplied by a tandem axle, turbocharged, diesel tractor unit, which is geared to restrict travel speeds to a maximum of 16 kilometers per hour.

The hulls containers are bottom loaded into the shielded cask via a shielded port in the ceiling of one of the large hot cells (Figure 11). Placement of the cask over the port enables the operator to open the horizontal sliding shield doors for cell access and cask access. An integral cask hoist is provided to transport the hulls containers. Use of a specially designed remotely operated engagement device permits retrieval from the interim storage area caissons.

The integral hoist assembly has a lift capacity of 9 tonnes and a maximum travel of 11 meters. Incorporated into the hoist assembly are seven spray nozzles with external quick connect couplings. Introduction of decontamination solution provides internal surface decontamination of the hoist and cask body enclosure. Limit switches are provided for crane and door operation along with a hoist overload device.

An extension piece may be installed between the hoist assembly and the cask body to allow for removal/replacement of the contact cell ceiling-mounted electrocell. Movement of a failed unit is from the contact cell to the hulls handling hot cell for remote repair.

The operating sequence, using crane and panel controls, for routine shipment of hulls containers is as follows:

(1) Position trailer with cask into loading area.

(2) Place cask on ceiling port with 54-tonne overhead bridge crane.

(3) Open ceiling and cask bottom shielding doors.

(4) Lower hoist with remote engagement device onto hulls container.

(5) Raise container into cask while operating remote rinse system.

(6) Close both sets of shielding doors.

(7) Using the crane, lift the cask for bottom decontamination.

(8) Load onto trailer for transfer to interim storage area.

5.2 Centrifuge/Contractor Cask

Another remotely operated cask unit, the Robatel centrifuge/ contactor cask, is designed specifically for removal/replacement of the contact cell centrifuge or contactor (Figures 12 and 13). Fabrication of this unit includes several features comparable to the hulls cask;

i.e., bottom loading, sliding shield door, and top-mounted hoist. In addition, a transition section containing a sliding door is utilized as a base plate.

Initial field setup for removal involves disconnect and removal of the drive motor, placement of the transition piece (door open), and engagement of the lifting attachment to the cell plug frame.

To remove the unit from the cell, the following sequence is used.

(1) Place the cask with hoist mechanism onto the transition piece.

(2) Open the bottom door.

(3) Lower hoist with lifting device attached and engage cell plug attachment.

(4) Raise hoist to upper limit.

(5) Bolt contactor/centrifuge assembly to cask upper frame.

(6) Close cask bottom door.

(7) Transport cask to maintenance area. Replacement is essentially the reverse of the removal procedure.

A setdown frame is planned which will support the cask while loading a new replacement unit.

5.3 Filter Disposal Cask

HEPA filters for hot cell and process vessel off-gas systems are contained within a multifilter, shielded niche area. Location of routine operating areas above the filter niche enclosure dictated development of a suitable remote handling system. A unique shielded filter handling cask was designed to accommodate these requirements (Figure 14). The cubical cask unit is equipped with a lead-glass shielding window, manual hoist mechanism, ball swivel manipulator, and internal lighting.

An explanation of the normal operating sequence is summarized to delineate design features:

(1) Place cask adjacent to filter niche opening (shield plug removed).

(2) Remove the four base plate pins.

(3) Lift cask from base and place onto niche cavity.

(4) Connect and energize internal lights.

(5) Using manipulator, release filter cover clamps with extension tool.

(6) Attach manual hoist hook to filter cover bail.

(7) Retract manipulator and extension to stored position.

(8) Raise filter element into the cask.

(9) Disconnect electrical hookup.

(10) Transfer cask to base plate and install locking pins.

(11) Transport to disposal site.

The remote filter unit covers presently use a capture bolt closure system. This is difficult to operate with the cask manipulator. These will be replaced with a simpler-to-operate overcenter locking lever closure.

The standard elastomer gasketed HEPA filter design is frequently difficult to seal properly. Conversion to a "liquid seal" filter system will alleviate this problem. The sealing surface in the modified configuration consists of a knife edge filter chamber base mated to a silicone-lubricated slot integral with a disposable filter frame.

5.4 Waste Tank Diverter

The waste tank diverter cell serves as a routing selection point for waste liquid from the plant or intertank transfers. Two diverter vessels are contained within the cell, equipped with a rotatable discharge nozzle and series of receiver funnels. One is shown in Figure 15. Liquid flowing through the system drains by gravity to the selected receiving tank.

The movable drain piece is remotely operable by means of an extension through the shielded floor to the operating area. The diverter jumper is lifted a few inches with a manual winch, rotated to the desired position, then lowered into the selected slot (Figure 16). A slotted position latch, coded with pipe line identification, assures correct routing.

6.0 REMOTE ANALYTICAL FACILITIES

The design of the remote analytical facilities maximizes the operating philosophies for the area: (1) employee safety, (2) safeguards for special nuclear material, and (3) efficient support of production activities.

The facilities at the BNFP consist of a sample analytical cell containing a line of eight hot compartments, two glovebox sample stations, an operating aisle, and a maintenance access aisle. Additional sample stations are located in the waste tank equipment gallery and the plutonium nitrate storage and loadout area.

Several features included in the design are significant in that they reduce the necessity of handling process solutions directly. These features are: (1) the air lift/ejector sampling system, (2) on-line instrumentation, (3) automated sample transfer system, and (4) a portable high-pressure decontamination system. This section will describe these features and their relationship to the overall operations of the facility.

6.1 Remote Samplers

The remote needle block samplers are located in three types of containments: heavily shielded compartment (Figure 17), standard gloveboxes (Figure 18), and double-walled gell-filled gloveboxes (Figure 19). The type of containment used to house a specific sampler is dependent upon the expected levels and type of radiation emitted from the solution being sampled.

The air lift/ejector closed-loop sampler used at the BNFP is shown in Figure 20. This system is similar to those used at the Hanford Purex Facility and the Nuclear Fuel Services Facility at West Valley, New York. Two major modifications were included in the design of the BNFP samplers: (a) a valve pot to protect the ejector and (b) on-line instrumentation.[2]

A problem associated with the operation of the earlier designs for the air lift/ejector sample loop was the premature failure of the ejector. The failures have most commonly been attributed to corrosion of the ejector throat due to contact with process solutions or pluggage. The financial costs as well as exposure to personnel resulting from the replacement of the ejector has been very high. In the BNFP sample loop, a valve pot or float mechanism has been positioned between the return leg of the sample loop and the ejector. Process solution entering the valve pot causes the float to rise closing the line to the ejector. With the loss of vacuum on the sample loop, submergence cannot be maintained and circulation ceases.

Preliminary testing at the BNFP indicates the valve pot has prevented damage to the ejectors located on sample points for the headend, as well as waste sections of the process on many occasions.

6.2 On-Line Monitors

A total of 18 on-line monitors were included in the original installation of the sample loops. Four types of monitors are used at the BNFP to measure (1) uranium concentrations, (2) nitrite concentrations, (3) beta-gamma activity, and (4) plutonium concentrations. The outputs from these monitors to the control room are used primarily for process control.

The on-line monitors reduce the frequency of sampling required to support production activity, reduce exposure to analytical personnel, and reduce the potential to divert special nuclear material.

A typical alpha monitor installation is shown in Figure 21. The monitor loops can be remotely decontaminated should maintenance be required for the detectors.

6.3 Sample Transfer System

Each of the major sampling stations is connected to the Hot and Cold Laboratory Area (HCLA) by a pneumatic, positive pressure, sample transfer system. The routing of the sample transfer system is shown in Figure 22.

The connection between the Sample and Analytical Cell (SAC) is a two-way system with an automatic reverse feature to send very hot samples back to the SAC. A NaI crystal is used to measure the activity of the sample as it passes through the transfer tube. An adjustable trip point is used to activate the reverse cycle. A sample having activity exceeding the preset level is returned to the shielded compartment.

Each of the routes is operated independently of the other. The sender is loaded with a polyethylene capsule, or "rabbit," containing a single sample bottle. The operator at the receiving station initiates the transfer and verifies that the proper sample has been received before initiating the next transfer. A single transfer takes approximately three seconds.

The transfer system provides the means to reduce exposure to personnel by eliminating manual transfer of samples and increases the ability to safeguard special nuclear material by reducing the accessibility to the sample.

6.4 Decontamination System

A high-pressure portable decontaminating system consisting of a pneumatic pump, reservoir tank, connecting hoses, and remote wand is used to decontaminate individual hot cells and gloveboxes. A photograph of the portable decontamination system is shown in Figure 23.

The pressure at the nozzle is approximately 700 psi. The remote wand enables the decontamination solution to be directed at very hot spots or generally throughout the area. The portability and ease with which the unit can be put into service greatly reduces the time required for decontamination. Because each shielded compartment and glovebox has its own connection points, decontamination can be done in one compartment without disrupting work being done in an adjacent compartment.

7.0 CONCLUSION

Remote system design at the Barnwell Nuclear Fuel Plant represents state-of-the-art technology adapted to specific plant criteria. A comprehensive testing program ascertained the validity of these concepts as applied to simulated operational conditions. Reliability and improvement modifications have been identified, and in many cases implemented, to assure handling of spent nuclear fuel in the future can be done in a safe and efficient manner.

REFERENCES

(1) Townes, George A., AGNS-1040-CONF-61, "Verification of the Barnwell Nuclear Fuel Plant (BNFP) Mechanical Headend Design," American Nuclear Society Winter Meeting, Washington, D. C. (November 1978).

(2) Belew, W. L., Huff, G. A., and Sears, L. F., "The Remote Sampling System and On-Line Analytical Monitors in the Barnwell Nuclear Fuels Reprocessing Plant," Proceedings of the 21th Conference on Analytical Chemistry in Energy Technology, Gatlinburg, Tennessee (October 1977).

