Boiling Water Reactor
GE BWR/4 Technology
Technology Manual

Chapter 10.0

Emergency Core Cooling Systems

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10.0 EMERGENCY CORE COOLING SYSTEMS

Learning Objectives:

1. State the system's purpose.
2. Describe the integrated ECCS response to small, intermediate, and large break Loss of Coolant Accidents.
3. List the ECCS acceptance criteria.
4. Explain the electrical division assignments of the ECCS.

10.0.1 Introduction

The purpose of the emergency core cooling systems (ECCSs) is to provide core cooling under Loss of Coolant Accident (LOCA) conditions to limit fuel cladding damage and therefore limit the release of radioactive materials to the environment.

The ECCS, shown in Figure 10.0-1, consists of two high pressure systems and two low pressure systems. The high pressure systems are the High Pressure Coolant Injection (HPCI) System and the Automatic Depressurization System (ADS). The low pressure systems are the Low Pressure Coolant Injection (LPCI) mode of the Residual Heat Removal (RHR) System and the Core Spray (CS) System.

10.0.2 High Pressure Coolant Injection System (Section 10.1)

The High Pressure Coolant Injection System maintains adequate reactor vessel water inventory for core cooling on small break LOCA's, depressurizes the reactor vessel to allow the low pressure emergency core cooling systems to inject on intermediate break LOCA's, and backs up the function of the Reactor Core Isolation Cooling (RCIC) System (Section 2.7) under reactor vessel isolation conditions.

10.0.3 Automatic Depressurization System (Section 10.2)

The Automatic Depressurization System depressurizes the reactor vessel so that the low pressure emergency core cooling systems can inject water into the reactor vessel following small or intermediate break LOCA's concurrent with HPCI System failure.

10.0.4 Core Spray System (Section 10.3)

The Core Spray System provides spray cooling to the reactor core to help mitigate the consequences of the large break LOCA's when reactor pressure is low enough for the system to inject water into the reactor vessel.

10.0.5 Low Pressure Coolant Injection (Section 10.4)

The low pressure coolant injection (LPCI) mode of the Residual Heat Removal System restores and maintains water level in the reactor vessel following large break LOCA's when reactor pressure is low enough for the system to inject water. The RHR System has several other operational modes, some of which are safety related and some of which are not. Each mode is described in Section 10.4.

10.0.6 ECCS Acceptance Criteria

Emergency core cooling systems are designed to prevent melting and fragmentation of the cladding for any loss of coolant accident within the design basis spectrum. The objective of the systems is to keep the cladding and fuel from distorting to a degree that subsequent cooling would be ineffective. Satisfying these criteria does allow for the tolerance of cladding perforation. Even though the cooling equipment is successful in keeping cladding temperature below the 2,200°F limit, a small percentage of the fuel may perforate. However, the occurrence of even a large number of perforations does not prevent effective core cooling.

Cladding is perforated when the gas pressure within the rod exceeds the pressure the cladding can withstand for that particular cladding temperature. The perforation is local, in that a given fuel rod perforates at a particular location on the order of an inch in axial length. The perforation usually occurs, and is localized, at a weak point along the fuel rod length, probably at a point of cladding flaw, pellet chip, or slightly increased cladding oxidation. Such weak points are randomly distributed among the fuel rods within the fuel assembly.

The conclusion that the perforation is random and local is based on confirmed observations of irradiated fuel. Such random failures have also been demonstrated in test loops by placing zircalloy tubing, filled with $U0_2$ pellets and pressurized with gas, in an induction heating facility. The observed failures were always localized and random along the length of the heated rod. Only a slight change in diameter was observed, except within an inch or two on either side of the perforation. This is characteristic of high temperature burst failures in general. From these tests, the major conclusions are that perforations are indeed local and that the fuel rods do not grossly distort over the length of the fuel rod.

The ECCS acceptance criteria for light water reactors, which are listed in 10 CFR 50.46, are discussed in the paragraphs which follow.

10.0.6.1 Peak Cladding Temperature

The first criterion is that the calculated maximum fuel cladding temperature shall not exceed 2,200°F. Reflooding or spraying of water on the fuel rods must stop the heatup and reduce clad temperature before 2,200°F is reached because the zircalloy cladding at temperatures in excess of 2,000°F reacts with water to form zirconium oxide and hydrogen gas. The actual threshold of this reaction is about 1,800°F, but between 1,800°F and 2,200°F the reaction is slow. As temperatures increase the reaction rate increases.

This reaction is exothermic and at temperatures >2,200°F the reaction accelerates and dominates core heat up. This reaction, producing free hydrogen gas, could cause an explosive mixture within the containment. The 2,200°F criteria is also imposed because zircalloy when heated to >2,200°F and then rapidly quenched may brittle fracture with consequent loss of core geometry.

This effect is due to the fact that the zirconium oxidation from the above reaction causes zirconium to become more brittle.

10.0.6.2 Maximum Cladding Oxidation

The calculated total oxidation of the cladding shall nowhere exceed 0.17 times the total cladding thickness before oxidation. As used in this sense total oxidation means the total thickness of cladding metal that would be locally converted to oxide if all the oxygen absorbed by and reacted with cladding locally were converted to stoichiometric zirconium dioxide. If cladding rupture is calculated to occur, the inside surface of the cladding shall be included in the oxidation, beginning at the calculated time of rupture.

Cladding thickness before oxidation means the radial distance from inside to outside the cladding, after any calculated rupture or swelling has occurred but before significant oxidation. Where the calculated conditions of transient pressure and temperature lead to a prediction of cladding swelling, with or without cladding rupture, the unoxidized cladding thickness shall be defined as the cladding cross sectional area, taken at a horizontal plane at the elevation of the rupture, if it occurs, or at the elevation of the highest cladding temperature if no rupture is calculated to occur, divided by the average circumference at that elevation. For ruptured cladding, the circumference does not include the rupture opening.

10.0.6.3 Maximum Hydrogen Generation

The calculated total amount of hydrogen generated from the chemical reaction of the cladding with water or steam shall not exceed 0.01 times the hypothetical amount that would be generated if all the metal in the cladding cylinders surrounding the fuel, excluding the cladding surrounding the plenum volume, were to react.

10.0.6.4 Coolable Geometry

Calculated changes in core geometry shall be such that the core remains amenable to cooling.

10.0.6.5 Long Term Cooling

After any calculated successful initial operation of the ECCS, the calculated core temperature shall be maintained at an acceptably low value and decay heat shall be removed for the extended period of time required by the long lived radioactivity remaining in the core.

10.0.7 Design Bases

The ECCS is designed to provide protection against postulated loss of coolant accidents (LOCAs) caused by ruptures in primary system piping. In addition to satisfying the ECCS acceptance criteria mentioned in paragraph 10.0.6 above, the ECCS is designed to meet the following requirements:

1. Protection is provided for any primary line break up to and including the double ended break of the largest line.

2. Two independent phenomenological cooling methods (flooding and spraying) are provided to cool the core.

3. One high pressure cooling system is provided which is capable of maintaining water level above the top of the core and preventing ADS actuation for small line breaks.

4. No operator action is required until 10 minutes after an accident to allow for operator assessment and decision.

5. A sufficient water source and necessary piping, pumps, and other hardware are provided so that the containment and reactor vessel core can be flooded for possible core heat removal following a loss of coolant accident.

6. In the event of a break in a pipe that is part of the reactor coolant pressure boundary, no single active component failure in the ECCS shall prevent automatic initiation and successful operation of less than the minimum number of ECCSs required to mitigate the consequences of the accident.

7. Long term (10 minutes following the initiation signal) cooling requirements call for the removal of decay heat via the Reactor Building Service Water System. In addition to the break which initiated the loss of coolant event, the system is able to sustain one failure,

either active or passive, and still have at least one low pressure ECCS pump operating with one heat exchanger and 100% service water flow.

8. Off site power is the preferred source of power for the ECCS network, and every reasonable precaution is made to ensure its high availability. However, on site emergency power is provided with sufficient diversity and capacity so that all the above requirements can be met even if off site power is not available.

9. Non ECCSs interfacing with the ECCS power supply buses shall automatically be shed and/or be inhibited from the buses when a LOCA signal exists and off site AC power is not available.

10. All active components shall be testable during normal operation of the nuclear system.

11. The components of the emergency core cooling systems within the reactor vessel shall be designed to withstand the transient mechanical loadings during a loss of coolant accident so that the required standby cooling flow is not restricted.

10.0.8 ECCS Network

The ECCS network is shown in Figure 10.0-2. During normal operation, power to the Core Spray and Residual Heat Removal Systems' components is supplied by the Normal AC Power System. During loss of power conditions, these loads are supplied by Emergency AC Power System. The Automatic Depressurization and High Pressure Coolant Injection Systems utilize DC power provided by the DC Electrical Systems (Section 9.4).

10.0.9 ECCS Initiation Signals

Both low reactor water level and high drywell pressure are conditions which indicate that a loss of coolant accident is in progress.

The low-low (level-2) reactor water level initiation setpoint is set low enough to allow the HPCI system to recover level in the case of small line breaks or loss of reactor feedwater without causing unnecessary initiation of the low pressure emergency core cooling systems. The low-low-low (level-1) reactor water level initial setpoint is high enough to allow start up of the low pressure ECCS in sufficient time to reflood the reactor vessel before fuel cladding temperatures reach 2,200°F following a design basis loss of coolant accident.

The high drywell pressure initiation setpoint is high enough to prevent inadvertent initiation due to normal fluctuations in pressure but low enough to ensure earliest practical cooling to the core. High drywell pressure sends a signal to the initiation logic of most emergency core cooling systems.

10.0.10 Performance Analysis

The manner in which the ECCS operate to protect the core is a function of the rate at which coolant is lost from the break in the nuclear system process barrier. The HPCI System is designed to operate while the nuclear system is at high pressure. The Core Spray System and LPCI mode of the RHR System are designed for operation at low pressures. If the break in the nuclear system boundary is of such a size that the loss of coolant exceeds the capacity of the HPCI System, nuclear system pressure drops at a rate fast enough for the Core Spray System and LPCI mode to commence coolant addition to the reactor vessel in time to cool the core.

Automatic depressurization is provided to automatically reduce nuclear system pressure if a break has occurred and the HPCI System is inoperable. Rapid depressurization of the nuclear system is desirable to permit flow from the Core Spray System and LPCI mode to enter the vessel, so that the temperature rise in the core is limited.

If for a given size break, the HPCI System has the capacity to make up for all the coolant loss from the nuclear system, flow from the low pressure portion of the ECCS is not required for core protection until nuclear system pressure has decreased below approximately 150 psig. This pressure is above the value at which the HPCI turbine steam stop valve shuts due to low steam supply pressure.

Adequate net positive suction head (NPSH) is provided for the ECCS throughout the loss of coolant accident under the most severe case of power availability and equipment failure. Therefore, proper operation of the ECCS is assured.

