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MAINTENANCE OF CLINCH RIVER BREEDER REACTOR NUCLEAR ISLAND SYSTEMS

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ABSTRACT

The Clinch River Breeder Reactor Plant is being designed to be maintained so that a high plant availability goal can be achieved. The plant is being designed so that equipment disassembly, cleaning, repair, reassembly, and return to service can be conducted in an expeditious manner. The layout of the plant and of individual cells provides adequate accessibility, work clearance, laydown areas, removal paths, and handling areas. Wherever possible, the plant systems have been designed to provide capability for hands-on inspection and maintenance without undue hazard to maintenance personnel.

Major sodium system components are removed by special transfer and bag-out techniques and placed in shielded casks when required. Systems and facilities have been provided for removal of sodium and decontamination of components, supported by Radwaste Systems which provide for control and disposition of radioactive wastes generated or released during maintenance.

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I. INTRODUCTION

The 380 MWe (gross) Clinch River Breeder Reactor Plant is a three-loop sodium cooled plant which is being designed for the Department of Energy and the Project Management Corporation as a demonstration plant to show that plants of this size can breed fuel and can be operated and maintained in a manner similar to present Light Water Reactor Plants. The plant availability goal of the Clinch River Breeder Reactor Plant is expected to be higher than the 70% to 75% figure currently being achieved by Light Water Reactor Plants. Key factors in achieving this availability are reliability and maintainability. Reliability of systems and components is essential to minimizing unplanned failures and plant shutdowns. Systems and components must be highly maintainable so that when failures do occur, turnaround time is kept to a minimum. This is achieved by plant layouts which provide adequate space for access of personnel and equipment in order to perform maintenance functions quickly and efficiently. Maintenance equipment and facilities are being designed to perform all functions necessary to maintain and repair the plant process equipment and systems.

While many aspects of maintaining the Clinch River Breeder Reactor Plant (CRBRP) are similar to maintaining a Light Water Reactor (LWR) Plant, the use of sodium as a coolant in the Clinch River Breeder Reactor Plant requires special attention. The significant differences between CRBRP and LWR maintenance requirements are as follows:

1. There is more radioactive piping in CRBRP than in a 1000 MWe Light Water Reactor. Most of the CRBRP radioactive piping contains the sodium in the primary and auxiliary coolant systems. Comparable LWR systems contain water. Radioactive sodium system piping and components are located in cells which are lined with carbon steel and inerted with nitrogen during plant operation to reduce the potential hazards associated with accidental release of sodium into the cells. Prior to personnel entering these cells to perform inspection and maintenance functions, the cells must be deinerted and provided with an air atmosphere. In addition, primary and auxiliary sodium systems will have to be shutdown for up to ten days before cells can be entered to allow for Na^{24} decay. This is not a problem for LWR's. Primary sodium piping will have to be drained prior to maintenance due to the high specific activity of the primary sodium (approximately 130 microcuries per cubic centimeter at ten days after shutdown for CRBRP versus 5 microcuries per cubic centimeter for water in the LWR Plants at ten days after shutdown, assuming 1.0% failed fuel). In-cell activities must be performed as efficiently as possible to minimize plant turnaround time and keep radiation exposure to personnel as-low-as-reasonably-achievable (ALARA) consistent with the guidelines of Regulatory Guide 8.8 (See Reference 1 and 9). Contact and semi-remote maintenance schemes are utilized. By providing suitable space, shielding, and equipment, maintenance and in-service inspection should be readily performed in cells within refueling outage periods established by other activities.

2. The CRBRP has an intermediate cooling system containing non-radioactive sodium. Location in air atmospheres facilitates inspection and maintenance, with special precautions required only when penetrating the systems. There is no comparable LWR system.

3. The CRBRP has a non-radioactive sodium and NaK auxiliary cooling system with more piping than comparable LWR systems. The LWR systems contain water. Non-radioactive sodium and NaK systems are located in air atmosphere areas of the plant and can be readily inspected and maintained, with special precautions required only when penetrating the systems.

4. Removal of components from sodium systems require special inerting and bagout procedures to avoid formation of sodium oxides which make repair difficult, to avoid contact of personnel with the toxic sodium, to minimize the fire hazard, and (for radioactive systems) to prevent the spread of radioactivity.

5. Radioactive and non-radioactive sodium piping systems in CRBRP may require more inspection and in-service testing than LWR systems due to:

    a) The number of welds which may require inspection to meet ASME Code, Section XI, requirements for Safety Class 1 Piping. The total length of high temperature thin-walled piping impacts this requirement. Section XI is currently undergoing review and revision by the industry. The number of welds requiring inspection in LWR plants, and difficulty of inspection, may make this a tradeoff.

    b) The greater number of snubbers in sodium systems which must be inspected and tested.

    c) The leak detection systems which must be inspected and maintained (no comparable LWR system).

    d) The heat tracing systems which must be inspected and maintained (no comparable LWR system).

6. Equipment removed from sodium systems must be cleaned with techniques which vary from those used on Light Water Reactor Plants. Removal of sodium from major equipment to permit inspection and/or maintenance is performed by a water vapor nitrogen process wherein the sodium is reacted with moisture under controlled conditions. Decontamination is further accomplished by acid etching and rinsing. Fluids from the sodium removal and decontamination process are sent to the Radwaste System.

Each CRBRP project participant responsible for the design of a system and the preparation of a System Design Description is also responsible for defining the maintenance requirements of that system and designing special purpose maintenance tools (Westinghouse, Atomics International, General Electric, and Burns and Roe). Atomics International is also responsible for the design of general purpose maintenance equipment and facilities for the Nuclear Island. Burns and Roe has a similar responsibility for the Balance of Plant. Burns and Roe is responsible for the layout of all buildings and the routing of all pipe, duct, cable tray, and conduit (except Primary and Intermediate Heat Transport System and Steam and Feedwater Piping in the Steam Generator Building). The building layouts and system routings provide for all system maintenance and in-service inspection requirements through the proper location of pipes, ducts, cable, supports, valves, instruments, equipment, access platforms, shielding, padeyes, monorails, hatches, doors, periscopes, corridors, stairways, and elevators and providing adequate space for all functions. CRBRP is designed to limit the average exposure of plant radiation workers to 1.5 man-rem/year, which is similar to average exposure levels currently being received by plant radiation workers in light water reactors and is considerably below the allowable level of 5.0 man-rem/year as defined in 10CFR20 (Reference 1 and 9).

II. OVERALL NUCLEAR ISLAND PLANT LAYOUT CONSIDERATIONS

The need to provide adequate space for maintenance and in-service inspection has been a primary consideration in the layout of the Clinch River Breeder Reactor Plant. Conceptual plant layouts were developed by Burns and Roe on the basis of equipment locations established by preliminary hydraulic calculations, equipment size envelopes which provided some growth margin, and preliminary routing of pipe, duct, and cable for all systems so that space requirements could be determined. Removal paths for all components were identified, such as removal space within cells, space to move components horizontally within corridors, and space to move components vertically through hatches. The size and location of walls and floors were established by preliminary structural and bulk shielding calculations to minimize future changes. As the detailed routing of pipes, cable, and duct has proceeded, space for equipment access, laydown, and removal has been monitored. Access platforms, ladders, padeyes and monorails for rigging components, maintenance shielding, hangars and snubbers, auxiliary steel, large diameter pipe insulation, large valve operators, and reach rods are some of the features which must be designed so that space remains for maintenance and in-service inspection. Figure 1 shows the overall plant layout. Major features of the Nuclear Island General Purpose Maintenance System are shown in Figure 2.