FIGURES

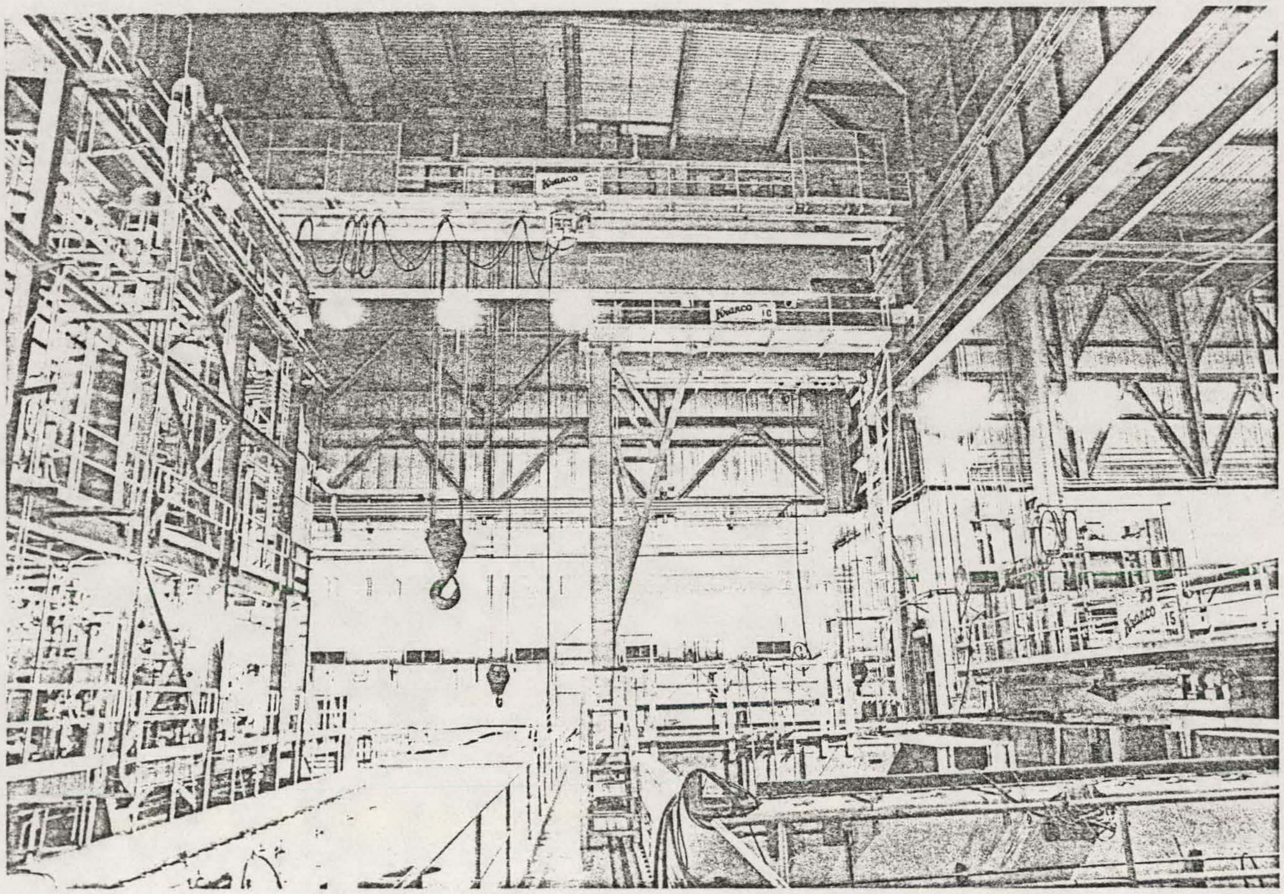


FIGURE 1

CASK HANDLING, CASK UNLOADING, AND CANISTER CRANES

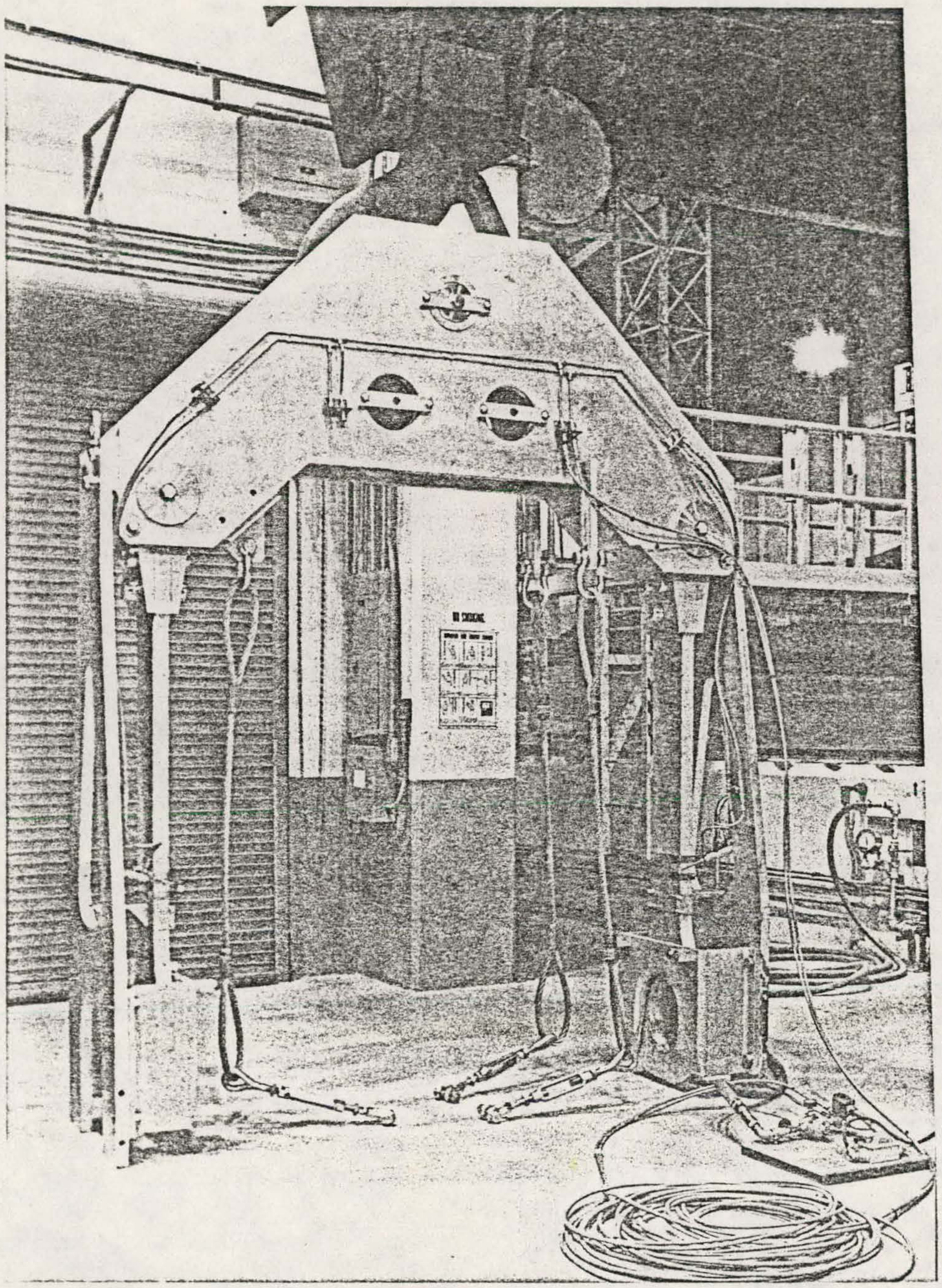


FIGURE 2

NL 10/24 RAIL CASK LIFT YOKE

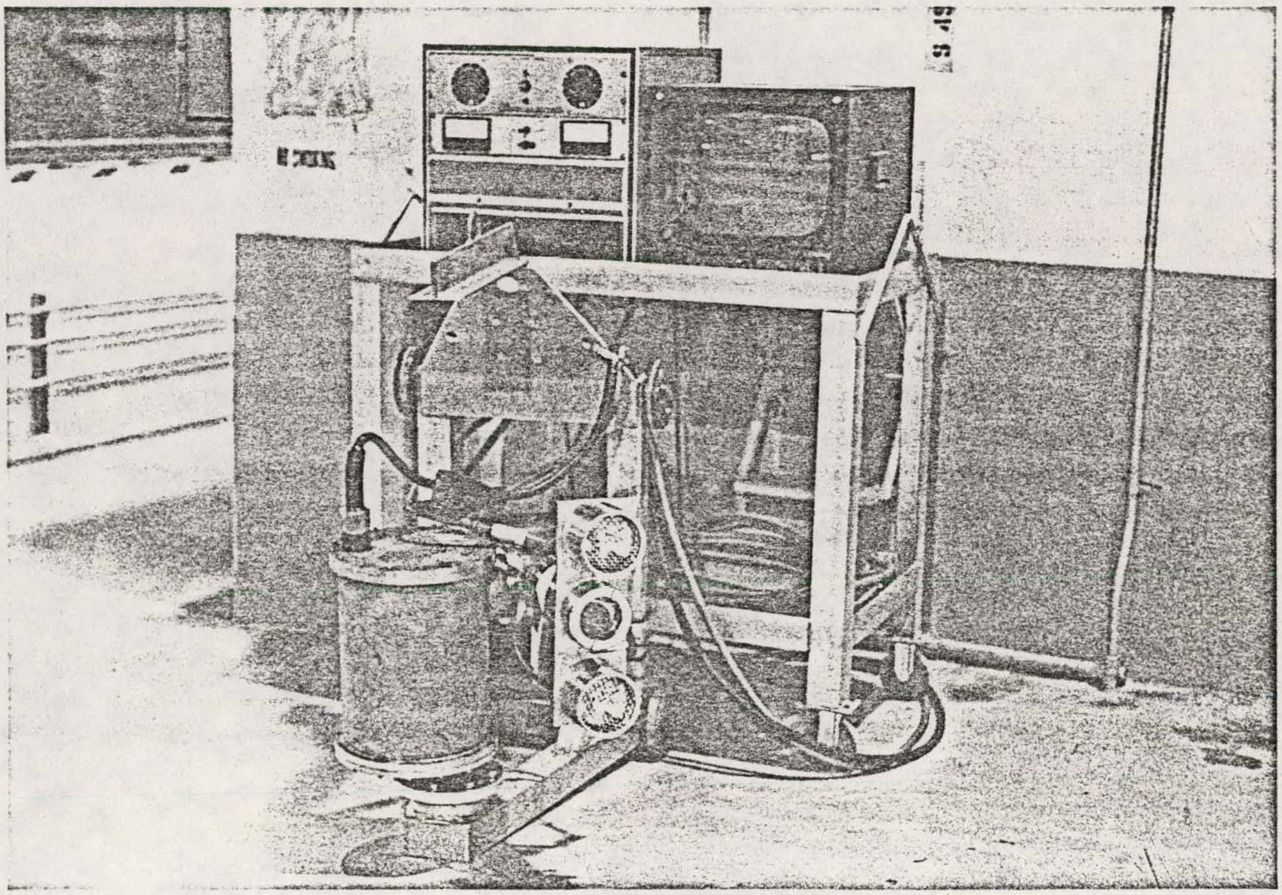
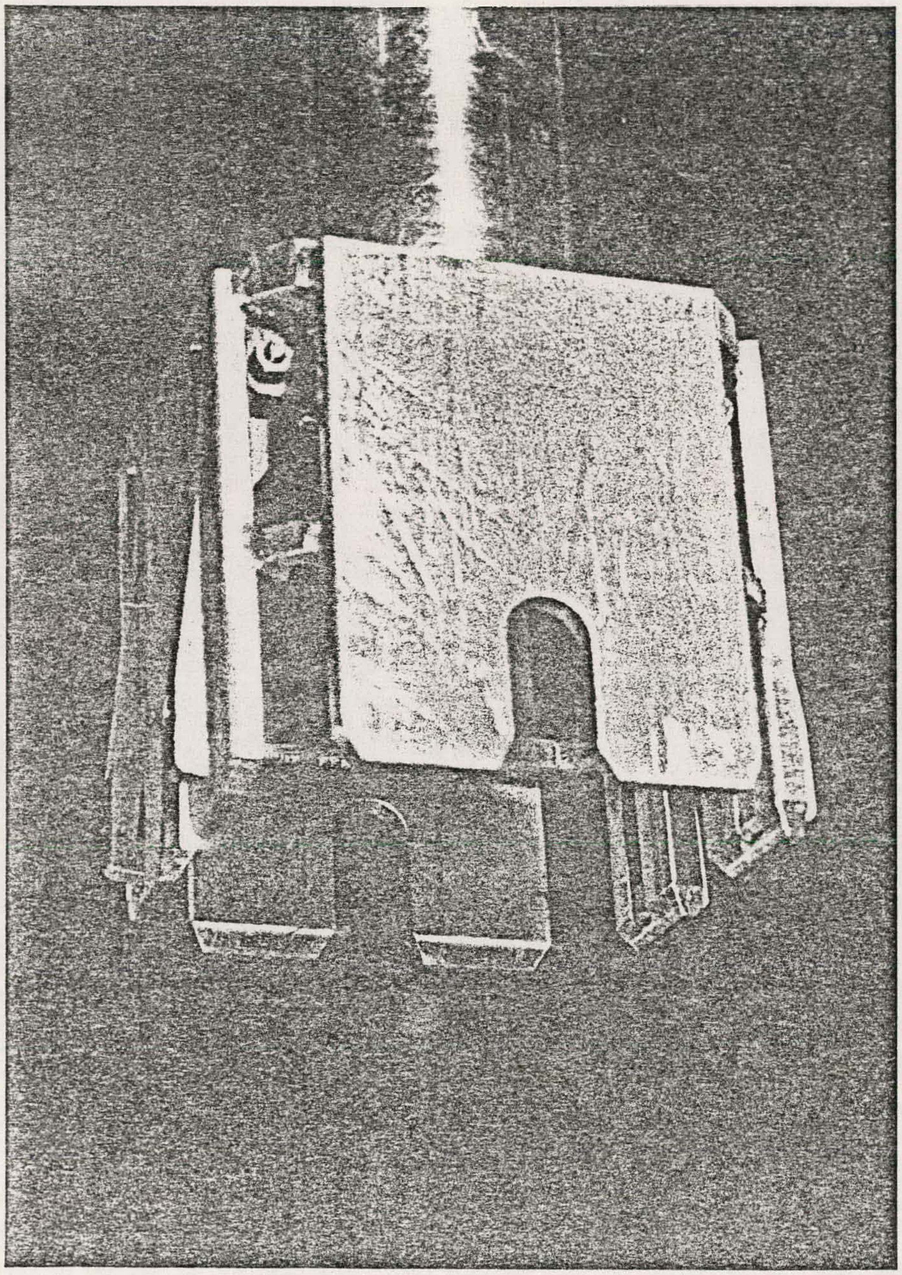