The redundant features of the ECCS are shown on Figure 10.0-3. Capability for cooling exists over the entire spectrum of break sizes even with concurrent loss of normal auxiliary power and even with a single active component failure within the ECCS network.

10.0.11 Design Basis Loss of Coolant Accident (DBLOCA)

A design basis accident is a hypothesized accident, the characteristics and consequences of which are utilized in the design of those systems and components pertinent to preservation of radioactive material barriers and the restriction of radioactive material release from the barriers.

The assumptions for the DBLOCA are:

1. The break is assumed to have an effective break size producing a PCT closest to the 10 CFR 50.46 limit. The break size for THIS PLANT is equal to 2/3 of a double ended rupture of a recirculation pump discharge line. The calculated flow area for this break is 1.3 ft^2.

2. The reactor is assumed to be operating at 105% of rated steam flow, 105% thermal power, 1055 psia pressure in the vessel steam dome, and reactor water level at the minimum allowed low water level setpoint (this corresponds to +12.5 inches indicated) at the time of the rupture.

3. Worst case fuel parameters such as peaking factors, steady state minimum critical power ratios, average and peak linear heat generation rates, and decay heat history are assumed at the time of the rupture.

4. Loss of all off site electrical power sources and all site auxiliary power (turbine generator trip) is assumed at the time of the rupture.

5. A most limiting single component failure is assumed to occur at the time of the rupture. This has been analyzed to be failure of the LPCI injection valve to open on the intact recirculation system.

10.0.12 Integrated ECCS Performance

The performance of the ECCS as an integrated package is evaluated by determining what is left functional after a postulated LOCA (concurrent with loss of off site power) and a single failure of an active ECCS related component Tabel 10.0-2. The remaining ECCS and components must meet the 10 CFR requirements over the entire spectrum of LOCA's. The integrated performance for small, intermediate, and large sized breaks is shown in Figure 10.0-3. Table 10.0-1 gives the sequence of the ECCS actions in the case of a design basis LOCA, a double ended circumferential recirculation line break, concurrent with a loss of off site power.

10.0.13 Steam Line Breaks

Discussion and illustration of the ECCS performance capability has purposely been directed toward the liquid breaks below the core. In general, the ECCS design criterion for limiting cladding temperatures to less than 2,200°F is more easily satisfied for steam breaks than for liquid breaks, because the reactor primary system depressurizes more rapidly with less mass loss. Thus the ECCS performance for a given break size improves with increasing steam quality of the break flow.

The most severe steam pipe break would be one which occurs inside the drywell, upstream of the flow limiters. Although the isolation valves would close within 3-5 seconds (10.5 seconds is assumed in the evaluation), a break in this location would permit the pressure vessel to continue to depressurize to the drywell. As serious as this accident could be, it does not result in thermal hydraulic consequences as severe as the rupture of a coolant recirculation pipe.

10.0.14 ECCS Supperssion Pool Suction Strainers

In BWRs that have carbon steel components, corrosion product particulate buildup in the suppression pool can lead to ECCS suction strainer blockage and subsequent failure of the pumps to provide design flow rates. Particulate buildup can be removed from suppression pools, but will be regenerated, overtime, at a rate of 10-100 kg/year. In addition, there are numerous sources of fibers in a BWR Drywell.; thermal insulation on pipe and equipment, protective clothing, welding fabric, fire protection materials and even human hair are some observed sources.

Recent studies have shown that very small quantities of fibrous material (0.1 m^3) combined with 100 kg or so of particulate, is enough to bring about RHR pump cavitation when collected on small passive strainers with 1/8 inch holes, like those found in many of the world's BWR suppression pools.

Removing all sources of fibrous material from a pool is realistic and achievable. Guaranteeing that all fibers have been removed from the drywell is not realistic, and even if there are just a few fibers the ECCS stainers can easily become blocked.

On May 6, 1996, the NRC issued Bulletin 96-03, "Potential Plugging of Emergency Core Cooling Suction Strainers by Debris in Boiling-Water Reactors," which requested actions by BWR addressees to resolve the issue of BWR strainer blockage because of excessive buildup of debris from insulation, corrosion products, and other particulates, such as paint chips and concrete dust. The bulletin proposed four options for dealing with this issue:

1. Install large capacity passive strainers,
2. Install self-cleaning strainers,
3. Install a safety related backflush system that relies on operator action to remove debris from the surface of the strainer to keep it from clogging, or
4. Propose another approach that offers an equivalent level of assurance that the ECCS will be able to perform its safety function following a LOCA.

The most practical and cost effective of the mechanical solutions is to replace the existing small passive suction strainers with large passive strainers. The modification represents the simplest, the most reliable, and the least disruptive option. The conclusion that large suction strainers are necessary is inescapable, especially when it is recognized that only a thin layer of fibrous material , combined with a relatively small quantity of particulate, is required to bring about ECCS pump cavitation at most of the world's BWRs.

Figure 10.0-4 Illustrates the large capacity suction strainer that has replaced the old smaller passive strainer. This new larger passive suction strainer has increases the surface area of the strainer from approximately 9 ft^2 to 108 ft^2. The strainers measure approximately three and one half feet in height and five feet in diameter. The uppermost stacked disc measures two inches in thickness and contains perforations on both surfaces. The remaining thirteen discs are one inch in thickness with perforations on both surfaces. The center section is truncated to provide a mounting platform for the stacked disc and provide additional surface area. The stacked disc sections are held in place by vertical stiffener bars spaced at even intervals.

Table 10.0-1 Operational Sequence of Emergency Core Cooling Systems

Time (Sec.)	Events
0	Design basis Loss of Coolant Accident starts; normal auxiliary power lost.
0	Drywell high pressure and reactor low water level is reached. All diesel generators start; reactor scrams; HPCI, CS, LPCI signaled to start on high drywell pressure.
3	Reactor low-low water level reached. HPCI receives second start signal.
7	Reactor low-low-low water level is reached. Main Steam isolation valves close, second signal to start LPCI and CS; ADS sequence begins.
<30	HPCI injection valve open and pump at design flow, which completes HPCI startup.
<40	LPCI and CS pumps at rated flow, LPCI an CS injection valve open and Recirculation System discharge valves close which completes the LPCI and CS startup.
230	Water level approximately 2/3 core height. Core effectively reflooded, assuming worst single failure , heatup terminated.
300	Water level above top of active fuel.

Table 10.0-2 Single Failure Evaluation

Assumed Failure	Suction Break Remaining Systems	Discharge Break Remaining Systems
LPCI Injection Valve	All ADS, HPCI, 2CS, 2 LPCI (1 loop)	All ADS, HPCI, 2 CS
HPCI	All ADS, 2 CS, 4 LPCI (2 loops)	All ADS, 2 CS, 2 LPCI (1 loop)
D/G A or B	All ADS, HPCI, 1 CS, 3 LPCI (2 loops)	All ADS, HPCI, 1 CS,1 LPCI (1 loop)
D/G C	All ADS, HPCI, 2 CS, 2 LPCI (2 loops)	All ADS, HPCI, 2 CS,1 LPCI (1 loop)
One ADS Valve	All ADS, minus one valve, HPCI, 2 CS, 4 LPCI (2 loops)	All ADS, minus one valve, HPCI, 2 CS, 2 LPCI (1 loops)