The layout for CRBRP represents a considerable departure from the layout of FFTF. CRBRP has been designed to permit maintenance and in-service inspection to be performed in a utility environment. The need to perform such work as expeditiously as possible in order to minimize plant down-time and maximize plant availability has been a prime consideration in the layout of the plant from the beginning of the project. Sufficient space, shielding, and component design features have been provided throughout the plant to perform all maintenance and in-service inspection functions with low radiation exposure to personnel and plant down-time.

A scale model (½ inch to the foot) is being constructed by Burns and Roe to confirm that interferences will not occur during construction and to insure that space in the completed plant is provided for maintenance and in-service inspection. All piping, duct, cable tray, and conduit will be routed on the model as each system design progresses. Model reviews are held periodically with all project participants to confirm that the design objectives are being satisfactorily achieved.

The Reactor Containment Building (RCB) size (186 ft. diameter) (56.69m) was established by the primary heat transport equipment and piping layouts, plus auxiliary equipment and space for access and maintenance. This diameter was partially influenced by the desire to provide a Large Component Cleaning Vessel (LCCV) within this building to remove radioactive sodium from the primary system components. This feature permits the components to be decontaminated to the extent that hands-on maintenance can be performed and to permit all subsequent handling operations to be performed on a hands-on basis. Sodium removal and decontamination operations in the LCCV can be performed with the reactor operating or shutdown. The location of the LCCV was based on the need to locate other equipment and access features in other quadrants of the building. A Large Maintenance Stand is located adjacent to the LCCV to support the primary sodium pump for inspection and maintenance operations. A polar crane is provided in the RCB for construction and maintenance. The crane hook elevation was based on lifting the reactor vessel lower inlet modules for inspection or maintenance. This hook elevation permits all other maintenance operations to be performed, including handling of the large maintenance cask. The maximum lifting capacity is 300 tons (272,150kg) with a 175 ton (159,000kg) redundant capacity (used for maintenance operations including lifting of the maintenance casks). A 50 ton (45,400kg) auxiliary hook is also provided for maintenance.

The RCB layout provides access hatches into the Primary Heat Transport System (PHTS) cells for installation and removal of the PHTS piping. Other hatches and clear space below them were provided to remove equipment from all non-PHTS cell areas below the operating floor. Corridors were sized to permit horizontal movement of equipment from all non-PHTS cells to the vertical removal areas. These corridors were sized to permit pipe, duct, and cable to be routed without encroaching into the equipment removal paths. Equipment removal paths were sized to accommodate the largest component to be removed from an area of the plant including size considerations of typical transport equipment. Monorails and padeyes are provided in appropriate locations. An elevator provides the means to move equipment and personnel between the operating floor and the basement level (83 feet) (25.29m). Stairs in three of the four quadrants plus a normal personnel/equipment air lock at the operating floor and an emergency personnel air lock below the operating floor provide personnel access in accordance with OSHA requirements. In addition, corridors below the operating floor provide for more than one exit. The RCB has been sized to readily permit removal and replacement of all components (fully assembled) except the following:

1. Reactor vessel and/or lower internals (requires use of construction opening in RCB)
2. Overflow Tank and Sodium Storage Tank (requires removal of knockout section of operating floor and other areas)
3. Guard vessels (requires repair in place)
4. Polar crane (requires replacement via construction opening in RCB)

The Reactor Service Building (RSB) provides space to receive major components removed from the RCB. The large maintenance cask, PHTS pump, intermediate heat exchanger and other large components will enter the RSB on a special dolly located on the Ex-Vessel Transfer Machine (EVTM) rails (via the Equipment Removal Hatch) and will be lifted by the RSB crane for the transfer to a truck or rail car. The cold traps will be removed from the RCB in a shielded cask via the Equipment Removal Hatch and removed from the plant in a similar manner. The Equipment Removal Hatch will only be opened when the reactor is shutdown. Smaller components can enter and leave the RCB via the personnel air lock at any time. Space has been provided in the RSB for staging and laydown of components leaving and entering the plant. Some lifting fixtures, slings, plastic bag making equipment, and housekeeping equipment are stored in the staging and laydown areas. The RSB size was also influenced by the need for vertical and horizontal equipment removal paths to permit removal of all fully assembled components except:

1. The Ex-Vessel Storage Tank (EVST) guard vessel (requires in-place repair)
2. The EVTM (requires disassembly)
3. The Large Component Transporter

All RCB and RSB components (except those noted otherwise above) are removed and replaced via the rail car door in the RSB.

The Radwaste Area of the RSB contains the liquid and solid radwaste systems. These systems primarily support maintenance functions in the Clinch River Breeder Reactor Plant. It is noted that in Light Water Reactor Plants, the liquid radwaste is needed to support the continuous coolant purification system functions (a job handled by cold traps in an LMFBR Plant). One of the main functions of the Clinch River Breeder Reactor Plant liquid radwaste system is to process water received from the LCCV during removal of sodium from components and subsequent decontamination. Water may be received from floor drains based on the radioactivity levels of these wastes which occur mainly from maintenance and decontamination operations. Waste water is also received from equipment drains, shower drains and laboratory drains. Radioactive water is concentrated in the evaporators and mixed with concrete in drums for shipment off site. The solid wastes generated during maintenance operations (blotter paper, tools, etc.) are also packaged in the Radwaste area for shipment to an off-site burial area.

The Radwaste Area also contains a Decontamination Facility, which is arranged as shown in Figure 3 and consists of two working rooms served by one equipment entrance chamber. This is a contamination control facility provided for the purpose of performing detail decontamination of maintenance tools as well as pieces of plant equipment. All equipment and provisions are identified for contact operations to be performed on low level radioactive contaminated items.

The entrance chamber of the facility is isolated from the outside and the other two rooms by sliding and folding doors which seal the openings when closed. This chamber provides isolation of the decon vault or decon bay from the surrounding building environment during transfer operations. Both the vault and the bay are served by a rail dolly which enters through the entrance chamber. A roof hatch is provided so that the Radwaste Building 20 ton (18,144kg) crane can be used for lifts within the chamber. The decon vault is for the purpose of heavy duty decontamination procedures. Processes such as high pressure vapor blasting, steam cleaning, and water deluge can be accommodated in this room without interfering with the other decontamination operations. This vault is served by a manual 10 ton (9,072kg) crane, as well as the 20 ton (18,144kg) Radwaste Building crane which can operate through a roof hatch.

The decon bay is the work shop area of the facility which is used for diverse cleaning operations, and also provides a controlled area for detail disassembly, cleaning, and reassembly of components and tools. This bay, like the decon vault, is served by a 10 ton (9,072kg) manual crane and the 20 ton (18,144kg) Radwaste Building crane. The Radwaste Building crane coverage is limited to the 10 ft x 10 ft (3.05m x 3.05m) square removable roof hatch.

A wash and dip tank is provided in the decon bay which can be used for immersion and scrubbing with detergent, solvent, or dilute acid solution. A fume exhaust system is incorporated around the periphery of the tank to control contamination and fumes which would permeate the rest of the bay. Other items of equipment in the decon bay include glove boxes, fume hooded areas, cleaning tanks, and a dishwasher. Personnel access to the decon bay is provided directly from the Radwaste Building through a doorway and a control step off area. Separate heating and ventilation is provided to the decon facility with exhaust filtering capability for contamination control. Air flow patterns are directed away from the room access openings.

An autoclave is to be provided for cleaning sodium from small components rather than tie-up the large Primary Sodium Removal and Decontamination (PSR&D) system for such work. This reduces the process requirements on the Radwaste System. The autoclave is a 4 ft. (1.2m) diameter by 5 ft. (1.5m) vessel combined with its own process system to remove sodium by the WVN process. No decontamination capability is provided by the autoclave. This system will be supplied as a package and installed in the Radioactive Waste Building adjacent to the Decontamination Facility.