FIGURE 3

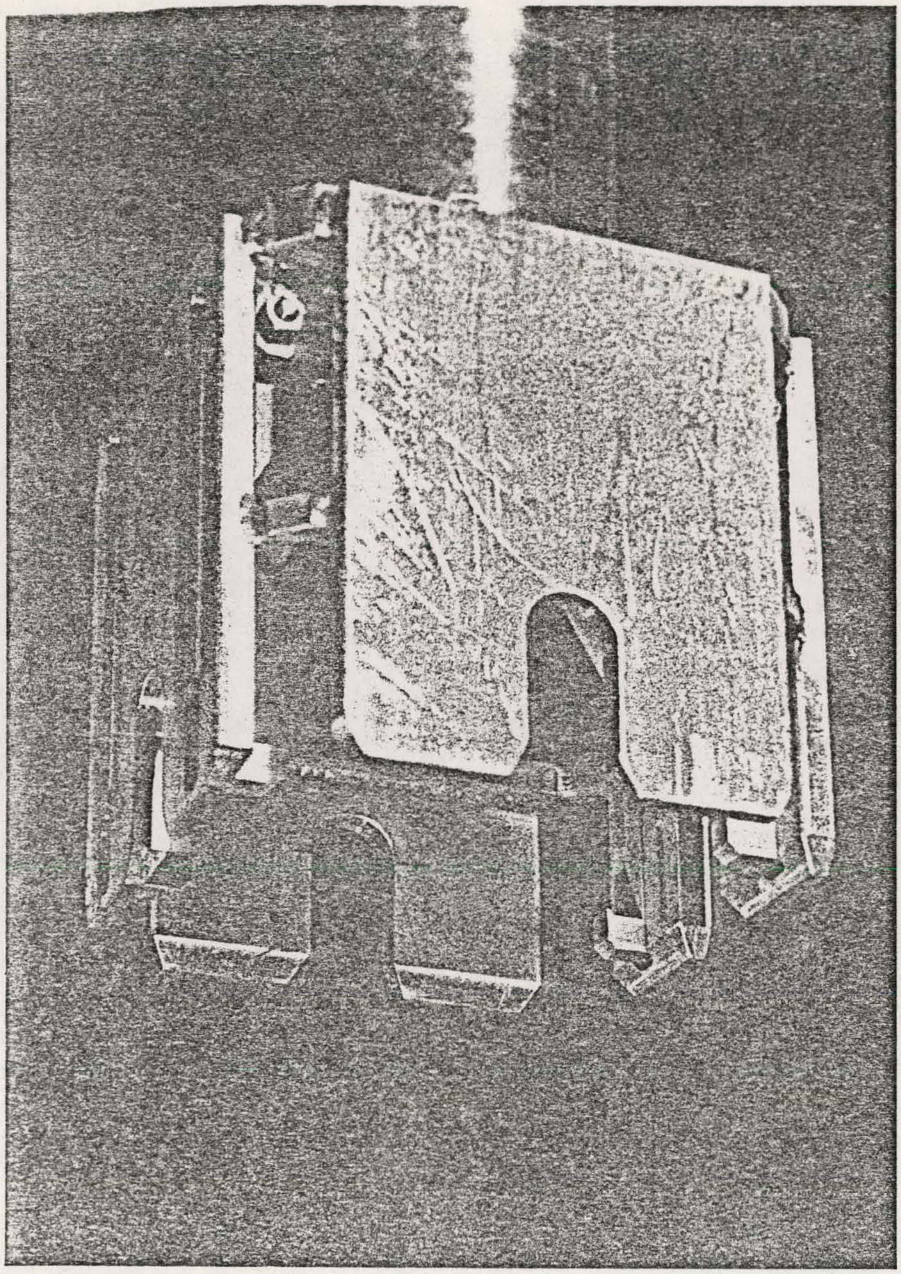
UNDERWATER TELEVISION UNIT



OPEN

FIGURE 4A

BABCOCK AND WILCOX FUEL GRAPPLE -- SLAVE END



CLOSED

FIGURE 4B

BABCOCK AND WILCOX FUEL GRAPPLE -- SLAVE END

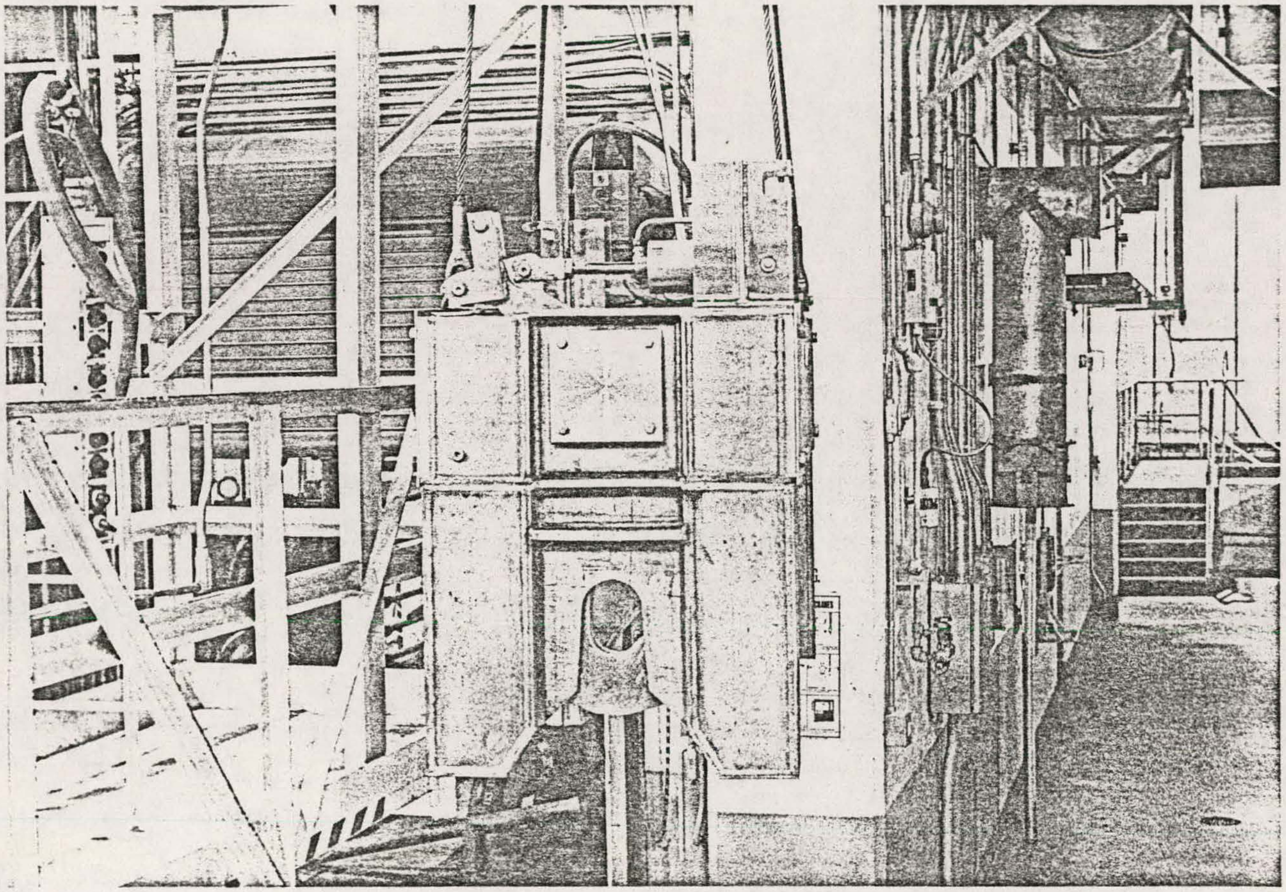


FIGURE 5

CANISTER CAP MECHANISM (ENGAGED)