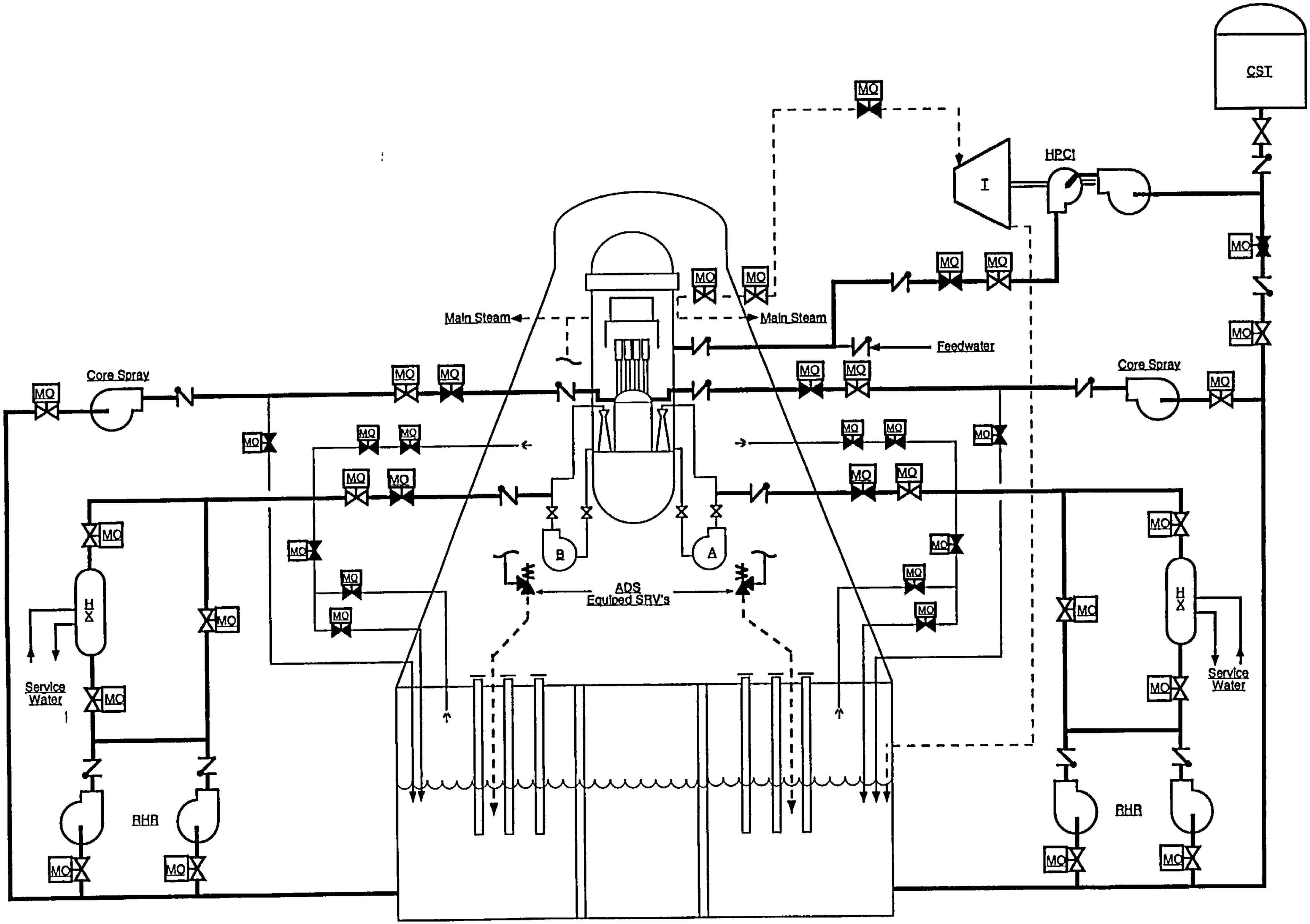


Figure 10.0-1 Emergency Core Cooling Systems

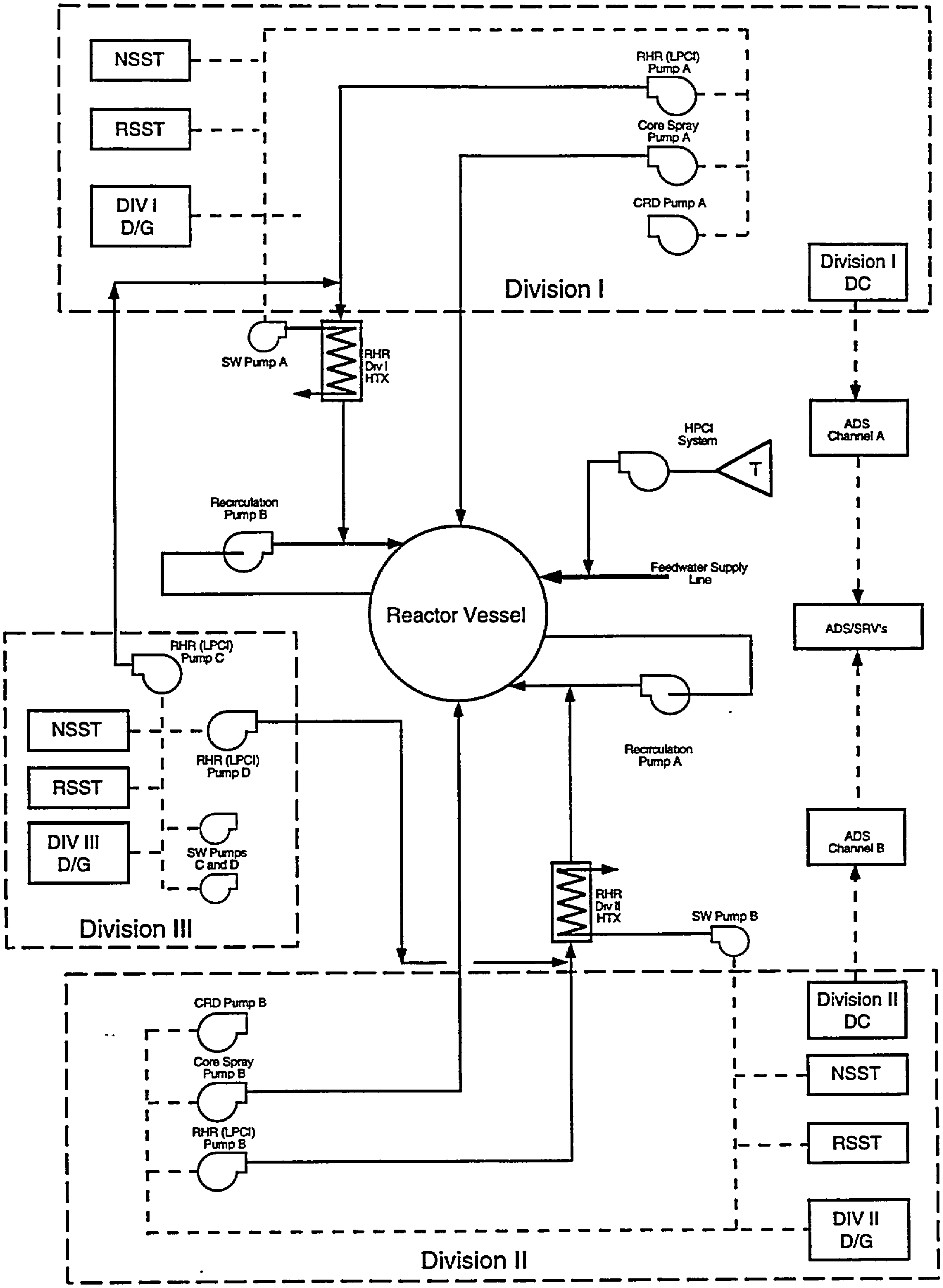


Figure 10.0-2 ECCS Divisional Assignment

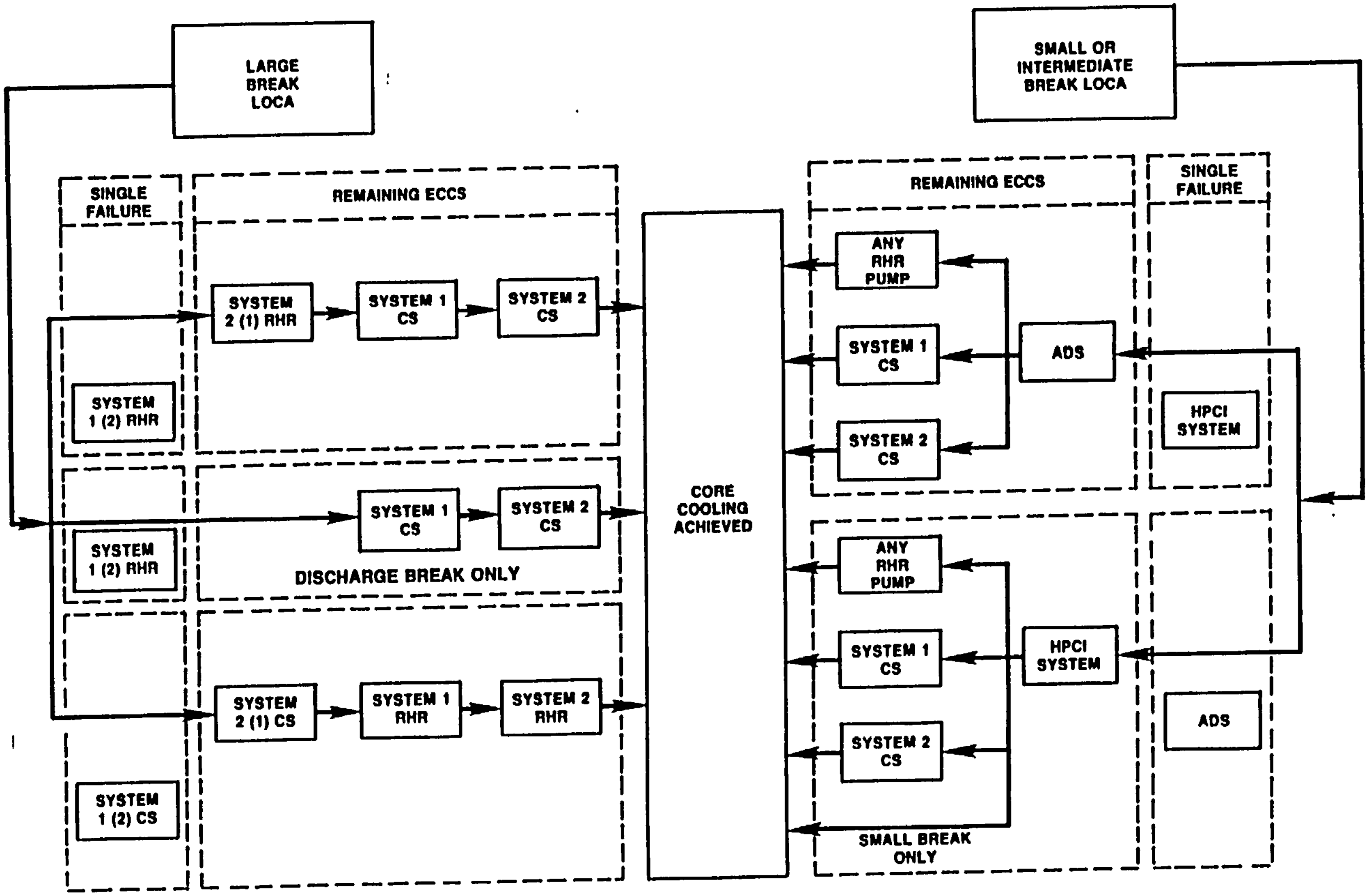
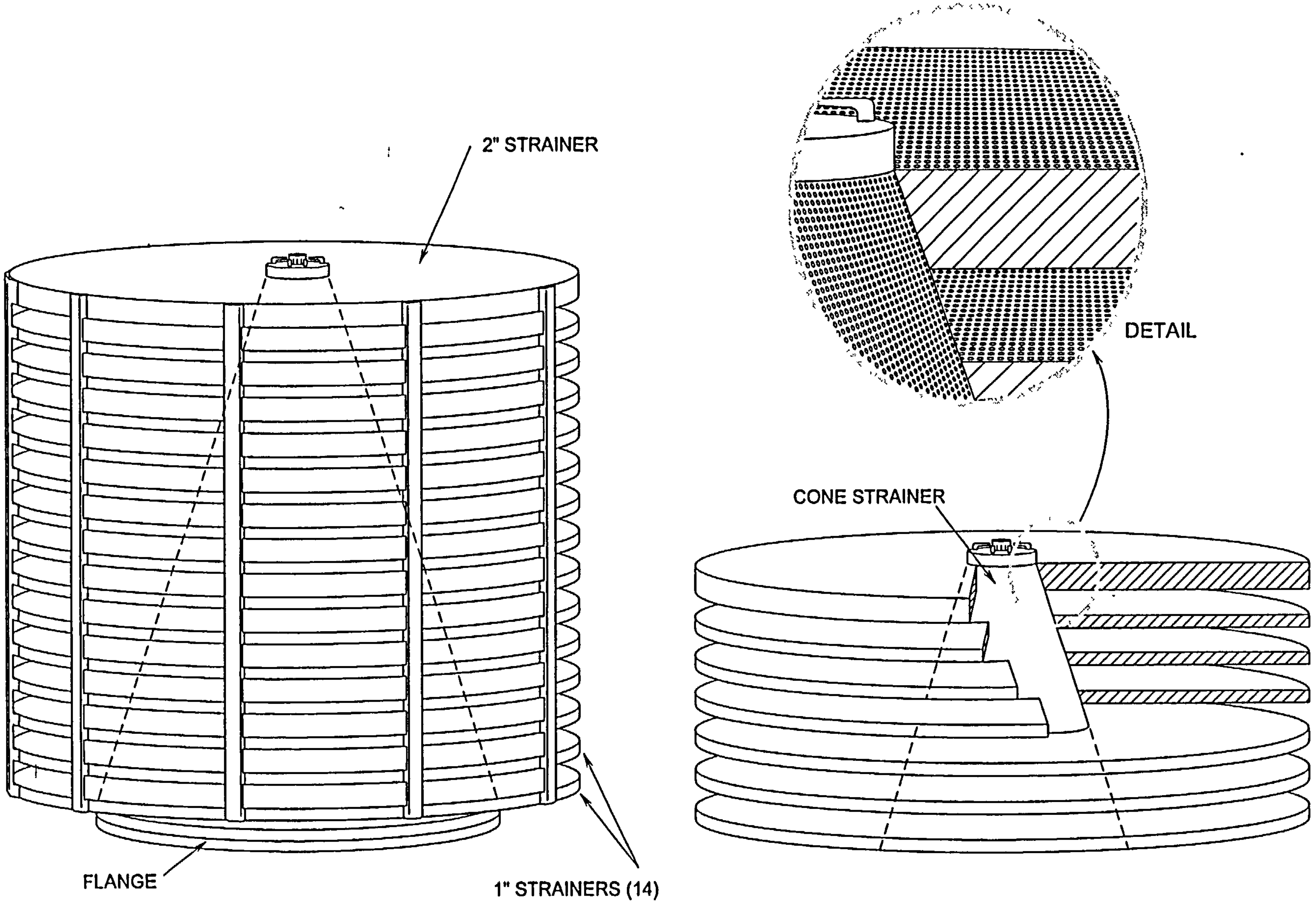