The Steam Generator Building (SGB) layout was influenced by maintenance considerations to the extent that the use of a common gantry crane to remove steam generator modules and transport them readily to a Maintenance Bay was considered essential for the Clinch River Breeder Reactor Plant. This would minimize plant down time associated with steam generator replacement, in recognition of the concerns for this component in LMFBR plants. The in-line location of the three Steam Generator Bays and the adjoining Maintenance Bay resulted. Space within the Steam Generator Building was provided to permit in-place maintenance (tube-plugging) of the steam generators. The method for sodium removal from the non-radioactive intermediate sodium system components has not been fully established at this time. Space has been provided in the Maintenance Bay for several suitable component flushing and cleaning processes.

The layout of the SGB was influenced by the need for access to perform in-place maintenance (such as tube examination and plugging in the steam generators) as well as the need to provide suitable horizontal and equipment removal paths and laydown space.

The Maintenance Bay has staging and laydown areas and is served by rail or truck. Space has been provided for the later addition of an intermediate sodium removal system including a cleaning vessel for cleaning the IHTS pump internals. Steam generator modules would be cleaned in their own shells.

The Regulated Shop Complex is a controlled area located in the Balance of Plant Machine Shop. This area is essentially a small machine shop and work area which is to be used for work on contaminated tools and equipment. A sand blast booth is included, and a separate regulated tool room is provided to inventory tooling and store tool boxes to be used by maintenance personnel in contaminated areas. Conventional machine tools and shop facilities are provided for fabrication, instrumentation, and hydraulic repair work. Fume hoods and glove boxes are also provided for detail work on contaminated items.

The Regulated Shop shares coverage with the Balance of Plant Machine Shop 15 ton (13,608kg) bridge crane.

Maintenance casks, large lifting rigs, the RCB-RSB equipment transport dolly, and other maintenance tools, jigs, and fixtures are stored in the Warehouse.

The Plant Service Building is located to facilitate flow of personnel into all Nuclear Island Buildings and to provide appropriate industrial security facilities. Change rooms provide space for processing maintenance personnel during shift changes, including space for clean and dirty coveralls, shoe covers, etc. Space is provided at the staging areas for entry into radioactive cells for locating portable change rooms.

III. RADIOACTIVE CELL LAYOUT CONSIDERATIONS

The CRBRP has been designed to limit the total radiation exposure of the 130 plant staff radiation workers (those who receive an annual dose in excess of 100 mrem) from all operation, surveillance, fuel handling and maintenance activities to 195 man-rem/year to assure their ability to perform these functions. This is based on a 1.5 man-rem/year average exposure to each radiation worker. A survey of light water reactor plants shows that radiation workers are currently receiving an average of about 1.4 man-rem/year, (±0.5 man-rem/year) with slight increases each year. This compares favorably with the 5.0 man-rem/year allowable exposure as defined in 10CFR20. Light water reactor plants also use contract labor to perform special maintenance and in-service inspection work in radiation areas. It is planned that CRBRP will be operated on a similar basis. Radiation exposure limits to the plant staff of radiation workers for specific types of functions and expressed in terms of design objectives are:

a. Plant shielding, cell arrangement, and procedures limit radiation exposure due to normal operations and routine maintenance in normally accessible restricted and radiation areas (See Figure 4 for definition) to 30 man-rem/year. This man-rem exposure includes radiation exposures due to the radiation penetrating bulk and penetration shielding.

b. Shielding and procedures are provided to limit the total radiation exposure due to all fuel handling operations to 20 man-rem/year.

c. Maintenance activities in cells containing significant internal sources use procedures, shielding, special tools, and services to limit radiation exposure to a total of 112 man-rem/year. Systems involved are Primary Heat Transport System (51A), Auxiliary Sodium System (81), Inert Gas Receiving and Processing System (82), Impurity Monitoring System (85), and Fuel Failure Monitoring System (94). A significant internal source is defined as a radiation source of sufficient magnitude to make the cell a high radiation area. (See Figure 4 for definition). This exposure is due to planned maintenance activities and includes those exposures associated with the transfer of equipment to the large component cleaning cell or designated handling/storage areas and the maintenance of ancillary systems. This exposure limit is allocated as follows:

   o System 51A and adjoining IHTS cells: 20 man-rem/year
   o Systems 81, 85, and 94 cells: 70 man-rem/year
   o System 82 cells: 22 man-rem/year

d. In-service inspection activities use procedures, shielding, and/or special tools to limit radiation exposure to 10 man-rem/year.

e. Radwaste (System 24) uses shielding, cell/equipment arrangements and procedures to limit total exposure to 3 man-rem/year for both operations and maintenance.

f. Special maintenance and abnormal operations are considered as a contingency of 20 man-rem/year.

The above allocations of exposure levels (man-rem/year) are used as the basis for the plant design. These allocations were based on initial assessments of expected radiation levels over the life of the plant and maintenance frequencies. On-going ALARA studies (in accordance with Reference 9) are being performed to confirm that the above values for cells containing radioactive systems remain valid as detailed pipe routing proceeds and the location of personnel within the cells to perform maintenance and in-service inspection is established. Radiation levels at locations outside of the cells containing radioactive systems shall also be evaluated as the design proceeds. Reallocation of radiation exposure levels within the 195 man-rem/year total may result from the on-going ALARA studies.

Plant shielding, procedures, and cell/equipment arrangements have been designed to assure that design dose rates are not exceeded. Shielding design includes identification and consideration of uncertainties for radiation source terms, shield wall thickness, design methods (including wall and equipment arrangements), and variations of radiation levels in the cell.

Additional requirements relative to specific functions or systems are as follows:

a. Dose rate on accessible contact surfaces of refueling and fuel handling equipment shall not exceed 200 mrem/hour during operations involving movement or transport of fuel.

b. Control room shielding is designed to protect personnel during accident conditions.

c. In Zone IV and V, (Figure 4), cells and/or areas (work locations) in which maintenance must be performed, either during normal or shutdown conditions, adequate space for maintenance shielding are provided in addition to maintenance space requirements. This maintenance shielding space is based upon reducing the radiation dose rate to 200 mrem/hour at specific work locations in cells where maintenance functions are most likely to be carried out (such as valves, removable sections of piping for in-service inspection, etc.). This is achieved by the use of maintenance shielding designed by Burns and Roe to block out radiation from sources in the cell other than the component being worked on. Maintenance shielding evaluations are made to determine if it should be permanently installed during plant construction, or basic supports provided for future installation of such shielding if needed. The time required to install maintenance shielding in a radioactive area and the subsequent radiation exposure of personnel are factors in the evaluations.

The CRBRP Nuclear Island cells/areas are zoned in accordance with the definitions of Figure 4. Radiation zone maps have been prepared by Burns and Roe for each cell similar to the one shown in Figure 5, based on source terms provided by Atomics International or Westinghouse and bulk shielding designed by Burns and Roe. These radiation zone maps specify the Nuclear Island radiation zones and the allowable design dose rates for each cell and area.

A detailed routing and system layout criteria document for the design of radioactive cells has been prepared by Burns and Roe for use by Clinch River Breeder Reactor Plant engineers and designers. This criteria, some of which are found in Reference 1, includes the following:

1. Pipe, cable, and duct routed to provide maximum possible accessibility to components which require maintenance and in-service inspection.

2. Valves grouped in radioactive cells as much as possible to reduce the extent of maintenance shielding within the cells and the extent of platforms. Valves grouped outside radioactive cells to facilitate operation.