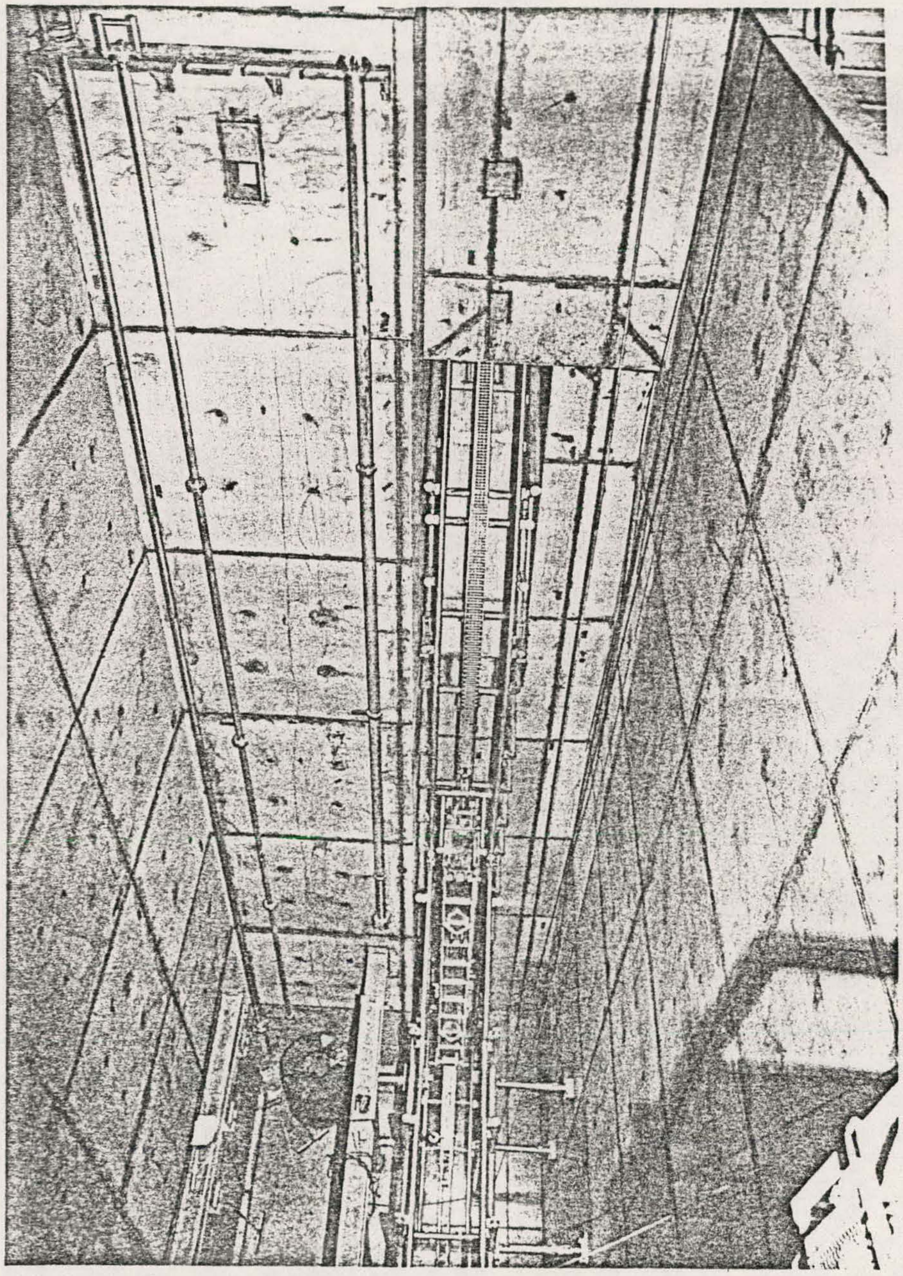


FIGURE 6

FUEL TRANSFER CONVEYOR

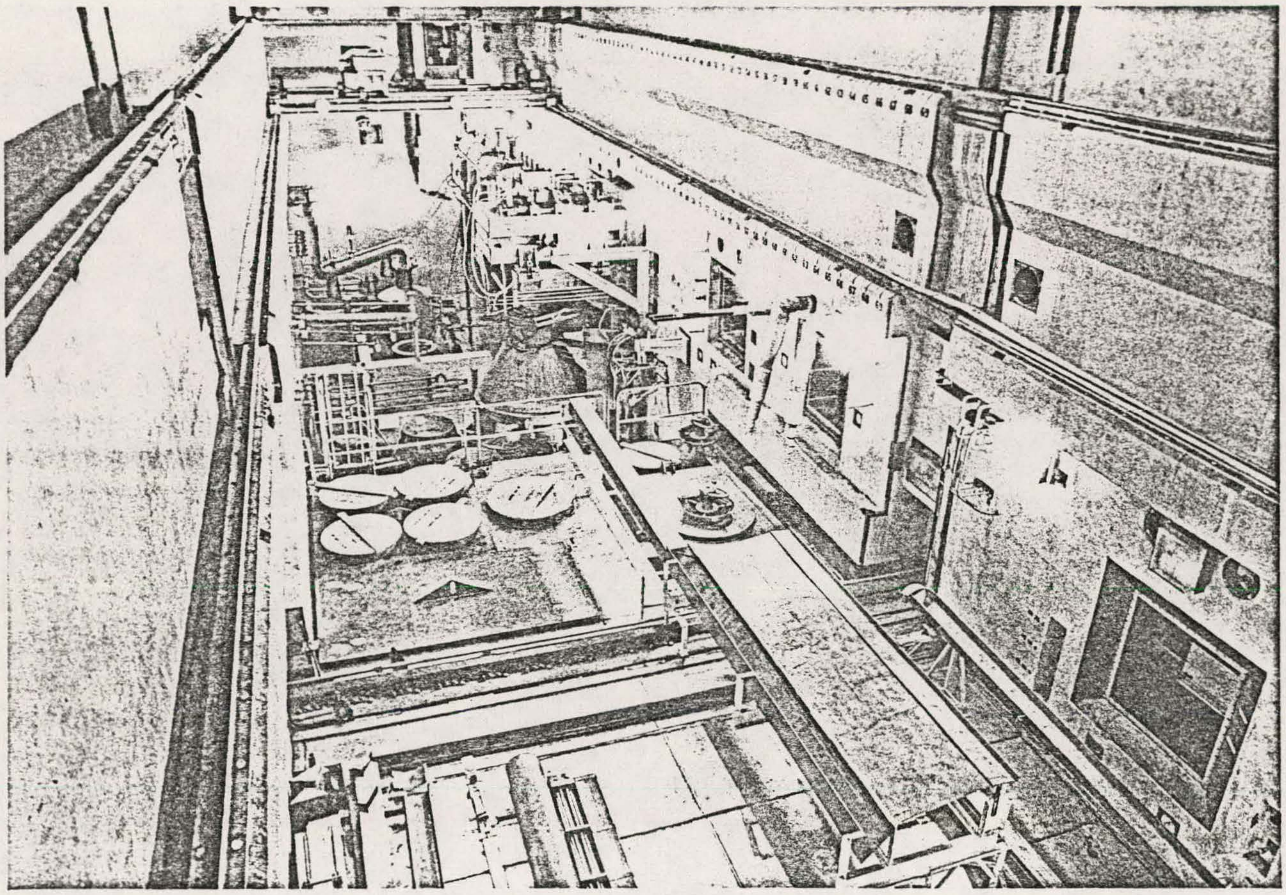
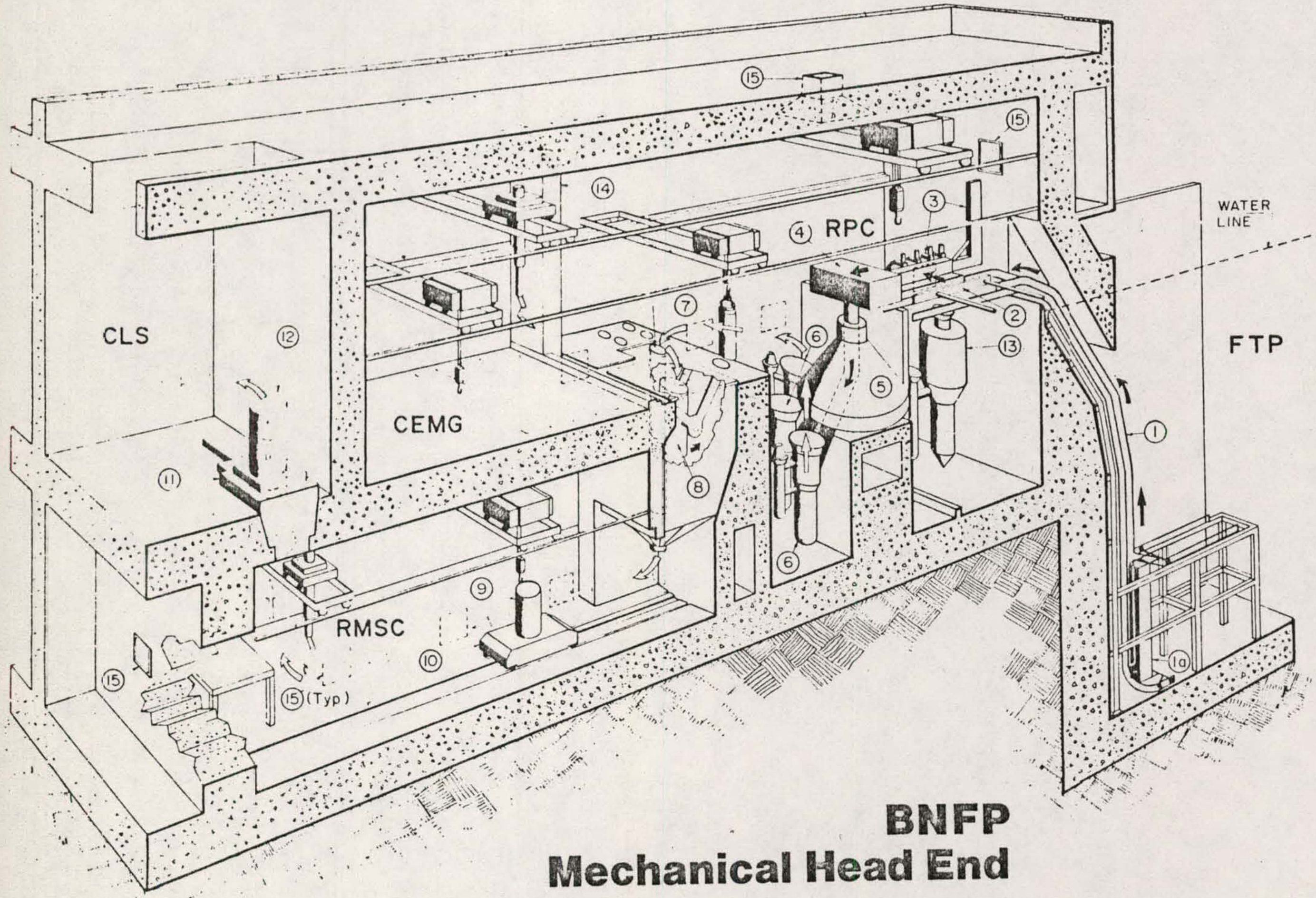


FIGURE 7

REMOTE HOT CELL INTERIOR



Equipment

1 Fuel Transfer Conveyor (cart 1a)
2 Transfer Fuel Pusher
3 Shear Feed Magazine
4 Shear
5 Diverter
6 Dissolver
7 Hull Monitor
8 Dissolver Basket Dumper
9 Hull Disposal Container
10 Hull Transfer Car
11 Ceiling Hatch
12 Hull Container Cask
13 HAW Concentrator
14 Shielding Door (partially closed)
15 Shielding Windows

Process Area

FTP Fuel Transfer Pool
RPC Remote Process Cell
CEMG Crane Equipment & Maintenance Gallery
RMSC Remote Maintenance & Scrap Cell
CLS Cask Loading Station