FIGURE 10.0–3 ECCS INTEGRATED PERFORMANCE



CUT AWAY VIEW OF TOP SECTIONS

Figure 10.0-4 ECCS Suction Strainer Assembly

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Chapter 10.1

High Pressure Coolant Injection System

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10.1 HIGH PRESSURE COOLANT INJECTION SYSTEM

Learning Objectives

1. State the system's purpose.
2. Explain the major system flow paths.
3. List the automatic initiation signals.
4. Explain the system's response to an automatic initiation signal.
5. State the difference between a HPCI trip and a HPCI isolation.
6. State the basis of the precaution that warns against prolonged operation of the HPCI system below 2200 RPM.
7. State the condition under which the manual isolation push button may be used to produce an isolation.
8. Concerning the HPCI system flow controller, state the parameter that is controlled in the following modes.
   - Manual
   - Automatic
9. Explain the interrelationships this system has with the following systems:
   - Condensate Storage Tank
   - Primary Containment System
   - Reactor Core Isolation Cooling System
   - Emerency AC Power System
   - DC Power System
   - ECCSs

10.1.1 Introduction

The purposes of the High Pressure Coolant Injection System are to maintain adequate reactor vessel water inventory, for core cooling, on small break LOCAs, depressurize the reactor vessel to allow low pressure ECCSs to inject on intermediate break LOCAs, and to backup the Reactor Core Isolation Cooling (RCIC) System under reactor vessel isolation conditions.

The functional classification of the HPCI System is that of a safety related system. Its regulatory classification is an engineered safety feature system.

The HPCI System, shown in Figure 10.1-1, is an independent emergency core cooling system requiring no auxiliary AC power, plant service and instrument air, or external cooling water systems to perform its purposes. The HPCI system consists of a turbine, turbine driven pumps, and the normal auxiliary systems required for turbine operation, and associated piping and instrumentation.

The HPCI System is normally aligned to remove water from the condensate storage tank and pump the water at high pressure to the reactor vessel via the "B" feedwater line. The alternate source of water to the HPCI pump is provided by the suppression pool. Both manual and automatic transfer of the suction path are provided. A test line permits functional testing of the system during normal plant operation. In the event the pump is operated with a closed discharge path a minimum flow path to the suppression pool is provided for HPCI pump cooling.

The HPCI system can supply makeup water to the reactor from above rated reactor pressure to a reactor pressure below that at which the low pressure ECCS can inject. By supplying cool water and using decay heat steam as a motive force for the HPCI turbine, the reactor will depressurize and allow the low pressure ECCSs to inject.

System initiation can be accomplished by automatic signals or manually by the control room operator. Receipt of either a reactor water level 2 or high drywell pressure will automatically start the HPCI system. To prevent component damage from water hammer effect on system initiation, the HPCI system is kept pressurized by the line fill pump.

10.1.2 Component Description

The components of this system are discussed in the paragraphs that follow, and are illustrated on Figure 10.1-1.

10.1.2.1 Steam Supply Isolation Valves

The steam supply line to the HPCI turbine taps off the "A" main steam line on the reactor side of the inboard main steam isolation valve, downstream of the flow restrictor. HPCI steam line contains an inboard and outboard isolation valve, along with bypass valves, that will automatically close upon receipt of an isolation signal. The isolation valves are aligned with the inboard valve normally open and the outboard valve closed. The outboard isolation valve is closed, with its companion bypass valve open, to limit contamination levels in the secondary containment due to a steam line failure when in the standby condition. Power supplied to the isolation valves is from different emergency distribution systems to ensure isolation of the system upon failure of one of the emergency power supplies. Power for the inboard isolation valve is from the emergency AC power system while the outboard is from DC power.

A motor operated bypass valve is provided around each of the steam line isolation valves to pressurize and warm up the steam line from an isolated condition. The outboard bypass valve is normally open to ensure the HPCI steam supply line is kept warm when the system is in the standby state. Both bypass valves automatically close on HPCI system isolation.

10.1.2.2 Steam Supply Shutoff Valve

The steam supply shutoff valve is used for normal turbine isolation to maintain it in standby readiness. The valve is normally closed and receives an open signal on HPCI automatic initiation. It may also be remotely operated from the control room.

10.1.2.3 Turbine Stop Valve

Located in the HPCI steam line ahead of the control valves is the hydraulic operated turbine stop valve. The stop valve provides turbine protection by rapidly shutting off steam flow to the turbine, during turbine trip conditions.

10.1.2.4 Turbine Control Valves

The HPCI turbine control valve is a spring to close hydraulic to open multipoppet valve that provides the means to vary steam flow to the turbine. By throttling the steam supply to the turbine, turbine speed and therefore pump flow can be controlled. Positioning of the control valves is accomplished by adjusting the hydraulic operating oil via HPCI flow controller.

10.1.2.5 HPCI Turbine

The HPCI turbine is designed to accelerate rapidly from a cold standby condition to full load conditions within 25 seconds. The HPCI turbine is a two stage, horizontally mounted, radial reentry, non-condensing turbine designed to operate with a steam supply pressure ranging from 1120 psig to 150 psig. Turbine exhaust is routed to the suppression pool to condense the unused steam energy. Prolonged operation below 2200 RPM is avoided to guard against cycling the turbine exhaust check valve, supplying inadequate control fluid for valve operation, and inability to maintain proper lube oil temperature and pressure.

10.1.2.6 HPCI Turbine Auxiliaries

The HPCI turbine auxiliaries consist of the HPCI oil system and the HPCI barometric condenser system. These systems are described briefly in the paragraphs that follow:

HPCI Oil System

Lubrication and control oil for the HPCI System is provided by an attached IMO pump mounted on the governor end of the turbine and an auxiliary D.C. motor driven gear pump. Cooling for the lubricating oil is supplied by the HPCI booster pump.

The motor driven auxiliary oil pump provides control oil for the HPCI turbine stop and control valves, and lubricating oil for the turbine and pump bearing during low speed turbine operation. The auxiliary oil pump is required to operate at turbine initiation since the turbine shaft-driven oil pump does not develop adequate discharge pressure at low speeds.

The auxiliary pump starts automatically on HPCI initiation and operates until deenergized by a signal from a pressure switch in the turbine shaft-driven oil pump line. This occurs at a turbine speed of approximately 1800 rpm. The auxiliary pump will again operate on HPCI shutdown when the turbine decreases below approximately 1550 rpm. The pump may also be manually started.

HPCI Turbine Barometric Condenser System

The barometric condenser system is supplied with the turbine. The system prevents out leakage from the turbine shaft seals and turbine exhaust casing drain. The system includes a barometric condenser, vacuum tank blower, a hotwell, and a vacuum tank condensate pump. The system starts simultaneously with automatic startup of the HPCI system, although it may be started manually.

Steam leakage from the gland seals, turbine control and stop valve stems, and turbine exhaust drainage is collected in the barometric condenser. The condensate flows by gravity into the hotwell where it is retained until the barometric condenser vacuum tank condensate pump is started by a high level signal in the hotwell. Condensate is pumped from the hotwell to the suction side of the booster pump if the steam supply valve to the turbine is open or to clean radwaste (CRW) if the HPCI system is in "standby".

Exhaust gases from the barometric condenser are discharged by the vacuum blower to the Reactor Building Standby Ventilation System (Section 4.4). The vacuum blower is operated for 15 minutes after turbine shutdown to void all steam and condensate from the turbine casing. The cooling water is pumped to the barometric condenser and the lube oil cooler by the HPCI booster pump and then returns to the HPCI booster pump suction.

10.1.2.7 HPCI Turbine Exhaust Path

The HPCI turbine exhaust line routes steam from the exhaust of the HPCI turbine to the suppression pool below water level. The exhaust line is normally kept free of water during shutdown conditions by a drain system that removes condensation to the barometric condenser. Check valves serve as a vacuum breaker. The valves are installed between the suppression pool free air volume and the exhaust line to prevent drawing suppression pool water into the line when a vacuum is created by condensation of steam in the exhaust line following a HPCI operation. The exhaust line may be isolated by a motor operated shutoff valve.

The exhaust line is protected from overpressure by a HPCI turbine trip at 150 psig high turbine exhaust pressure. The high exhaust pressure trip is backed up by a set of mechanical rupture diaphragms (nominal rupture point is 175 psig) which will relieve pressure to the HPCI room. The rupture diaphragms are arranged in a manner such that the inboard rupture diaphragm is constantly exposed to HPCI turbine exhaust pressure while the outboard rupture diaphragm is only exposed to exhaust pressure if the inboard one fails. A space between the exhaust rupture diaphragms is provided with an orifice leak off to the HPCI room and a series of pressure switches which will initiate a HPCI isolation at 10 psig.

10.1.2.8 HPCI Pump Suction Path

The HPCI System can take suction from the condensate storage tank (CST) or the suppression pool. Normal suction is from the CST on a line common with the RCIC System suction line. The HPCI/RCIC suction line from the CST is located lower than all other system suction lines. This ensures a reserved volume of water in the CST exclusively for the HPCI and RCIC Systems.

The suppression pool suction is from a 16 inch pipe that includes a stainless steel suction strainer. The strainer is located above the suppression pool bottom to minimize plugging.

Automatic transfer of the suction path from the condensate storage tank (CST) to the suppression pool occurs on low CST level or high suppression pool level.

10.1.2.9 HPCI Pump Assembly

The HPCI pump assembly is turbine driven and consists of a single stage centrifugal booster pump, a reduction gear, and a multistage centrifugal main pump. The booster pump takes water from one of the two water sources and discharges the water, at higher pressure, to the suction of the main pump. The main pump further increases the water pressure for injection into the reactor vessel via the "B" feedwater line.

The booster pump has a capacity of 4250 gpm at a discharge pressure range of 60 to 265 psig. The main pump can provide at least 4250 gpm to the reactor over a 1120 to 150 psig pressure range. The HPCI pumps are located in the reactor building at an elevation that ensures that the HPCI booster pump suction is lower than either the CST or suppression pool minimum levels to ensure the pump net positive suction head (NPSH) requirements are met.