3. Valve reach rods designed to be as short as possible and not in way of access paths.

4. Platforms and ladders provided to facilitate access to work locations for in-service inspection and maintenance.

5. Piping routed to provide access to insulation, heat tracing, welds requiring in-service inspection, and snubbers.

6. Piping routed with sufficient slope to provide draining for maintenance.

7. Piping, duct, and cable routed to share as much auxiliary steel as possible to reduce its quantity and provide more space for access.

8. Piping, duct, and cable routed to provide clear access and laydown space on two sides of complex piping areas to the extent possible.

9. Equipment removal and laydown space is provided.

10. Penetrations through walls located to reduce the extent of penetration shielding required.

11. Space provided for maintenance shielding (permanent and portable).

12. Pipes routed with sufficient length of straight runs to provide freeze seals.

13. Access provided to snubbers for periodic inspection and testing.

14. Padeyes and monorails located to facilitate component handling.

15. Quick-removal pipe insulation provided at weld locations requiring in-service inspection.

16. Trace heating cable penetrations located to reduce in-cell and ex-cell cable lengths.

17. Quantity of valves and other active components in radioactive cells are kept to a minimum.

18. Suitable clearance around all pipes and components provided for access and maintenance.

19. Removal of equipment or piping to gain access for maintenance or in-service inspection of adjacent equipment or piping is avoided.

Special consideration has been given to the selection, and location of snubbers used to restrain the sodium piping during a seismic event. Mechanical snubbers are used since reliability is higher and maintenance less frequent than hydraulics snubbers. Snubbers are located to facilitate in-service inspection and maintenance.

In-service inspection of welds in piping systems and components are a consideration in the location of platforms and ladders and radiation shielding. The location of welds in some piping systems has been revised with subsequent revision to the stress calculations to improve accessibility. The layout of CRBRP provides features which anticipate that the in-service inspection requirements of ASME Section XI may become more stringent in the future, in order to minimize the impact on plant down-time associated with those requirements.

The design of doors and hatches to radioactive cells has been influenced by maintenance frequency forecasts. Trade-off studies are being performed by Burns and Roe to determine the most economical scheme for each cell in Clinch River Breeder Reactor Plant. Labyrinths, rolling plug-type doors, and stacked shielding bricks are being considered.

Carbon steel cell liners provide the means to control the quality of the inert nitrogen atmosphere in the radioactive cells and prevent sodium/concrete reactions which could cause pressure buildup and release of radioactivity which could result from a sodium spill. In addition, they also provide the means to minimize the plant turnaround time in the event of a large or small spillage of radioactive sodium by facilitating decontamination of the walls, floor, and ceiling. Decontamination of the concrete, if the liners were not provided, could be a significant problem. Catch pans prevent a sodium concrete reaction and facilitate cleanup in air atmosphere cells containing sodium systems. Cell liners and catch pans are being designed by Burns and Roe.

IV. PRIMARY SODIUM REMOVAL AND DECONTAMINATION SYSTEM

A. General

A Primary Sodium Removal and Decontamination System (PSR&DS) is being designed by Atomics International for installation in the Reactor Containment Building to service sodium and NaK components from the primary heat transport system, the auxiliary sodium system, and the fuel handling system. The system provides the capability for cleaning sodium, NaK, and sodium frost from components removed from service. It also provides the capability to remove the radioactive deposition of corrosion and fission products from the components by means of metal removal. This process is to be used either in preparation for maintenance and requalification of components or for the purpose of cleaning residual sodium from spent components prior to disposal.

The PSR&D system is located in the Reactor Containment Building in order to minimize the handling problems associated with contaminated components from the Primary Sodium System. In most cases, a component may be transferred directly from the point of removal to the PSR&D system with no intermediate handling operation. With the exception of components having induced radioactivity, the processed components, when removed from the cleaning system, are suitable for hands-on contact maintenance operation.

B. Sodium Removal Process

Sodium is removed by the water-vapor-nitrogen (WVN) at 160°F to 190°F (71°C to 88°C). Water vapor mixed with nitrogen reacts with the component residual Na in the cleaning vessel. The reaction rate $Na + H_2O \rightarrow NaOH + \frac{1}{2}H_2$) and hence, the H_2 evolution is controlled by limiting the amount of water available for reaction. The reaction rate is measured by hydrogen concentration at the cleaning vessel gas outlet. The cleaning vessel inlet temperature is adjusted to maintain a stable reaction and to avoid thermal excursions. The evolved hydrogen concentration is limited to 1% or less through control of the water vapor concentration and nitrogen flow. Hydrogen is vented to atmosphere by the Reactor Containment Building ventilation system. Reaction completion is indicated when the H_2 concentration in the gaseous effluent decreases to below 100 ppm.

Inerting and preheating are accomplished prior to the sodium-steam reaction which is followed by rinsing and drying. Nitrogen is used to displace oxygen in the system prior to placing the component in the cleaning vessel and the N_2 atmosphere is maintained throughout the cleaning operation. After inerting, the component and system are preheated to 160°F (71°C) by hot circulating nitrogen. Preheating prevents steam condensation which would cause a violent sodium-water reaction. Sodium hydroxide which forms during the Na and H_2O reaction is removed by rinsing with water. The rinse water also reacts with and removes crevice sodium. Drying, following the rinsing, is accomplished by a vacuum and/or purging with hot nitrogen.

The WVN Process has been developed by Hanford Engineering Development Laboratory (HEDL) and qualified for the FFTF program (Reference 5). A parallel development effort was conducted by Atomics International (AI) to qualify an alcohol sodium removal process (Reference 6). Both processes were evaluated for use on Clinch River and both were judged to be acceptable in terms of function and licenseability. The WVN process was chosen primarily on the basis of cost and compatibility with future commercial plants.

C. Decontamination Process

The decontamination process consists of surface metal removal (Chemical Milling) by immersion in a dilute acid solution. Development of the decontamination process is in the preliminary stages at Atomics International and Hanford Engineering Development Laboratory (References 4 and 5). The preliminary selection of decontamination fluid is an aqueous solution containing 2.5% each of glycolic and citric acid monohydrates. The process requires an oxygen-free environment which avoids passivation of metal surfaces and retardation of metal removal. The recommended process temperature is 158°F (70°C). The process also requires inert gas sparging agitation to enhance uniform milling. The sparge rate required is approximately 3 to 5 cfm per 1000 gal (.4 to .6 cc/sec per liter) of solution. Decontamination time is determined by rate of metal removal. After the decontamination is completed, the acid solution is discharged to the liquid radioactive waste system and the component is rinsed as in the case of the WVN process. For components in which crevices are present, a 0.1% w/o of H_2O_2 is added to the final rinse cycle to stop acid reaction and to passivate the component.

D. Large Component Cleaning Vessel

The Large Component Cleaning Vessel (LCCV) is located in the northwest quadrant of the Reactor Containment Building (RCB) beneath the floor in the Large Component Cleaning Cell (LCCC) as shown in Figure 6. The LCCV provides the containment for components from which sodium and corrosion and fission products are to be removed. There are more than 30 components of different shapes and sizes requiring cleaning at various times during the Clinch River Breeder Reactor Plant lifetime. Some of the largest components are the Reactor Upper Internals Structure (UIS), PHTS Pump Internals, Intermediate Rotating Plug (IRP), and the Auxiliary Handling Machine (AHM) cask containment barrel. The LCCV is approximately 54 ft. (16.46m) high, with a maximum diameter of 15 ft. (4.57m) ID) and has a total internal cleaning fluid volume of about 40,000 gallons (151,430 liters).