Legend

Fuel Path
Scrap or Hulls Path

FIGURE 8

REMOTE HOT CELLS CONFIGURATION

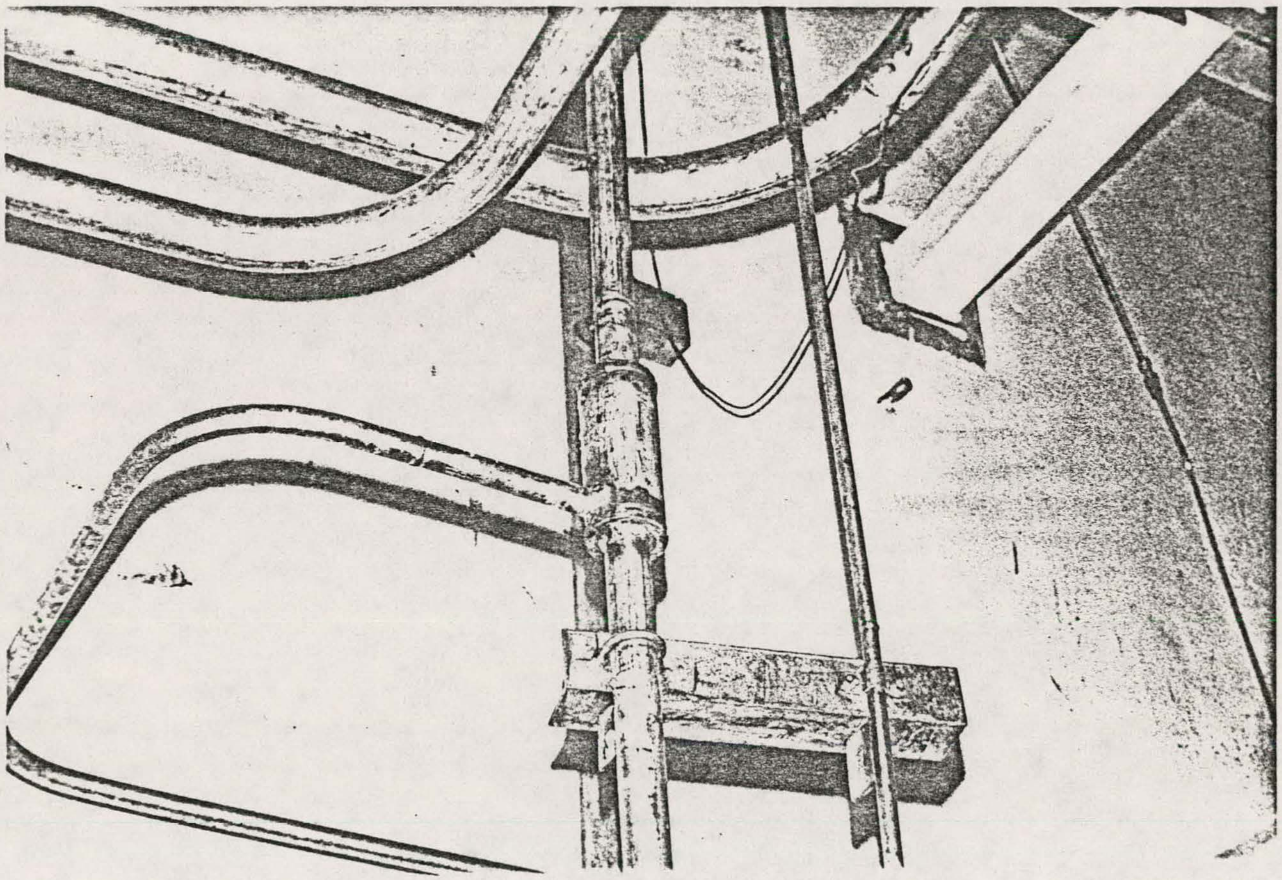


FIGURE 9

TYPICAL FREEZE PLUG

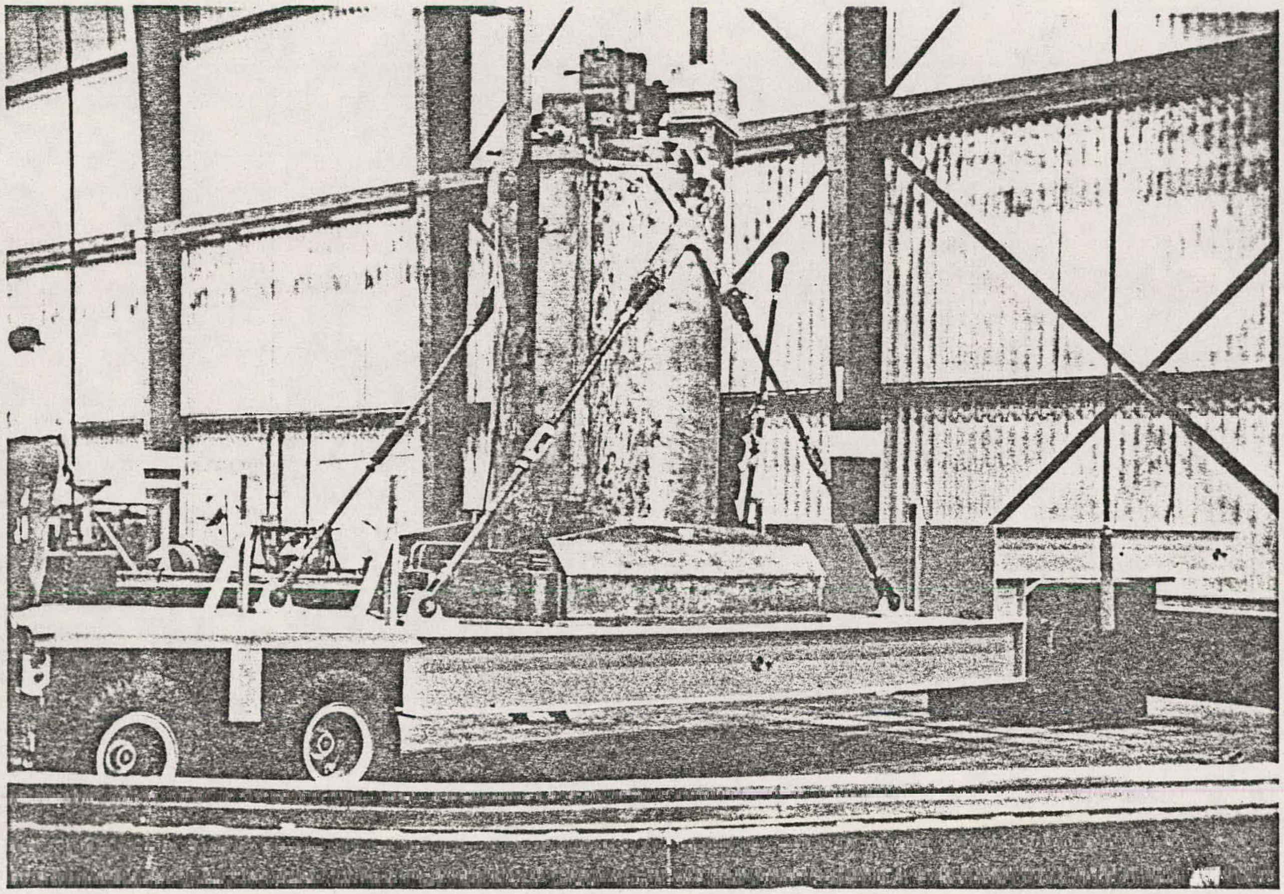


FIGURE 10

HULLS CASK AND TRAILER

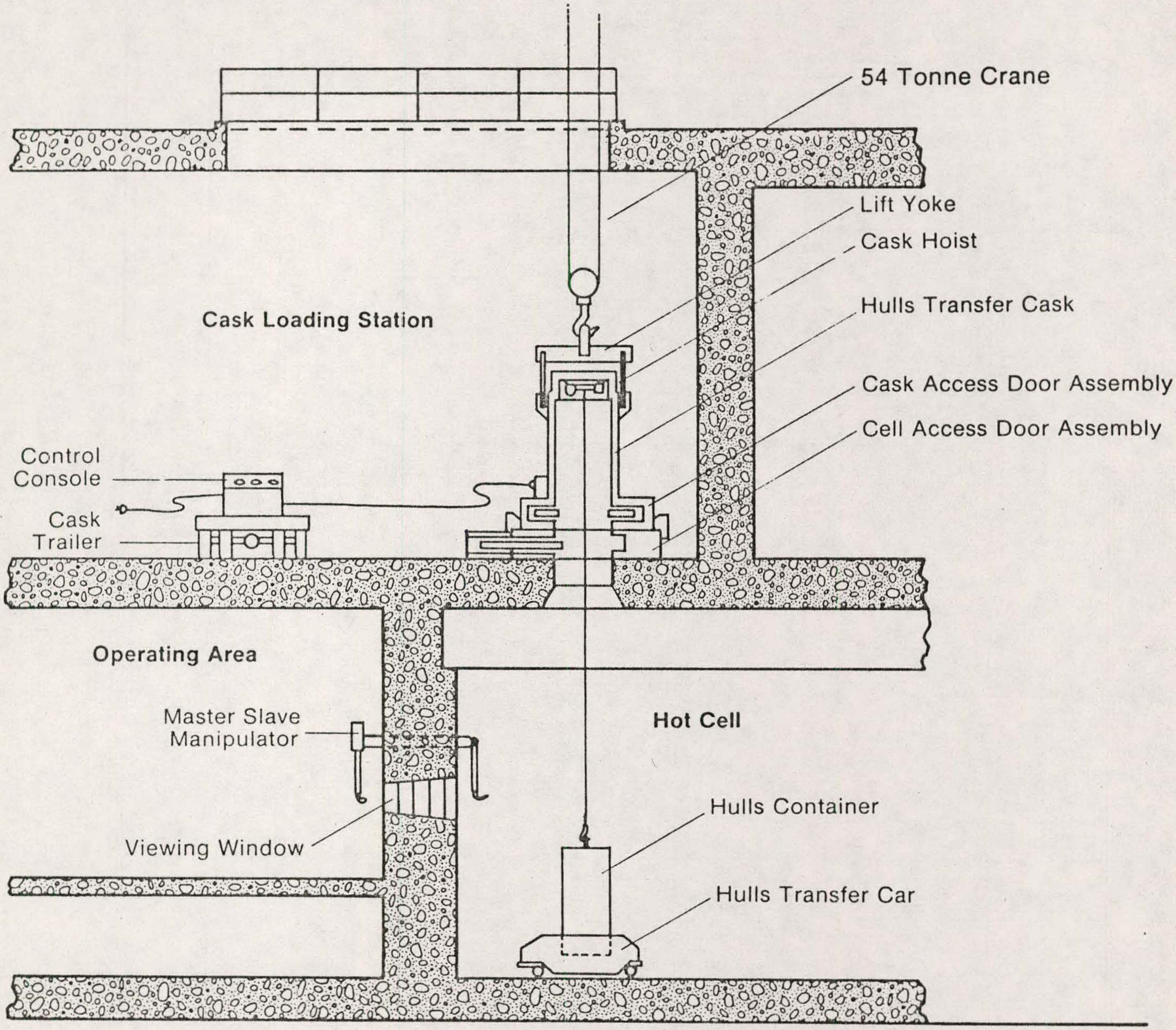


FIGURE 11

HULLS HANDLING SCHEMATIC

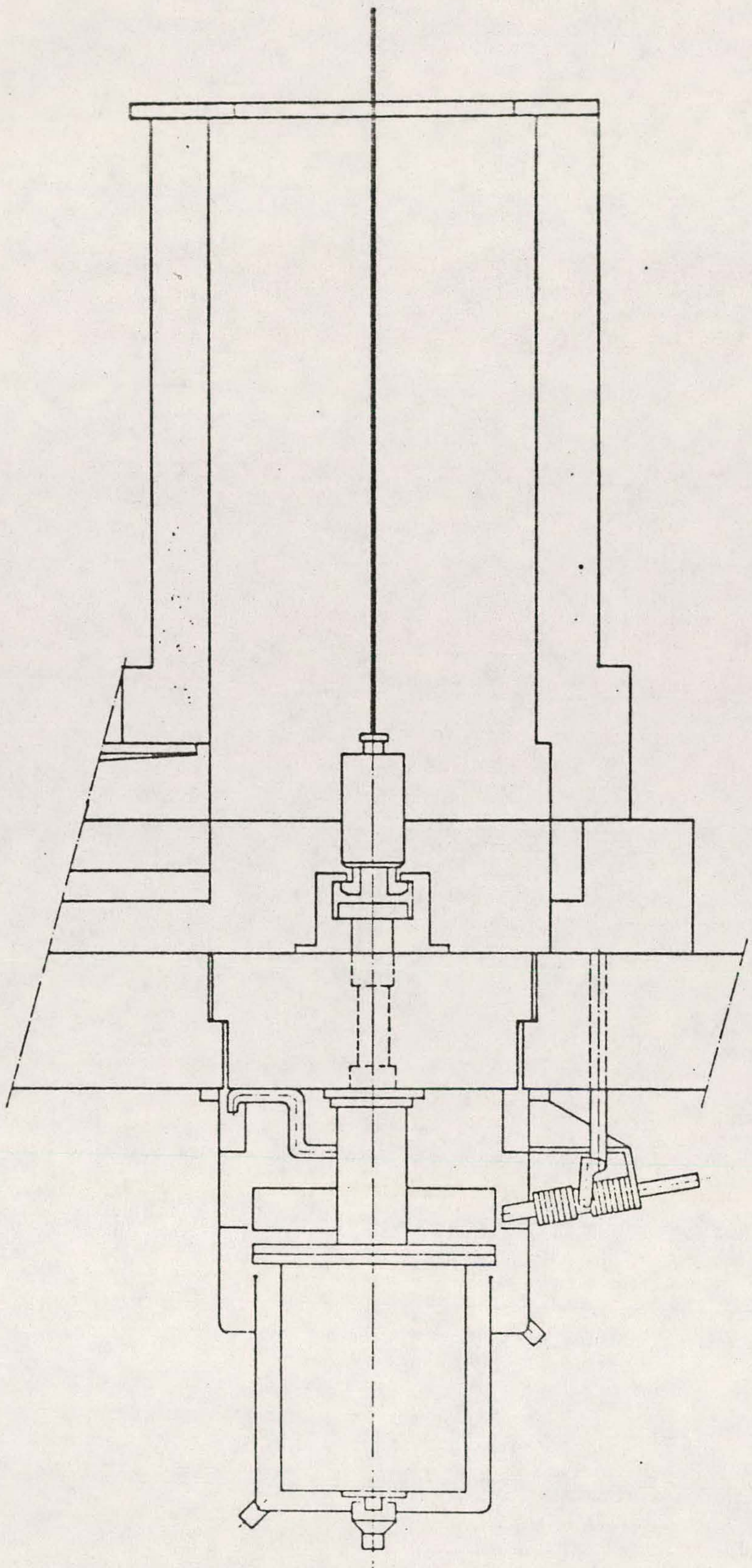


FIGURE 12