10.1.2.10 HPCI Pump Discharge Path

The HPCI pump discharges through the system flow element, outboard and inboard discharge valves, the air operated check valve and into the "B" feedwater line where the flow is distributed inside the reactor vessel by the feedwater spargers. A pump minimum flow line to the suppression pool taps off just before the flow element. The minimum flow valve will open when system flow is <575 gpm and pump discharge pressure is >125 psig with the turbine stop valve and steam supply shutoff valve open.. In addition, a full flow test line (shared by the RCIC System) to the CST taps off just downstream of the outboard discharge valve.

The air operated check valve (Figure 10.1-2) is provided to prevent leakage from the feedwater line into the HPCI System when the injection valves are open. A pneumatic actuator and solenoid enable the valve to be tested to ensure that it will operate properly under emergency conditions. The valve is tested when no differential pressure exists to prevent valve damage and minimize the size of the air actuator. The actuator is not capable of closing the check valve and does not interfere with its operation if HPCI is initiated.

To prevent component or pipe damage due to a water hammer effect on system initiation, the HPCI system is kept pressurized by the line fill pump up to the outboard discharge valve.

10.1.2.11 HPCI Valve Controls

The major HPCI System valves respond to automatic inputs from HPCI initiation, automatic isolation or turbine trip circuits. In addition they may be remotely operated from the control room or the remote shutdown panel.

Except for the inboard steam line isolation valve, power to the valve motors and control circuits is 125 VDC. The inboard steam line isolation valve, which is in the drywell, uses 480 VAC power to operate the valve motor and 125 VDC control power.

10.1.3 System Features and Interfaces

A short discussion of the system features and interfaces this system has with other plant systems is given in the paragraphs which follow.

10.1.3.1 HPCI Flow Controller

The HPCI System utilizes a flow controller to automatically or manually control system flow upon initiation. Selection of either automatic or manual mode is performed by the control room operator. In the automatic mode (normal position), the controller compares actual HPCI System flow (sensed by a flow element on the discharge of the pump) with the desired flow setpoint (adjusted by the operator at the controller). Any deviation between actual and desired flow is then converted into a hydraulic signal which positions the control valves as required to balance the flow signals. In manual mode the operator has direct control of turbine speed. The operator simply adjusts a manual potentiometer, at the flow controller, to create a signal used for positioning the control valves to obtain the desired turbine speed/flow. The HPCI turbine controls are shown in Figure 10.1-3.

10.1.3.2 HPCI Automatic Initiation

The HPCI System is automatically started by either of two initiating signals, high drywell pressure or level 2 reactor vessel water level. The logic (Figure 10.1-4) is arranged such that one-out-of-two-twice from the drywell pressure sensors or from the vessel level sensors will result in a system initiation.

When the initiation signal is received, several actions occur automatically:

- The turbine auxiliary oil pump and vacuum tank blower will start.
- The pump's minimum flow valve will open and then close as its setpoint is reached.
- The turbine stop valve and control

valves open.

- The outboard steam isolation valve and turbine steam supply valve will open.
- The HPCI outboard discharge valve will open and stay open untill the steam supply valve closes or the turbine trips.
- The barometric condenser's vacuum tank condensate pump will start when hotwell level reaches high level.
- The HPCI test valves will receive a close signal.
- The inboard discharge valve receives an open signal even though it is normally open.
- The CST suction valve receives an open signal and, if closed, will open if either suppression pool suction valve is closed.
- When the steam supply valve is fully open, the steam line drain valves to the main condenser and the hotwell drain pump discharge valves to clean radwaste (CRW) close.

After the auxiliary oil pump starts, the oil pressure increases, and the turbine stop valve and control valves begin to open. The stop valve opens fully, while the control valves throttle the steam flow to the turbine to regulate the turbine speed hence pump flow. As the turbine speed continues to increase, pump flow and discharge pressure increase until a flow of 4250 gpm is achieved (flow controller setting). The HPCI System will then run until an automatic isolation or turbine trip shuts down the system. At any time, the operator can take control. However, an initiation signal will not override manual control.

10.1.3.3 Suction Path Transfer

Automatic transfer from the normal condensate storage tank suction to the suppression pool occurs when the condensate storage tank level is low or the suppression pool level is high. The automatic transfer of the suction path on low condensate storage tank level ensures a sufficient water source is available to the HPCI pump. Requiring the suction path to transfer on suppression pool high level ensures a sufficient free air space above the water level exists to allow the accumulation of non-condensible gases, following a LOCA. Automatic suction transfer on low CST level or high suppression pool level takes place by first opening the suppression pool suction valve and then closing the CST suction valve.

10.1.3.4 Manual Initiation

If the operator detects a condition that should have resulted in the automatic initiation, or determines that the HPCI system is needed, manual system initiation is executed. Manual initiation can be performed by depressing the armed Manual Initiation push button, or by manually aligning the system.

The Manual Initiation push button is activated by "arming" the switch (turning the arming collar through 90°) and then depressing the push button. System initiation is the same as that described above with the exception of the starting the Reactor Building Standby Ventilation System which must be done by the operator.

Manual alignment of the system is accomplished in the following order:

1. Start the vacuum pump.
2. Open outboard steam isolation valve.
3. Open the lube oil cooling water valve.
4. Open the steam supply shutoff valve.
5. Start the auxiliary oil pump.
6. Open the injection valve.

7. With the controller in automatic mode the controller will increase turbine speed until a flow rate of 4250 gpm is reached.

10.1.3.5 Test Features

Pump operability and flow tests are done by manually (without an initiation signal) starting the system as outlined above with the exception of opening the injection valve and placing the HPCI flow controller in manual and minimum. The test throttle valve is opened at the same time as pump speed is increased until the desired test conditions are achieved. During pump operability and flow test the water is circulated back to the CST via the two test return isolation valves.

10.1.3.6 Automatic Isolation

Because the steam supply line to the HPCI turbine is part of the nuclear system process barrier, automatic isolation signals are employed to isolate the HPCI System. By isolating the HPCI System upon detection of a leak, the release of radioactive material is minimized. The HPCI System will automatically isolate from any one of the following signals:

- HPCI steam supply pressure low (100 psig).
- HPCI steam line flow high (290%).
- HPCI area leak detection, 155°F or 193°F depending on elevation of line.
- High pressure between turbine exhaust rupture diaphragms (10 psig).
- Manual (only if the system has been automatically initiated).

Once an isolation signal is generated, from both the A and B isolation logic, the following automatic actions occur:

- The inboard and outboard steam supply and their bypass valves close.
- The HPCI pump suction valve from the suppression pool closes, if open.
- The HPCI turbine trips.

If only one isolation logic is actuated either the inboard or outboard isolation valves will close. For example if the A isolation logic is actuated the inboard steam isolation valve and its bypass will close.

10.1.3.7 Automatic Turbine Trips

The HPCI turbine is automatically shutdown, by closing the turbine stop and control valves, to protect the physical integrity of the HPCI System. If any of the following conditions are detected the HPCI System will automatically trip:

- Turbine exhaust pressure high (150 psig).
- Turbine overspeed (125% rated).
- Pump suction pressure low (15" Hg vacuum).
- High reactor water level (+56.5").
- Any isolation signal.
- Manual

In addition to closing the turbine stop valve, injection valve and control valves, the minimum flow valve to the suppression pool also receives a close signal when the turbine trips. The isolation trips must be manually reset; the other trip signals will automatically reset. The turbine trip logic is shown in Figure 10.1-5.

10.1.3.8 System Interfaces

A short discussion of interrelations this system has with other plant systems is given in the paragraphs which follow:

Condensate Storage Tank

The condensate storage tank (CST) is the normal suction source for the HPCI System. Additionally the CST can be used for testing of the HPCI System.

Main Steam System (Section 2.5)

The Main Steam System provides the HPCI System with steam through a penetration from the "A" main steam line.

Condensate and Feedwater System (Section 2.6)

The HPCI System uses the "B" feedwater line to inject water into the reactor vessel.

Reactor Core Isolation Cooling System (Section 2.7)

The HPCI System has a functional interface with the RCIC System in that it backs up the function of the RCIC System by supplying high quality high pressure makeup to the reactor under isolation conditions. Additionally, the RCIC and HPCI systems share a suction line from the CST and a test line to the CST.

Primary Containment (Section 4.1)

The suppression pool is the alternate source of water for the HPCI pump. It also condenses the HPCI turbine exhaust steam and the HPCI pump minimum flow water is routed to the suppression pool.

Reactor Building Standby Ventilation System (Section 4.3)

The Reactor Building Standby Ventilation System removes and processes the noncondensible gases from the HPCI turbine barometric condenser.

Emergency AC Power System

The inboard steam line isolation valve is powered from the division 1 emergency power bus. Division 2 provides power to the loop level pump.

DC Power System

The 125 VDC division 2 power supply provides motive force for motor operated valves, auxiliary oil pump, and the mechanical vacuum pump.

Automatic Depressurization System

The HPCI System has a functional interface with the ADS since the ADS backs up the ECCS function of the HPCI system in the event it failed to perform its intended function.

10.1.4 Summary

Classification - Safety related system Engineered Safety Feature System.

Purpose - To provide makeup water to the reactor vessel for core cooling under small and intermediate sized loss of coolant accidents. To backup the RCIC system.

Components - Steam supply isolation valves; steam supply shutoff valve; turbine stop valve; turbine control valves; turbine; turbine auxiliaries; turbine exhaust path; pump suction path; pump assembly; pump discharge path; valve controls.

System Interfaces - Condensate Storage Tank; Main Steam System; Condensate and Feedwater System; Reactor Core Isolation Cooling System; Primary Containment System; Reactor Building Standby Ventilation System.