Components are transported to the LCCV within the AHM, maintenance casks, or plastic bags which in turn are carried via the 175 ton (159,000kg) hook of the polar crane. After the LCCV shield plugs have been removed, the transport containers interface with, and seal to, floor adapters installed on the RCB floor above the vessel. The transport and loading procedure is used to minimize the spread of radioactive sodium or other species to the RCB. Between the RCB floor and the LCCV, there is a contamination barrier which provides an inert atmosphere during transfer of sodium wetted components into the LCCV. The containment barrier eliminates purging the entire Large Component Cleaning Cell. Within the barrier and above the vessel is the cover closure mechanism. The vessel cover is remotely unlocked, lifted, and then transported to the stored position by the closure mechanism to facilitate component installation while minimizing personnel radiation exposure. Components are supported within the LCCV by a system of platforms and adapters.

The PSR&D process equipment is designed as two modules each mounted on a steel skid as shown in Figure 6. A simplified flow diagram is shown in Figure 7 which also identifies the major components of the process system. Maintenance of the PSR&D equipment is by direct access. When the system is not in use, the radiation exposure from surrounding cells is low (design dose rate of 10 mr/hr). If unscheduled maintenance is required during cleaning of a radioactive component, removal of the component, temporary shielding, and flooding the vessel with water for shielding are all options to reduce the personnel exposure.

V. MAJOR COMPONENT HANDLING SYSTEMS

A. Typical Primary Sodium Pump Removal Procedures

Handling equipment provided by the NSSS general purpose maintenance equipment system are multipurpose to the extent possible for performing equipment removal and installation operations. Atomics International is designing the handling equipment described in this section (Reference 4).

A typical handling procedure which involves a large portion of the equipment, is the removal and installation of the primary heat transport system sodium pump. Figure 8 shows the arrangement and identifies the major items of equipment used for this procedure.

Preparation for removal consists of draining the sodium from the loop, removing the pump motors, cutting the gas seal at the pump mounting flange, and removing the mounting flange fixtures. Handling equipment is then installed as shown, consisting of the floor valve adapter, floor valve, shroud liner, plastic handling bag, and lifting fixtures. The handling bag is then purged of oxygen and a controlled low-moisture nitrogen atmosphere is maintained by use of the bag atmosphere maintenance (BAM) cart. The pump internals are first loosened from its mounting by jacking screws and then lifted up through the floor valve opening into the handling bag. Once the pump internals clears the floor valve elevation, the floor valve gate is closed to maintain the inert atmosphere over the pump tank.

The handling bag is then sealed and separated from the floor valve so that the pump can be transported directly to the large component cleaning vessel by the building crane. Replacement pump internals can then be brought from the large maintenance stand and installed in the pump tank by essentially reversing the bagging procedure used for removal.

After several years of plant operation, the pump internals may be radioactively contaminated from corrosion product plate-out to a level which would preclude handling the internals in a plastic bag. A handling cask is to be designed, but not supplied initially, to fulfill this need when judged necessary.

B. Typical Cold Trap Removal Procedures

The removal procedure for a Primary Heat Transport System cold trap involves using the same large maintenance floor valve with a different adapter configured for the cold trap access port in the floor of the RCB. The activity level of a spent cold trap would be too high to allow contact maintenance operation or transporting in a plastic bag.

A maintenance platform is to be used in conjunction with the floor valve which provides remote tool capability for removal preparation. A cask is to be designed, but not supplied, for transporting the cold trap from the area. The cask is currently conceived as being an adaptation of the pump handling cask utilizing a different cask body segment and internal lifting module.

C. Large Component Floor Valve and Adapters

The large component floor valve and adapters are used to support replacement operations for the primary heat transport system sodium pump, the primary heat transport system cold trap, and the fuel ex-vessel storage tank (EVST) cold trap located in the Reactor Service Building. The floor valve mates with the floor access hatches at these locations by the use of adapter structures. Two such adapters are required; one is used at the primary pump (three locations), and the other is used interchangeably at the primary cold trap (two locations) and the EVST cold trap. Fixed embedments are provided in the floor surrounding the access hatches which allow structural attachment of the adapters and provide a sealing surface for the adapter seal.

The floor valve is a sliding gate enclosed by a rectangular steel structure. The overall dimensions of the floor valve are 33 ft. (10.06m) long, 17½ ft. (5.33m) wide, and 26 1/8 in. (.66m) high. Total weight of the floor valve without adapters is 137,000 lb. (62,142kg). Gas atmosphere seals consist of a retractable, inflatable seal for the valve gate and static O-ring type seals at all mating surfaces between the valve body, adapters, and floor embedments.

D. Large Component Transporter

A two-piece large component transporter is planned to move system components into or out of the Reactor Containment Building through the refueling hatch. The transporter is designed to roll on the fuel handling ex-vessel transfer machine gantry rails. It will be positioned on the gantry rails only during the time required to load, unload, and move a large component. The transporter dollies will normally be stored in the balance of plant storage area. The transporter incorporates seismic restraints and is capable of withstanding an "operational basis earthquake" when fully loaded. Motive power for the transporter is supplied by a commercially available tow vehicle.

At the present time, the laden cold trap handling cask requires two dollies for transport into the RCB. All other loads can be carried on one dolly. For this reason, only one transporter dolly will be delivered initially; a second dolly will be supplied later when the need is determined. A single four-wheeled dolly weighing approximately 60,000 lb. (27,215kg) is 17 ft. (5.18m) long, 31 ft. 8 in. (9.65m) wide, and stands 4 ft. 8 in. (1.42m) above the operating floor. When two dollies are used in conjunction with spacer bars, the transporter length is extended to 45 ft. 7 in (13.89m). A single transporter dolly is designed to carry loads up to 137,000 lb. (62,142kg).

E. Component Handling Cask

As previously mentioned, handling casks are to be designed, but not provided initially for handling the primary heat transport system sodium pump internals and the primary and ex-vessel storage tank cold traps.

Design work completed thus far incorporates a segmented and modularized cask which can be modified to serve the multiple purposes. The cask modules consist of a closure valve, a lower cask body, an upper cask body, a cold trap hoist module of 33,000 lb. (14,970kg) capacity, a pump hoist module of 160,000 lb. (72,570kg) capacity, and several shielding barrels to be used in conjunction with the cask bodies. The total height of the cask in the pump handling configuration is approximately 350 in. (8.89m) and in the cold trap configuration, it is approximately 215 in. (5.46m).

Major constraints on the design are imposed by the building crane capacities. The laden cask for pump internals handling will only be utilized within the Reactor Containment Building and is limited to a total weight of 175 tons (159,000kg). The laden cask for handling either cold trap must be lifted by the Reactor Service Building crane which is limited to a 125 ton (113,400kg) capacity. The cold trap handling limitation exists because the primary cold trap must be transported from the Reactor Containment Building to the Reactor Service Building via the large component, transporter, and the EVST cold trap is located in the Reactor Service Building where it must also be handled by the Reactor Service Building Crane.

The previously described large component floor valve is not designed with the structural capability to support either cask; for this reason, a supporting bridge structure is required in conjunction with the cask to transmit the loads directly to the building floor while the cask is mated with the floor valve. Embedments to support this bridge are to be provided in the floor structure.

F. Reactor Internals Handling Equipment

Although it is never expected that the reactor internals will require removal, the reactor is designed to accommodate such an operation, and the NSSS general purpose maintenance equipment system is to include the design for all major equipment which would be required to support the handling requirements. This group of equipment would be fabricated only if the need were established.

Concept studies for the removal of the reactor internals have identified the need for a containment shroud and support structure, a large floor valve, a shielded handling cask, shielded temporary storage container, and a shielded remote tool maintenance platform. Items to be removed by this group of equipment include the small rotating plug, the intermediate rotating plug, and the core upper internals structure assembly.