ROBATEL CASK -- READY TO RECEIVE CENTRIFUGE OR CONTACTOR INTERNALS

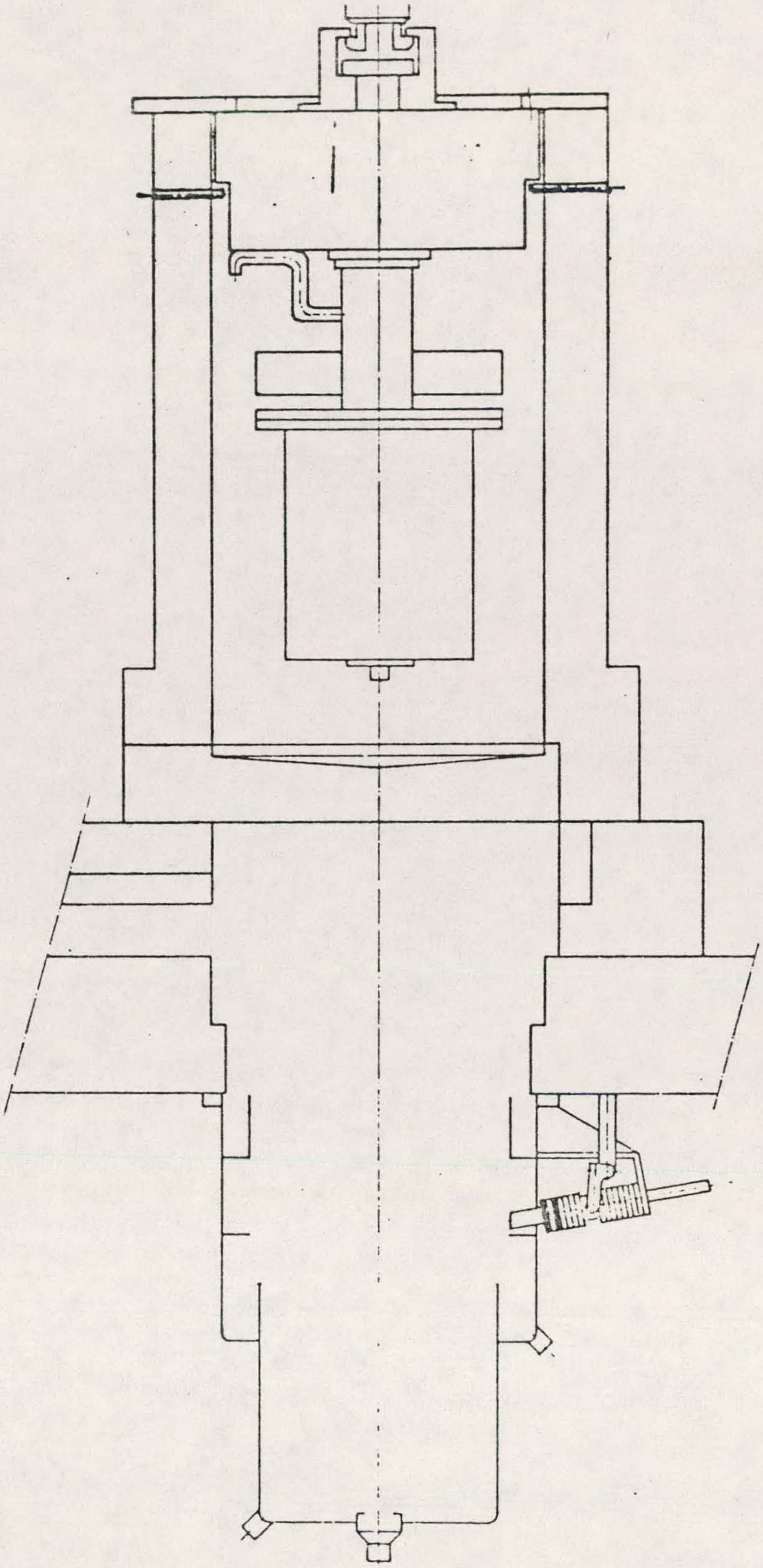


FIGURE 13

ROBATEL CASK -- CENTRIFUGE OR CONTACTOR INTERNALS LOADED, BOTTOM SHIELD DOOR CLOSED

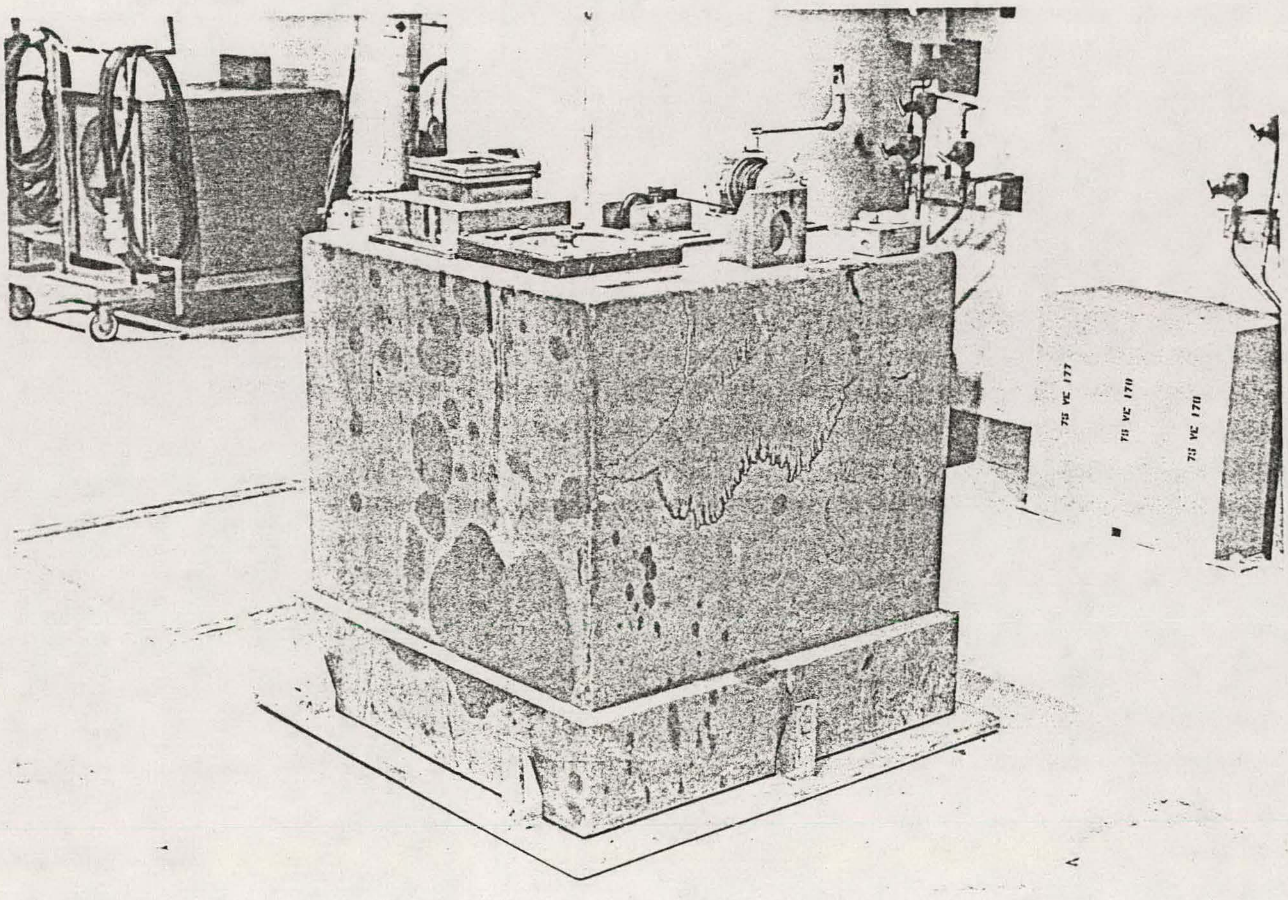


FIGURE 14

FILTER CASK

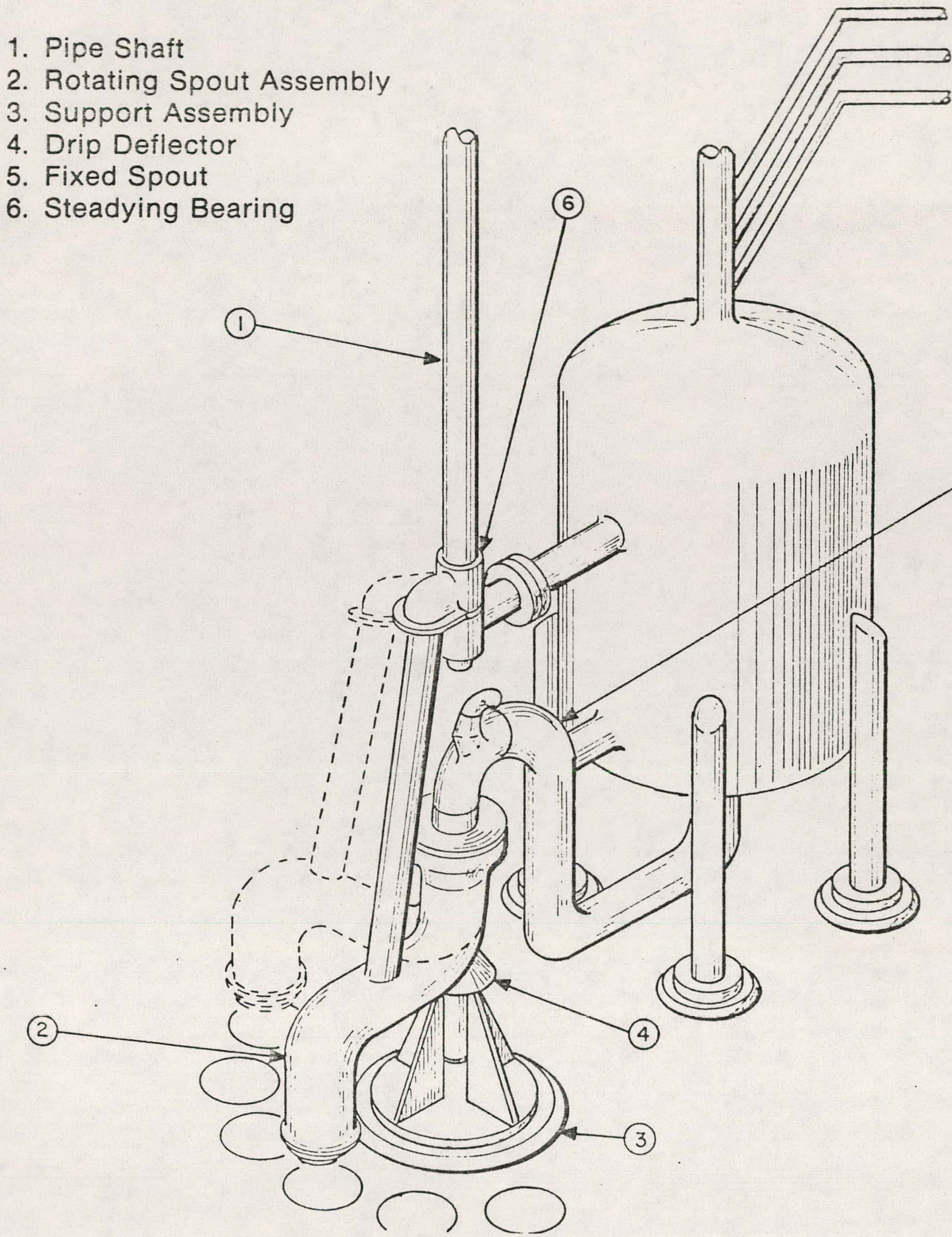


FIGURE 15

WASTE TANK DIVERTER

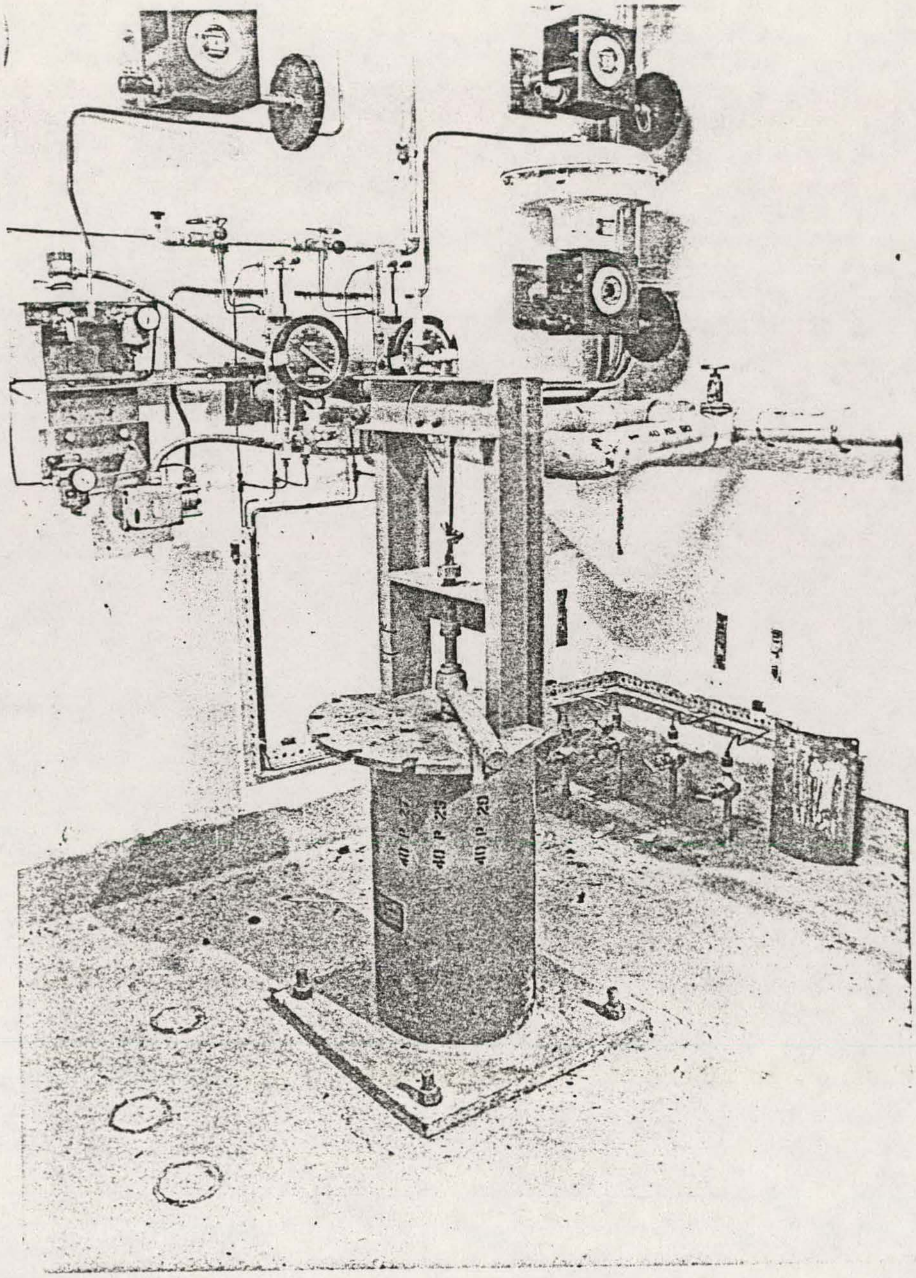


FIGURE 16