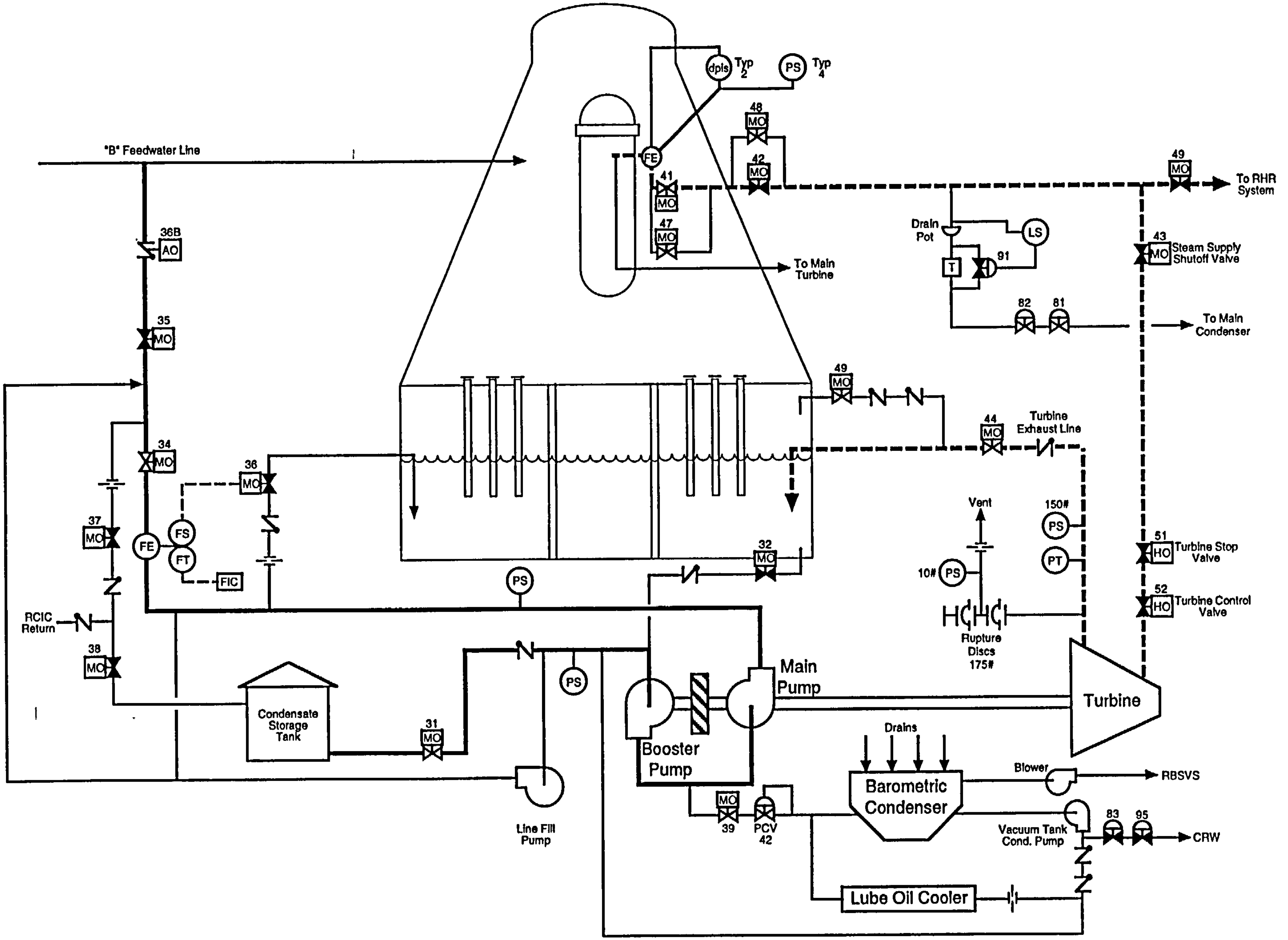


Figure 10.1-1 High Pressure Coolant Injection System

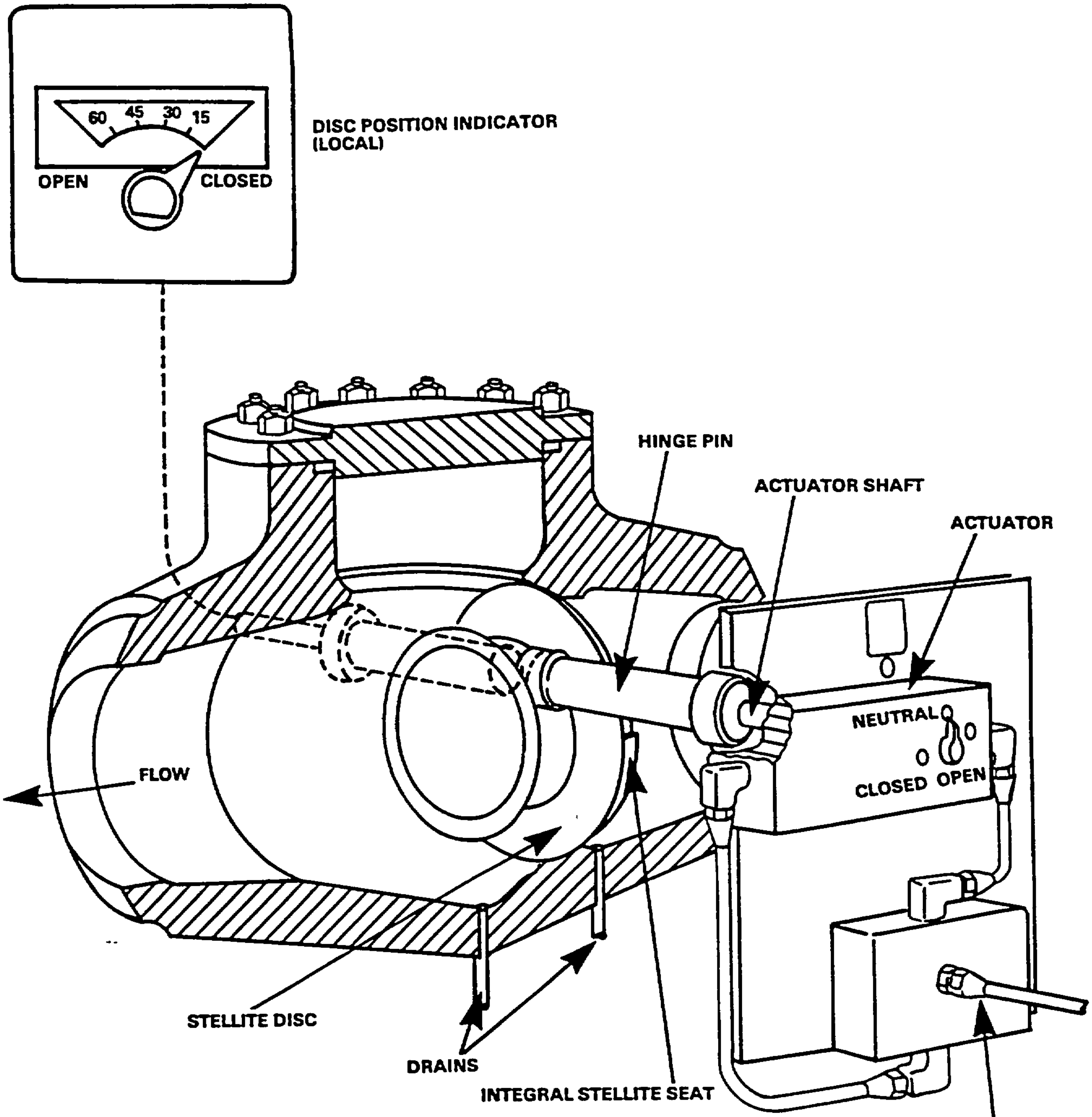


FIGURE 10.1-2 TESTABLE CHECK VALVE

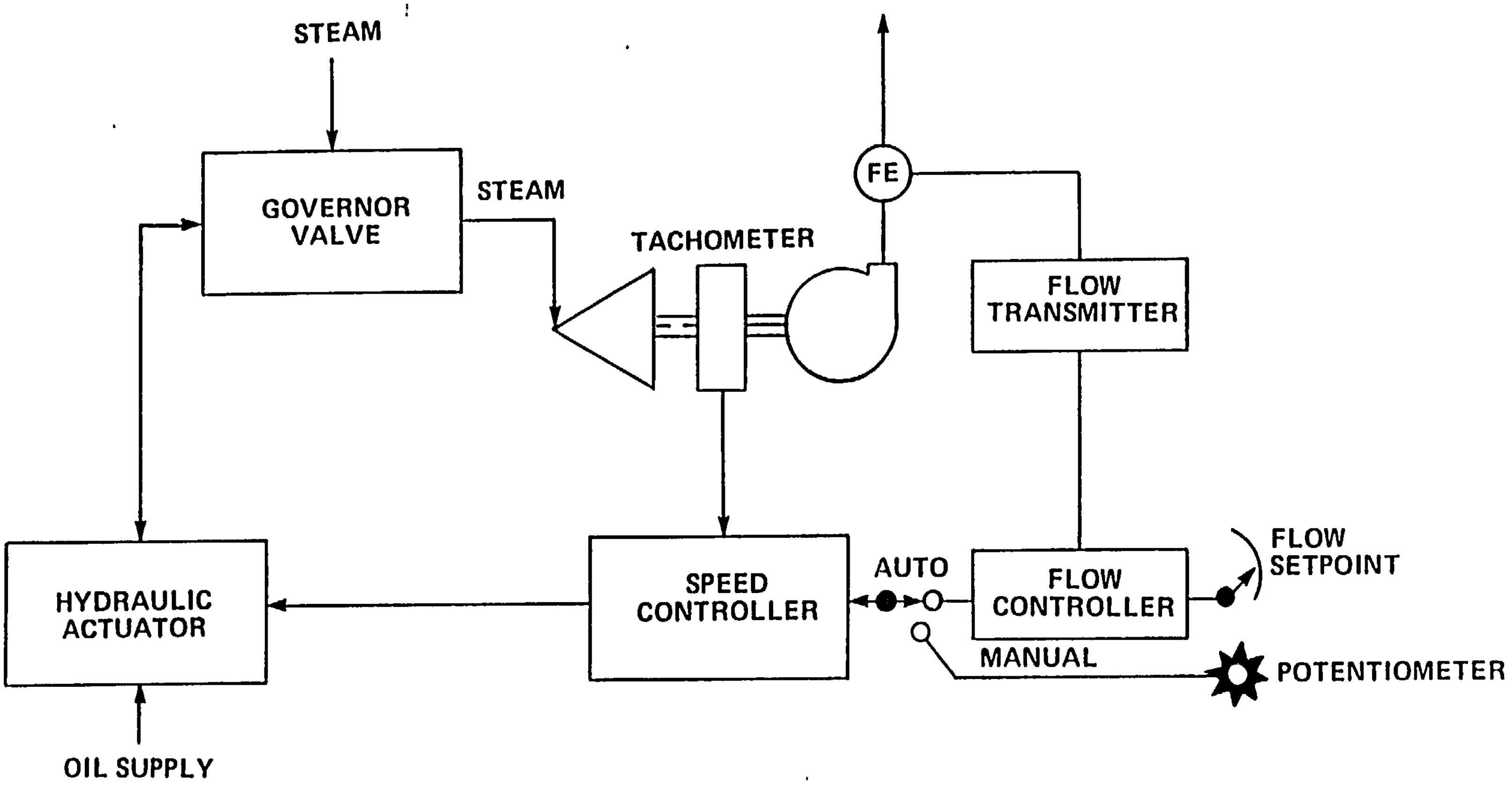


FIGURE 10.1–3 HPCI TURBINE CONTROL DIAGRAM

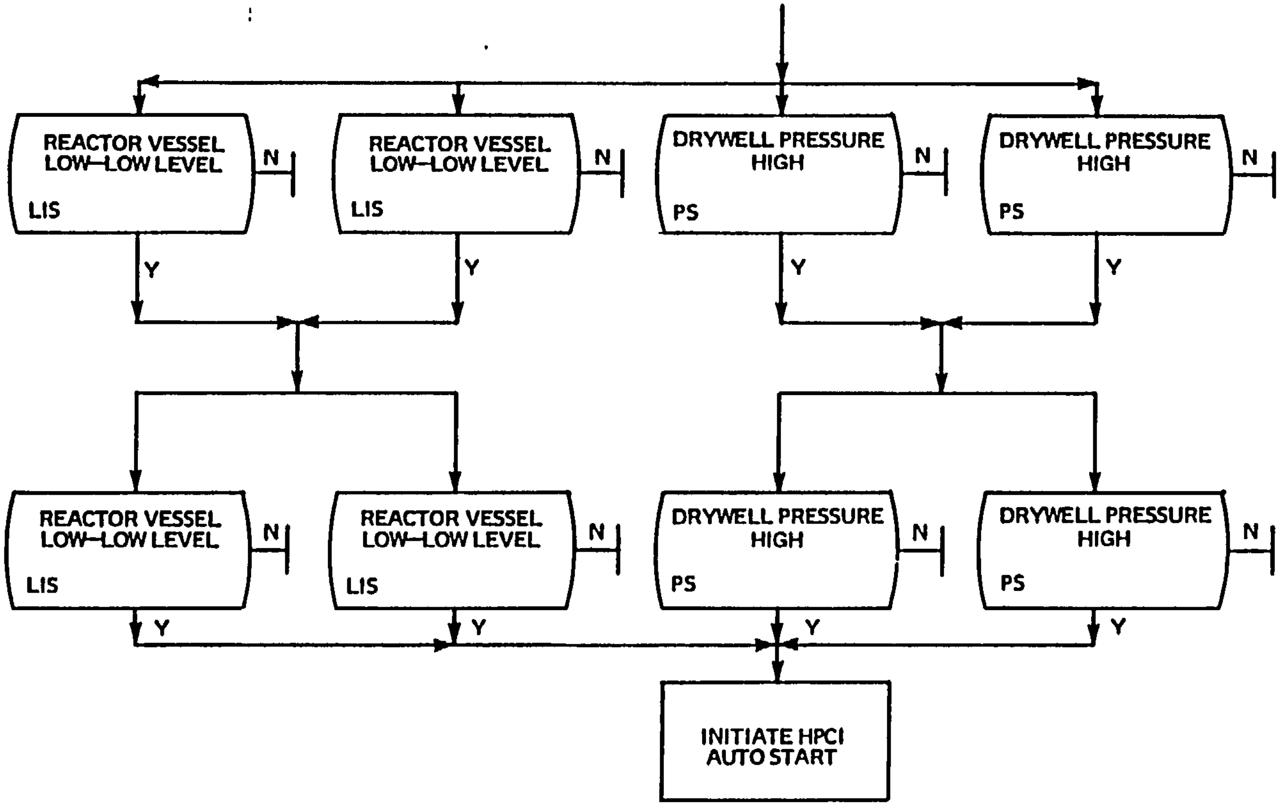
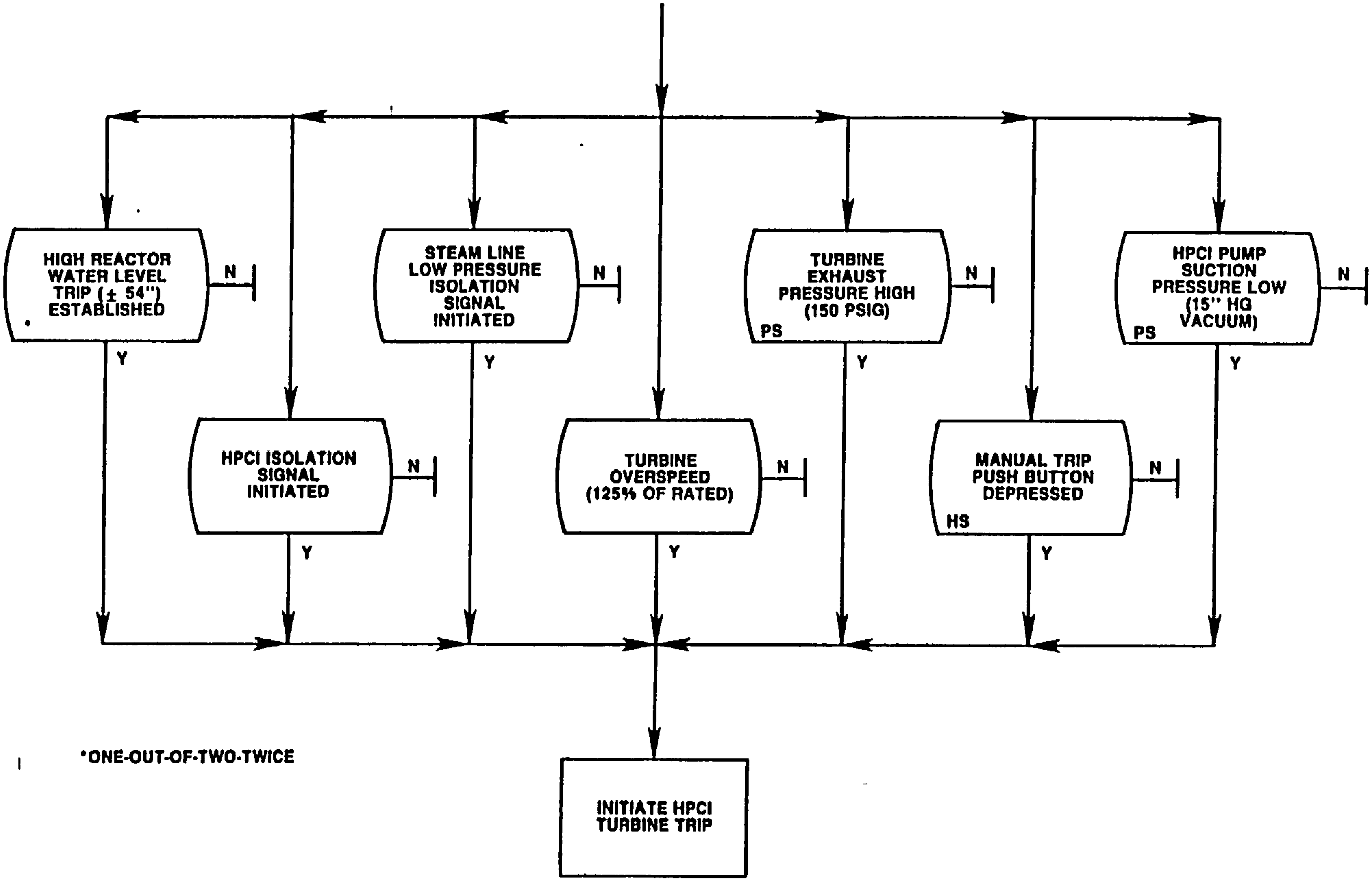


FIGURE 10.1–4 HPCI AUTOMATIC START INITIATION



*ONE-OUT-OF-TWO-TWICE

Figure 10.1-5 HPCI Turbine Trip Logic

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Chapter 10.2

Automatic Depressurization System

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10.2 AUTOMATIC DEPRESSURIZATION SYSTEM

Learning Objectives

1. State the systems purpose.
2. List the automatic initiation signals.
3. List the manual signals that will open the SRVs.
4. Explain the system's response to an automatic initiation.
5. Explain the manual override capability of the system.
6. Explain the interrelationships this system has with the following systems:
   - Main Steam System
   - Primary Containment System
   - ECCSs
   - DC Power System

10.2.1 Introduction

The purpose of the Automatic Depressurization System (ADS) is to depressurize the reactor vessel so that the low pressure emergency core cooling systems can provide cooling for small or intermediate size loss of coolant accidents, should the High Pressure Coolant Injection System fail.

The functional classification of the ADS System is that of a safety related system. Its regulatory classification is an engineered safety feature system.

The Automatic Depressurization System consists of redundant signal logic arranged in two separate channels that control solenoid operated air pilot valves on each safety/relief valve (SRV) assigned to the ADS function. Seven of the eleven SRV's receive input signals from the ADS logic circuits. The ADS associated SRV's open automatically, if required to provide reactor vessel depressurization for events involving small or intermediate breaks in the nuclear system process barrier, if the High Pressure Coolant Injection System is not available or cannot recover vessel level.

The signal for the ADS associated SRV's to open and depressurize the primary system sufficiently to permit the low pressure coolant injection (LPCI) mode of the Residual Heat Removal (RHR) System, and Core Spray (CS) Systems to operate, is based on signals from reactor vessel water level and confirmation of output pressure from at least one LPCI pump and one CS pump. The ADS is initiated by coincidence of low reactor vessel water level provided that a low pressure emergency core cooling source is available and a 105 second time delay has expired.