VI. MAINTENANCE AND INSPECTION EQUIPMENT

General purpose maintenance and inspection equipment are being designed by Atomics International and are provided to support plant component disassembly/assembly operations, replacement tasks, and visual inspections. This group of equipment includes various general purpose maintenance stands and adapters, a large component maintenance platform and associated tools, portable and temporary enclosures, general purpose pipe maintenance equipment, and a periscope system (Reference 4).

A. Large Maintenance Stand

The large maintenance stand (LMS) is a permanently installed structure in the Reactor Containment Building for the purpose of supporting the primary heat transport system sodium pump internals during assembly and disassembly operation. This structure was originally intended as a dual purpose stand to be used also for maintenance operation on the intermediate heat exchanger tube bundle, but it has since been decided that the tube bundle shall be repaired in place by tube plugging methods with no provision for removal being incorporated.

The LMS is a seismic Category 1 structure capable of withstanding a Safe Shutdown Earthquake while supporting a pump internals. It is fixed to the Containment Building operating floor at a position adjacent to the access hatch to the Large Component Cleaning Vessel which has been previously described. The primary structure of the stand is 14 ft. (4.27m) square by 22 ft. 8 in. (6.91m) high.

B. IHTS Pump Maintenance Adapter

An adapter assembly is to be provided for assembly and disassembly operation on the intermediate heat transport system sodium pump internals. This adapter is to be used in a pit area of the Steam Generator Building maintenance bay. Several floor levels and structural supports are included in the pit area, and, in conjunction with the adapter assembly, the area serves the same function for the IHTS pump as the large maintenance stand serves for the PHTS pump.

C. Large Component Maintenance Platform

The large component maintenance platform is a shielded structure which is placed on top of the large component floor valve. Although it can be used at any location, its primary function is to allow remote cutting, capping, welding, and disassembly operations on either the primary or EVST cold trap in preparation for removal. The platform is 210 in. (5.33m) square with a 156 in. (3.96m) diameter rotatable plug in the center. A three ton (2,721kg) capacity jib crane is mounted on the rotatable plug. The plug also contains

a 64 in. (1.62m) diameter equipment hatch and 12 **removable plugs** for mounting tools and viewing equipment.

When the platform is in use, the jib crane can be used to pass fixtures, tools, and components through the equipment hatch. Bagging methods will maintain the inert cell atmosphere. The remote operating tools, periscope, and lighting equipment can be strategically located through the choice of plug openings and by rotating the large plug. Specific tools have not been designed but the tool group will include manipulative devices for placing equipment.

D. General Purpose Pipe Maintenance

The general purpose pipe maintenance equipment is a system of modified commercially available equipment to be used for cutting, preparation, welding, and inspection of the sodium piping in the NSSS. This group of equipment includes restraining and clamping tools, pipe plugging devices, cutting and milling tools, and welding equipment.

The tools will be developed by HEDL as an outgrowth of Fast Flux Test Facility development. One group of equipment is identified as contact equipment. These tools will be designed for quick placement by 'hands on' methods and then operated from remote locations when necessary. A second group is to be developed as remote placement tools. These will be an extension of the contact equipment modified for placement and operation by remote methods. These tools will be used in application such as a primary cold trap removal whereby the tools will be remotely placed and operated from the maintenance platforms.

E. Periscope System

The periscope system is an adaptation of commercially available equipment, to provide remote visual inspection of primary heat transport system piping and components. It is a modular system consisting of a telescope, eyepiece, various length relay tubes, couplings, straight and 90° viewing heads, and camera mount. A penetration adapter is provided for mounting the system to viewing ports which are provided in the operating floor of the Reactor Containment Building.

The periscope and adapter are designed to provide in-service inspection capability without manned access. The gas lock valve feature of the adapter allows the periscope to be installed without disturbing the inert cell atmosphere. Integral lighting is provided.

VII. CONCLUSION

The layout of the Nuclear Island Buildings and the design of systems will provide the space and special features necessary to maintain the components in place or permit removal and replacement in an efficient manner so that high plant availability can be achieved. Sodium removal and radioactive decontamination facilities are being designed so that these functions can be performed satisfactorily, with waste streams to be processed by a Radwaste System specifically designed for that purpose.

The Clinch River Breeder Reactor Plant has been designed from the conceptual stage to the present stage of advanced detailed design with the maintenance requirements consistently a major consideration. The plant represents a considerable advancement in the design of all nuclear power plants, domestic and foreign, with regard to providing features which the plant owners and operators will find beneficial over the lifetime of the plant. Low maintenance costs and high plant availability should be readily achievable, and fully commensurate with the reliability of the components and systems being provided.

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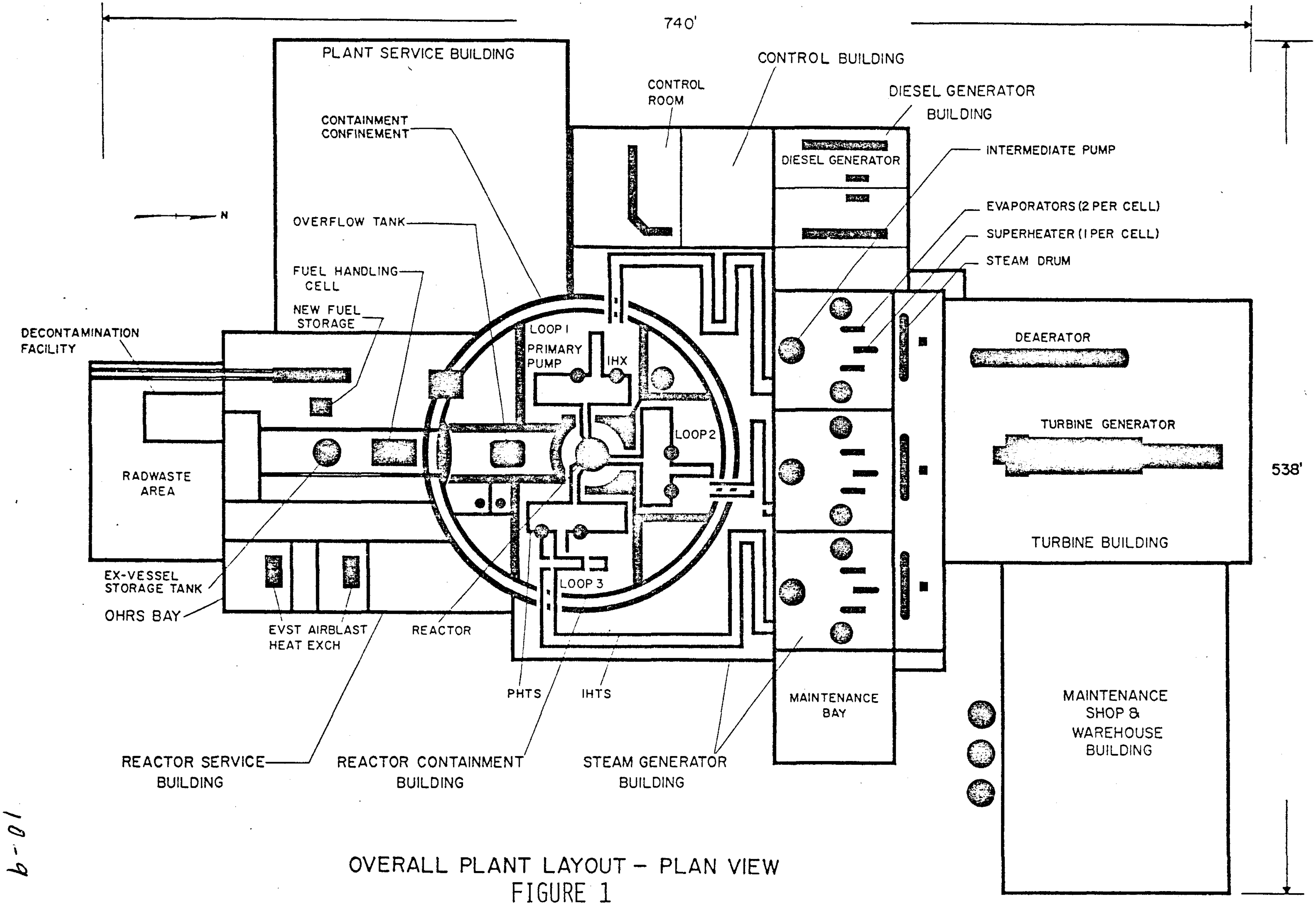
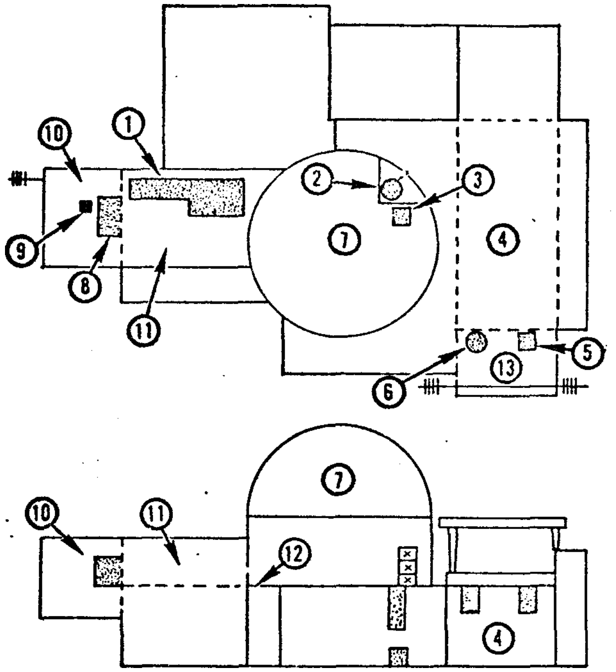