DIVERTER OPERATOR

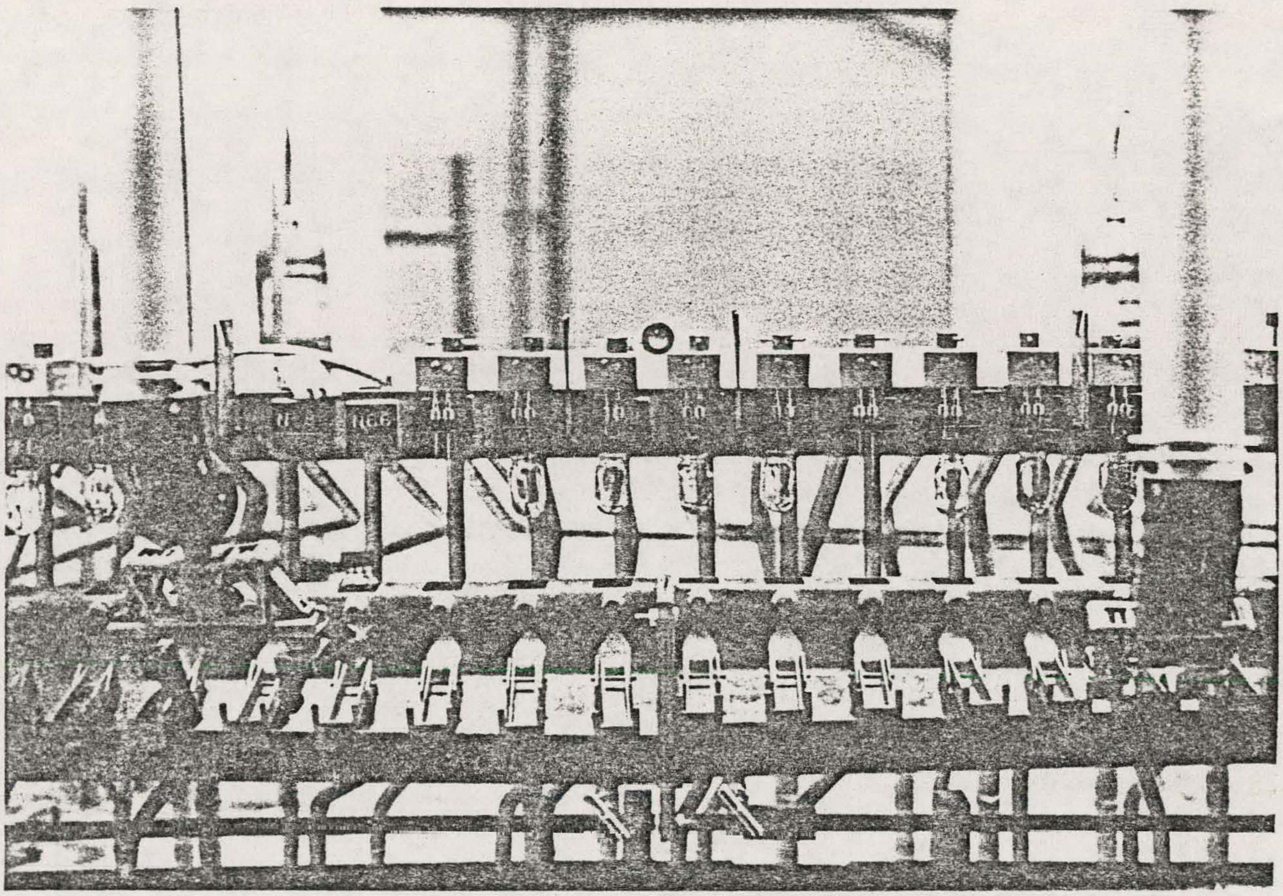


FIGURE 17

HOT CELL SAMPLE STATION

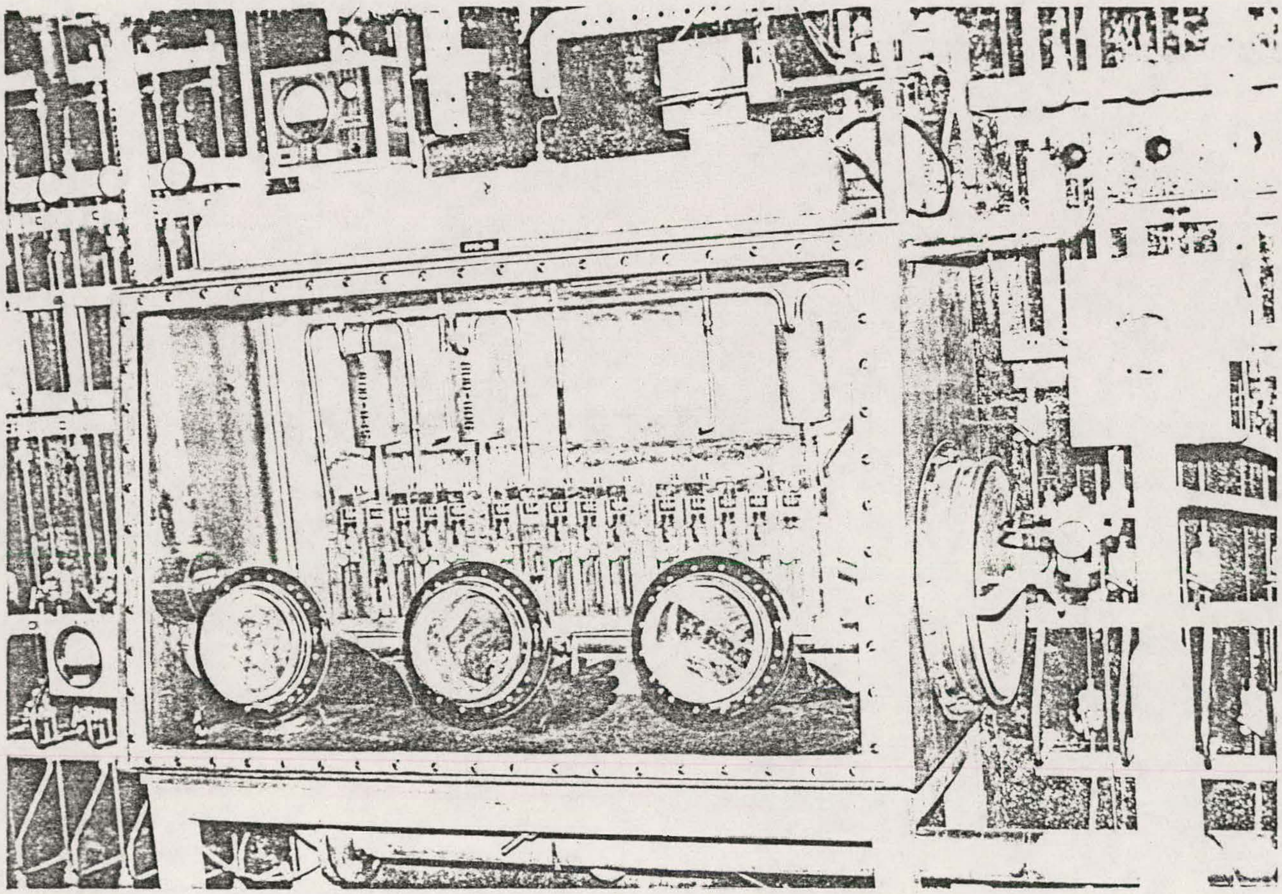


FIGURE 18

STANDARD GLOVEBOX SAMPLE STATION

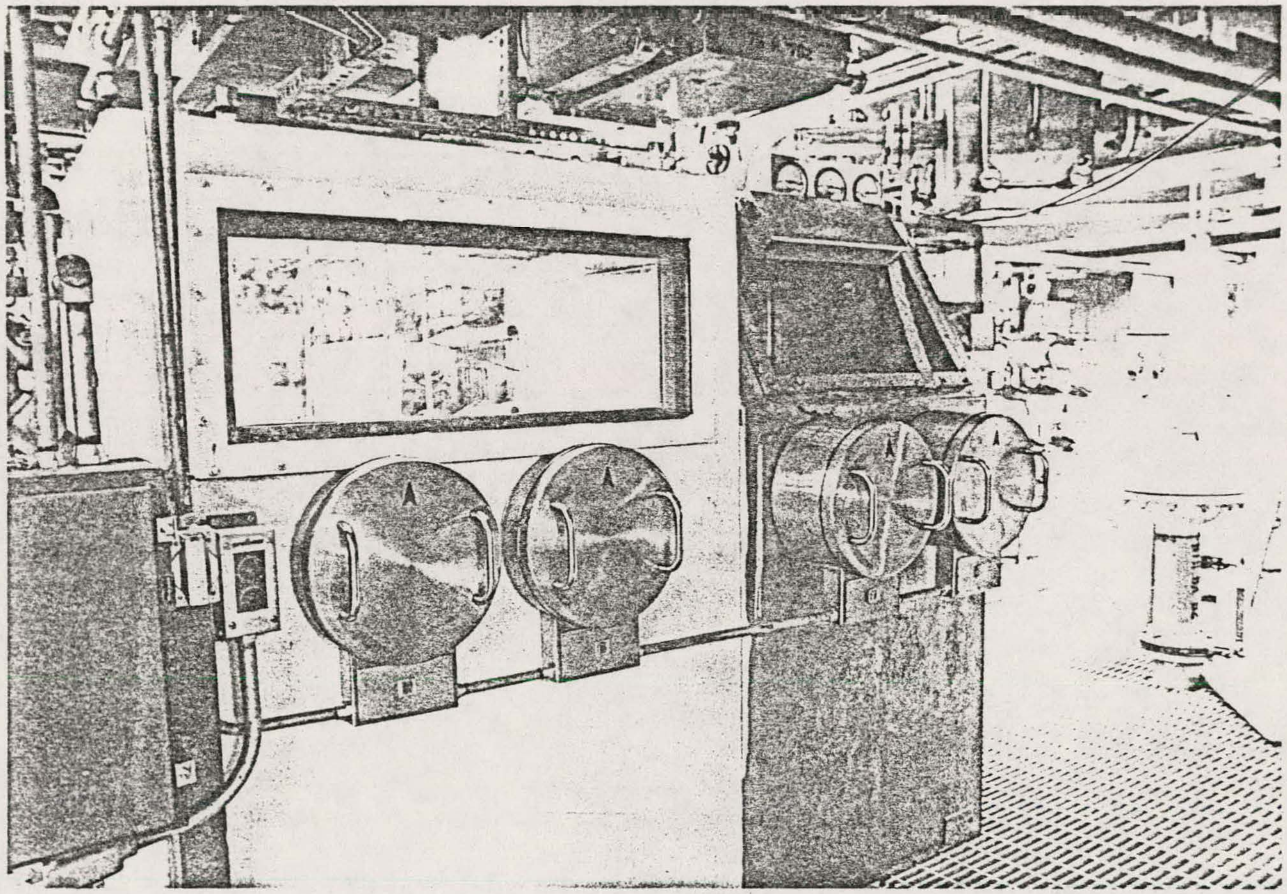


FIGURE 19

NEUTRON SHIELDED SAMPLE STATION

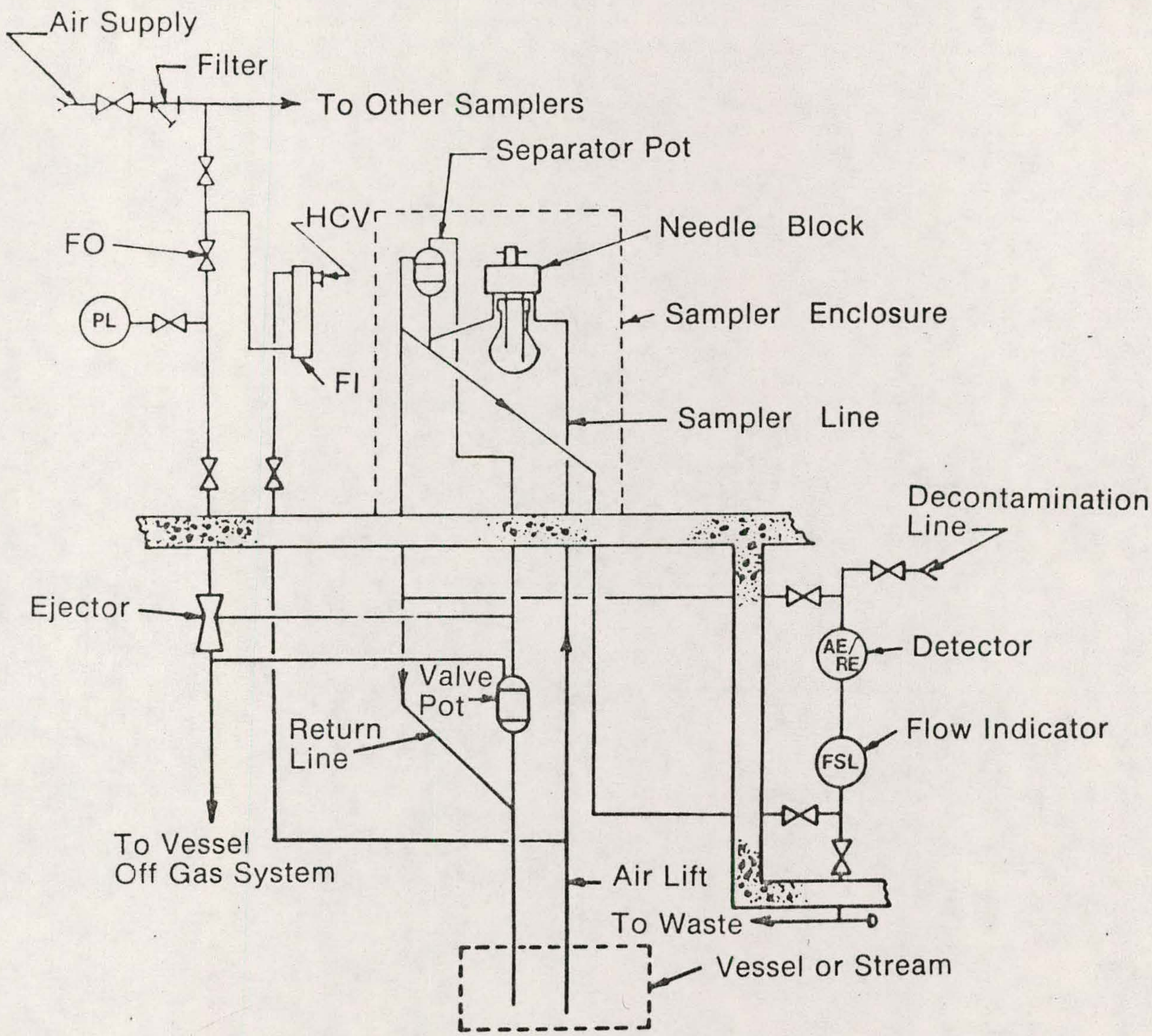


FIGURE 20

CLOSED-LOOP SAMPLER

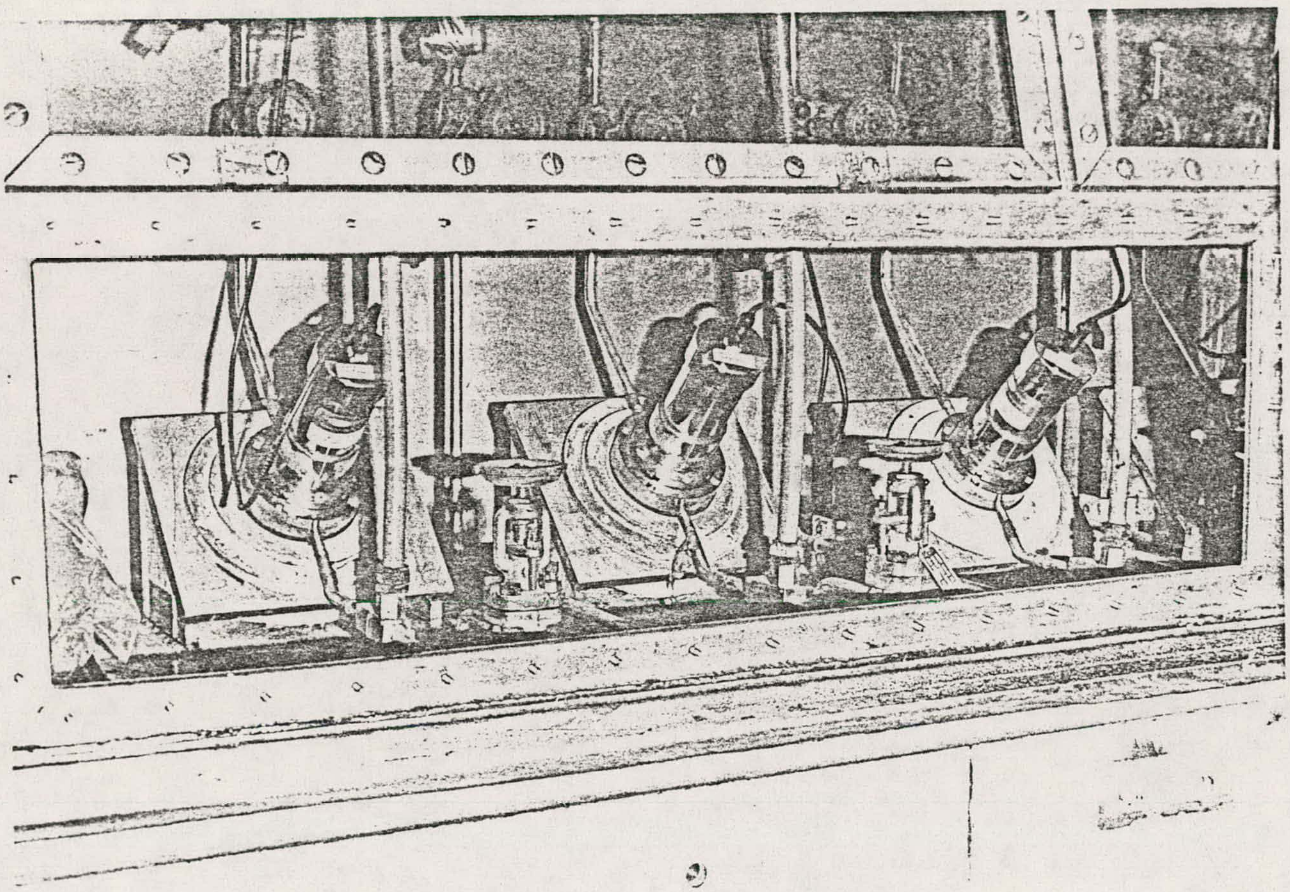