The SRV pilot valves control the pneumatic pressure applied to an air operating cylinder which in turn controls the operation of the SRV in the ADS mode. An accumulator is included with each ADS valve pneumatic control equipment to store pneumatic energy for valve operation. The accumulator operates the ADS valve following failure of the normal pneumatic supply to the valve.

Cables from the ADS associated logic sensors lead to two separate logic channels. Separate station batteries power the electrical control circuitry. The power supplies for the redundant logic are separated to limit the effects of electrical failures. Electronic components in the control system logic energize to cause the SRV's to open.

10.2.2 Component Description

The major components of the Automatic Depressurization System are discussed in the paragraphs that follow.

10.2.2.1 Safety/Relief Valves

The ADS uses seven of the safety/relief valves (SRV's) mounted on the main steam lines to carry out its function. The SRV's are dual actuated types, mechanically self actuating under conditions of high reactor pressure (safety mode), and electro pneumatically actuated via control switches, or by the ADS under LOCA conditions. Figure 10.2-1 shows the control arrangement for the ADS associated SRV's. Operation of the SRV's by the ADS logic is discussed with the Main Steam System.

10.2.2.2 Pneumatic Supply

Each of the safety/relief valves provided for automatic depressurization is equipped with an accumulator and check valve (Figure 10.2-1). The check valve is used to isolate the accumulator from the pneumatic supply upon loss of the normal supply.

The accumulators assure that the ADS valves can be opened and held open following failure of the pneumatic supply to the ADS valves. They are sized to contain sufficient air for a minimum of five valve operations.

10.2.3 System Features and Interfaces

A short discussion of the system features and interface this system has with other plant systems is given in the paragraphs which follow.

10.2.3.1 Automatic Initiation

Automatic initiation of the ADS is completed upon termination of a 105 second time delay concurrent with low reactor vessel water level, and one LPCI or one CS pumps running. The basic ADS logic is shown in Figure 10.2-2.

The reactor vessel water level signals, level 1 and 3, indicate that the fuel is in danger of becoming overheated. The low water level signal level 3 is only a confirmatory signal to prevent any spurious system actuation. The level 1 water level signal would not normally occur unless the HPCI System has failed.

The low pressure ECCS pump running signals are provided to ensure that there is reactor vessel inventory makeup available prior to completing the logic and allowing the seven ADS/SRV,s to open.