OVERALL PLANT LAYOUT - PLAN VIEW
FIGURE 1

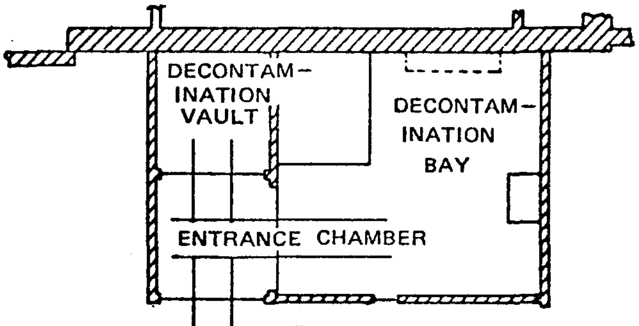


① STAGING AND LAYDOWN AREA
② PRIMARY SODIUM REMOVAL SYSTEM
③ LARGE MAINTENANCE STAND
④ STEAM GENERATOR BUILDING
⑤ INTERMEDIATE PUMP MAINTENANCE FACILITY
⑥ INTERMEDIATE SODIUM REMOVAL SYSTEM
⑦ REACTOR CONTAINMENT BUILDING
⑧ DECONTAMINATION FACILITY
⑨ AUTOCLAVE
⑩ RADWASTE AREA
⑪ REACTOR SERVICE BUILDING
⑫ OPERATING FLOOR
⑬ MAINTENANCE BAY