FIGURE 21

ON-LINE ALPHA MONITOR

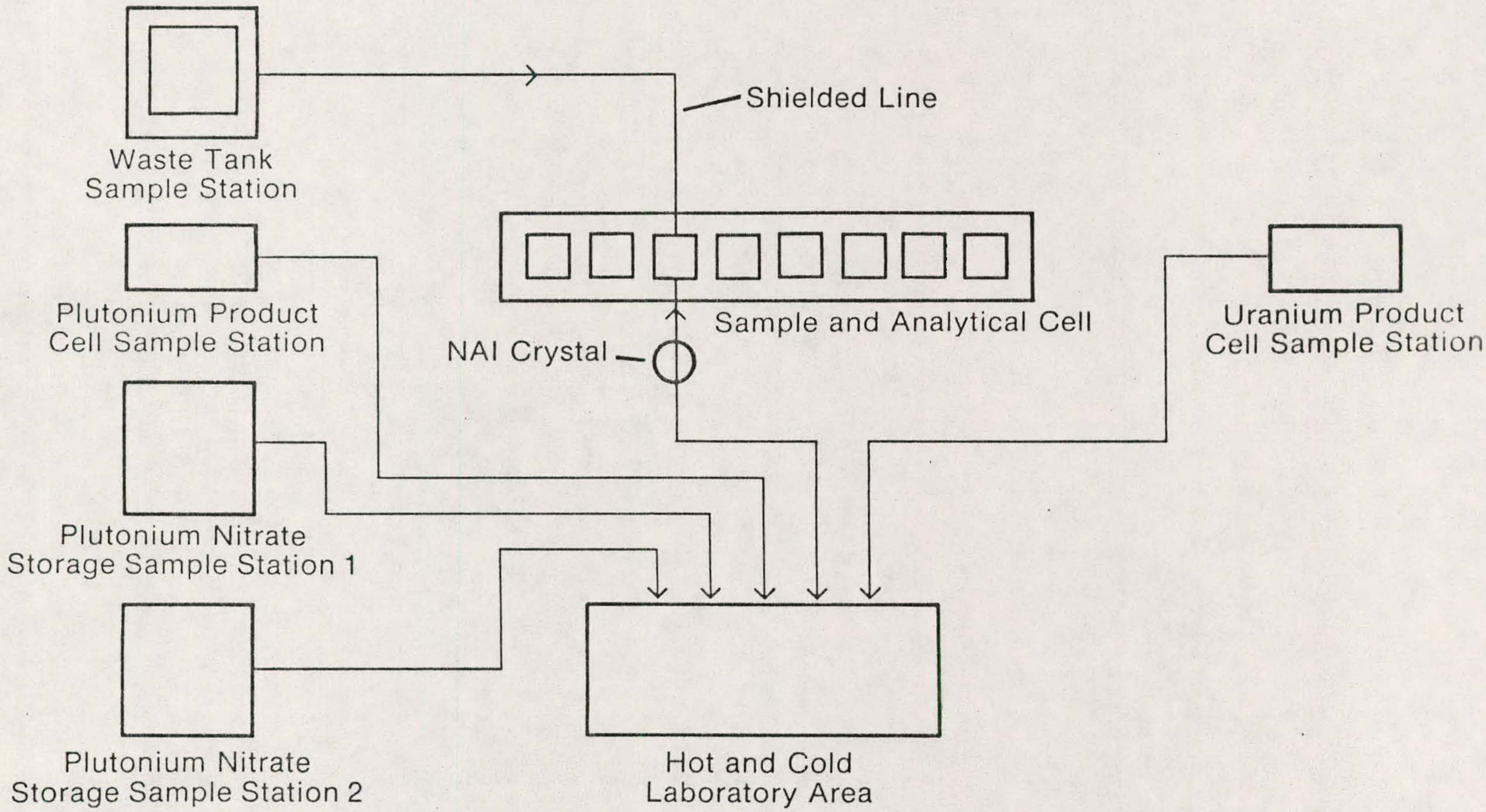


FIGURE 22

SAMPLE TRANSFER SYSTEM

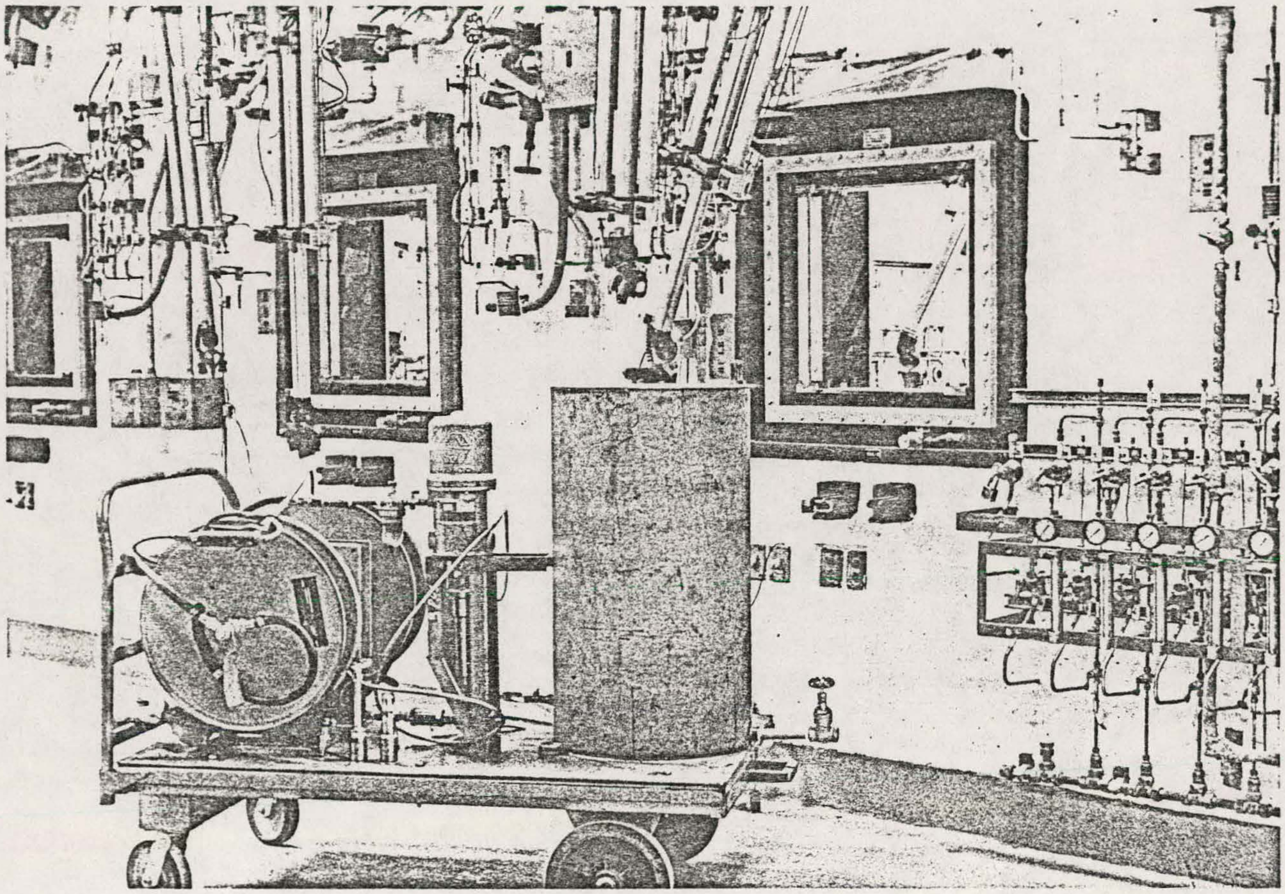


FIGURE 23

REMOTE DECONTAMINATION SYSTEM

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REMOTE HANDLING SYSTEMS AT THE BARNWELL NUCLEAR FUEL PLANT -- AN OVERVIEW

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