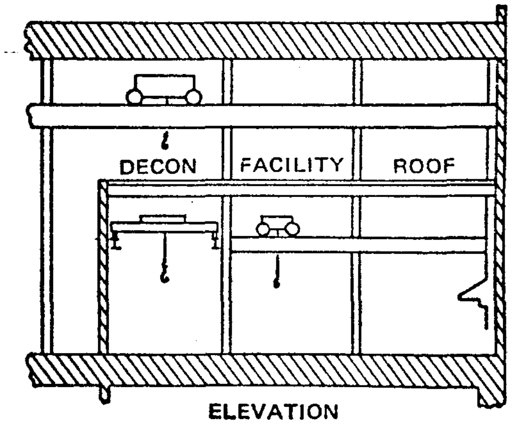
9127-1202

FIGURE 2

MAJOR FEATURES OF NUCLEAR ISLAND
GENERAL PURPOSE MAINTENANCE SYSTEM



PLAN VIEW



ELEVATION

9127-1203

FIGURE 3

DECONTAMINATION FACILITY
RADWASTE AREA

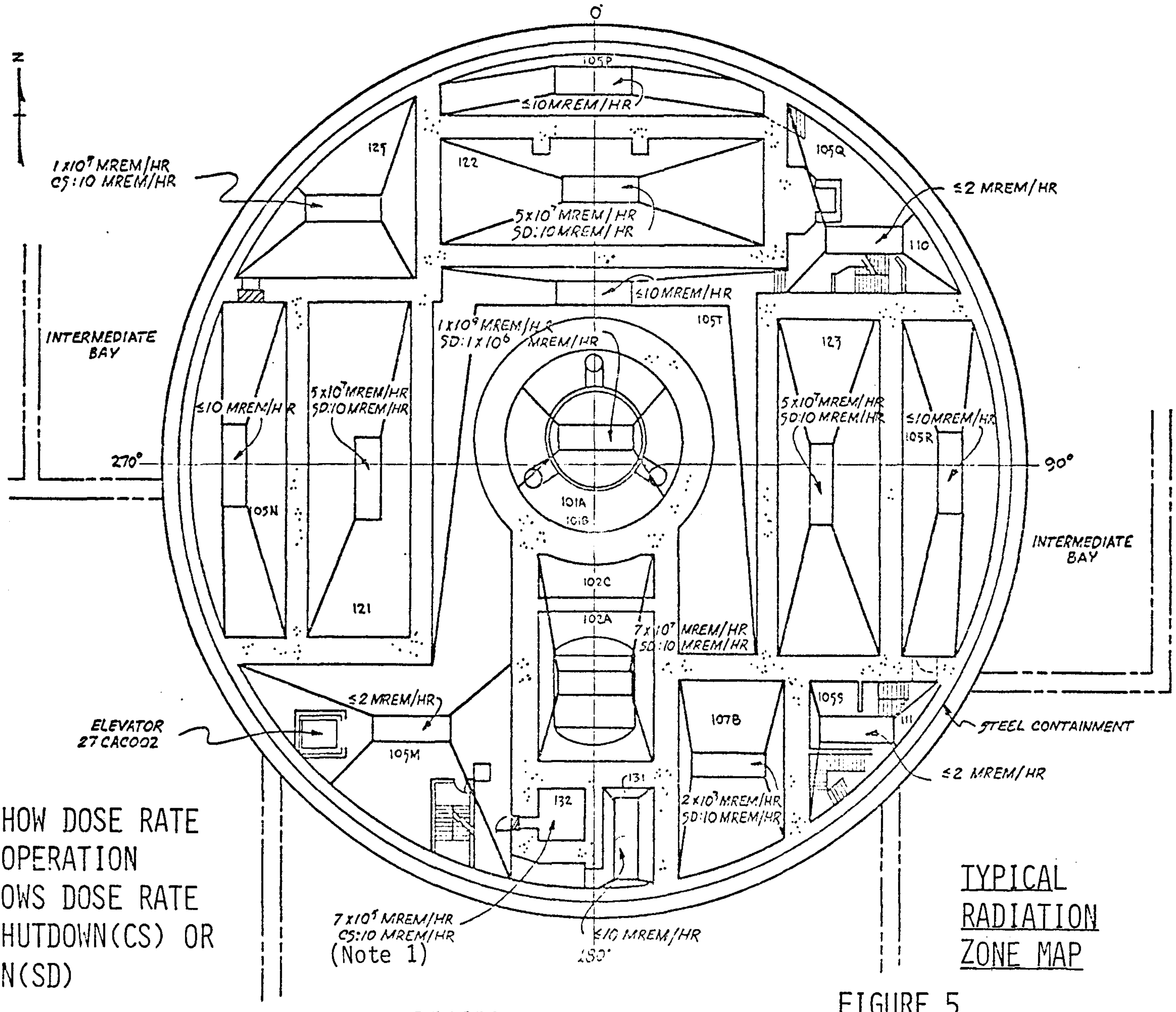
FIGURE 4

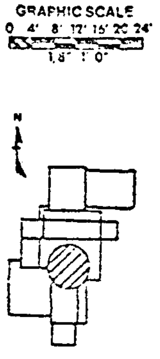
RADIATION ZONING CRITERIA

Zone Class	Design Dose Rate Range (mrem/hr)	Zone Description	Design Occupancy Criteria	Airborne Concentrations (% MPC) (1)
I	≤ 0.2	Restricted area, routinely occupied	Full Time	1
II	>0.2 to ≤ 5	Restricted area, non-routinely occupied	10CFR20$^{(2)}$	10
III	>5 to ≤ 100	Radiation area, limited access for routine task	10CFR20$^{(2)}$	10
IV	>100 to <5000	High radiation area, access to perform specific non-routine task	10CFR20$^{(2)}$	--
V	>5000	Inaccessible	10CFR20	

(1) Percent of maximum permissible concentration as defined in 10CFR20.

(2) And as described in Section III of this report.





KEY PLAN

NOTE 1:
1ST FIGURES SHOW DOSE RATE
DURING PLANT OPERATION
2ND FIGURE SHOWS DOSE RATE
DURING CELL SHUTDOWN(CS) OR
PLANT SHUTDOWN(SD)

TYPICAL
RADIATION
ZONE MAP

FIGURE 5

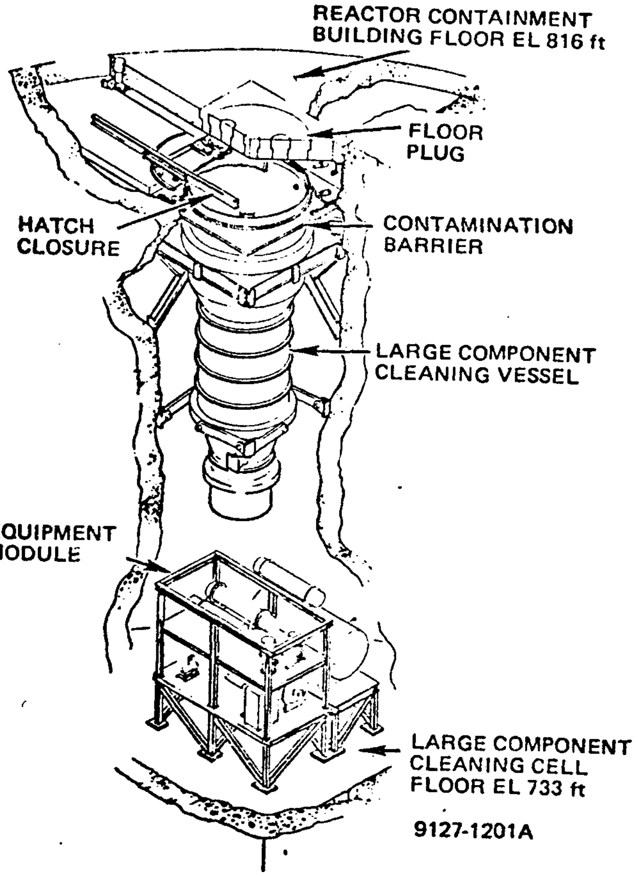
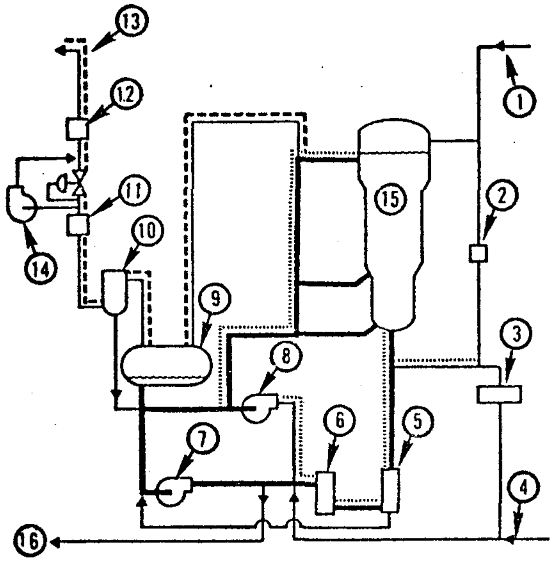


FIGURE 6

PRIMARY SODIUM REMOVAL AND
DECONTAMINATION EQUIPMENT ARRANGEMENT
REACTOR CONTAINMENT BUILDING



PROCESS FLUIDS:

━━━ WATER

┈┈┈ WATER-VAPOR NITROGEN

- - - - WASTE GAS

① NITROGEN SUPPLY
② HEATER
③ BOILER
④ WATER SUPPLY
⑤ COOLER
⑥ HEATER
⑦ PUMP
⑧ BLOWER
⑨ OVERFLOW TANK
⑩ CONDENSER
⑪ DEMISTER
⑫ FILTER
⑬ GASEOUS WASTE
⑭ VACUUM PUMP
⑮ CLEANING VESSEL
⑯ RADIOACTIVE LIQUID WASTE

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FIGURE 7

PRIMARY SODIUM REMOVAL AND DECONTAMINATION SYSTEM SCHEMATIC DIAGRAM REACTOR CONTAINMENT BUILDING

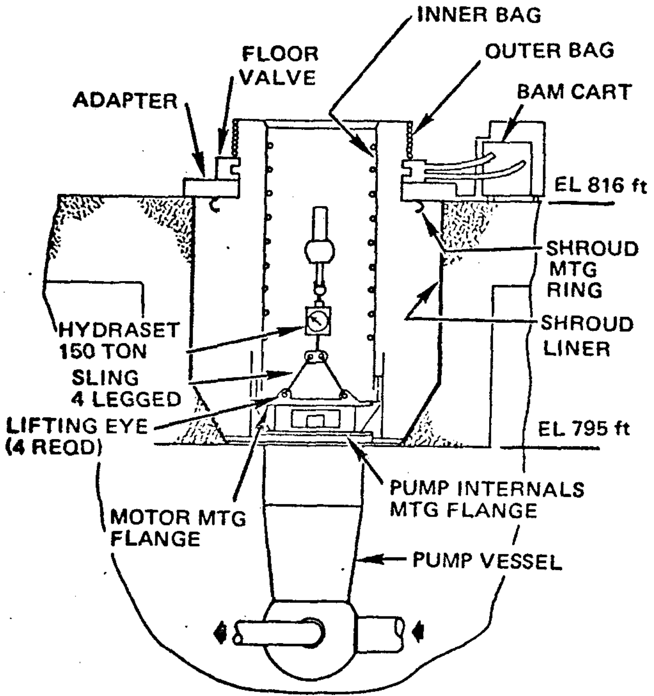

FIGURE 8

PRIMARY SODIUM PUMP REMOVAL SETUP
REACTOR CONTAINMENT BUILDING