The 105 second time delay allows the HPCI system time to restore reactor vessel water level. If during the 105 second period, reactor water level signals clear or the low pressure ECCS pumps are not running the 105 second timer will automatically reset. The operator can use a timer reset switch to delay automatic opening of the SRV's, when in his judgment, ADS is not needed. The timer reset pushbutton switch, when depressed, causes the timer to reset, if the initiation signals are still present the timer will restart at time zero and continue to time out. The 105 second timer completing its cycle seals in the water level signals until the timer reset pushbutton is depressed.

The ADS logic, shown in Figure 10.2-2, consists of two channels. Either channel can initiate ADS when the logic in that channel is satisfied. The two redundant logic channels are arranged such that there are two subchannels in each logic channel: subchannels A and C in logic channel I and subchannels B and D in logic channel II. All the logic requirements of both subchannels, A and C or B and D, must be satisfied for the corresponding logic channel to carry out the ADS function.

10.2.3.2 Manual Backup for ADS

Each of the seven ADS valves is equipped with a two position control switch, close/auto and open, located in the control room. The control room operator can individually open any ADS valve or any combination of the eleven SRVs to manually blow down reactor pressure should he desire to do so.

10.2.3.3 Component Interlocks

Once the seven ADS valves have been opened by ADS actuation, they will not close unless, the actuating pneumatic supply is depleted, loss of DC power or ADS logic is manually reset by the control room operator.

Should the required ADS automatic initiation conditions exist for 105 seconds after the ADS logic is manually reset by the control room operator, the ADS valves will reopen.

During accident conditions automatic initiation of the ADS system is not always desirable even though an initiation signal is present. Under these conditions, the Emergency Operating Procedures will direct the operator to inhibit automatic initiation of the ADS.

10.2.3.4 System Interfaces

The interfaces this system has with other plant systems are discussed in the paragraphs which follow:

Main Steam System (Section 2.5)

The ADS uses seven of the safety/relief valves, which are part of the Main Steam System, to carry out its function.

Primary Containment System (Section 4.1)

The safety/relief valves use the suppression pool as a heat sink.

DC Power System (Section 9.4)

The DC Power System provides power to the ADS logic and to the ADS solenoid valves.

High Pressure Coolant Injection System (Section 10.1)

The ADS has a functional interface with the HPCI System since the ADS backs up the ECCS function of the HPCI in the event of the HPCI System failure so that small and intermediate sized LOCA's can be mitigated.

Core Spray System (Section 10.3)

The ADS has a functional interface with the CS System with respect to integrated ECCS performance to mitigate the consequences of small or intermediate sized LOCA's (in conjunction with the RHR System LPCI mode) when the HPCI System fails.

Residual Heat Removal (Section 10.4)

The ADS has a functional interface with the RHR System LPCI mode with respect to integrated ECCS performance to mitigate the consequences of small or intermediate sized LOCA's (in conjunction with the CS System) when the HPCI System fails.

10.2.4 Summary

Classification - Safety related system, Engineered Safety Feature System.

Purpose - To depressurize the reactor vessel so that the low pressure emergency core cooling systems can provide cooling for small or intermediate size loss of coolant accidents.

Components - Safety/Relief Valves, pneumatic supply, logic.

System Interfaces - Main Steam System, Primary Containment System DC Power System, High Pressure Coolant Injection System, Core Spray, Residual Heat Removal System.

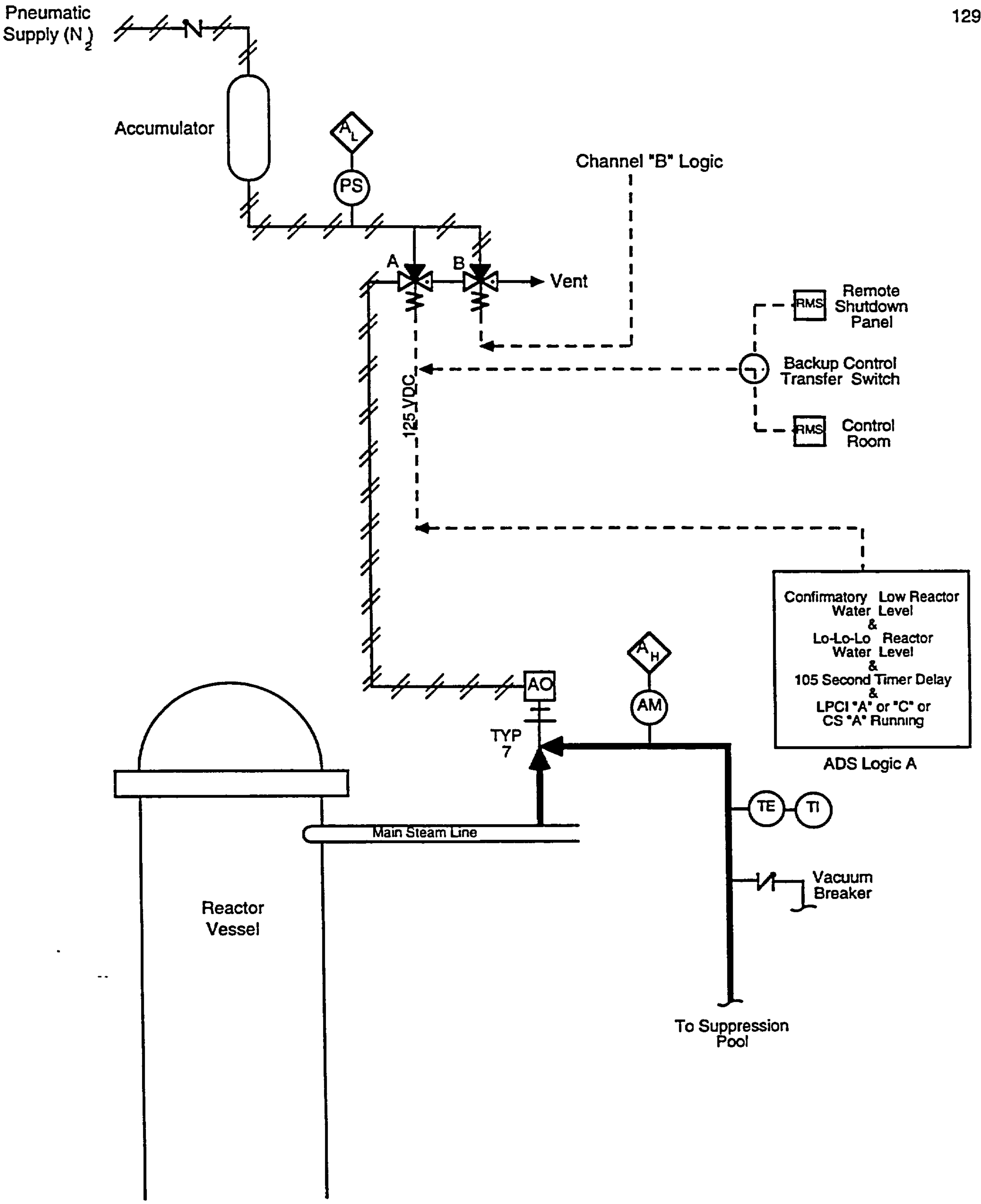
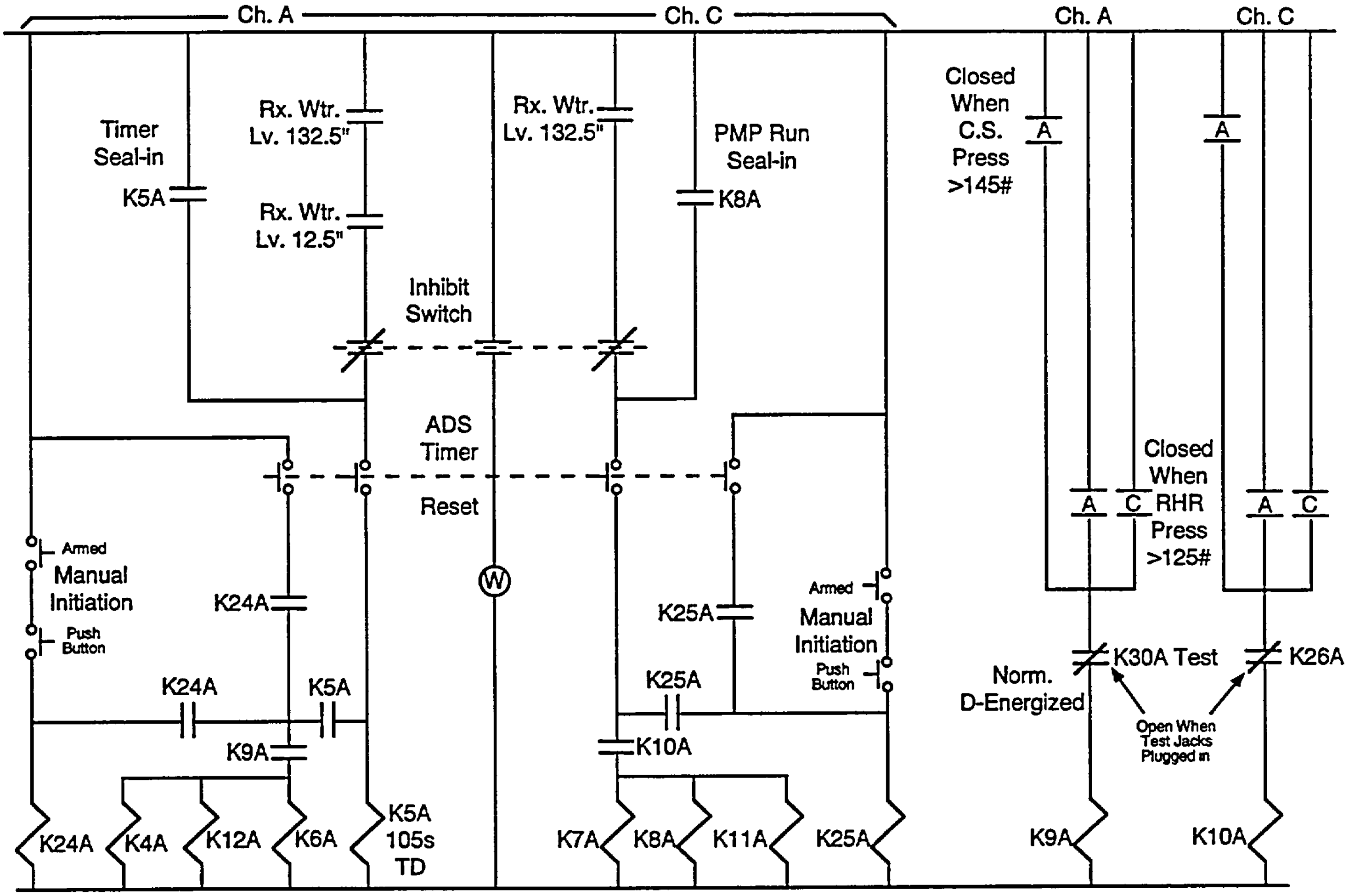


Figure 10.2-1 Automatic Depressurization System



K5A - Energized when 105 sec. timer times out, creates a seal in around Rx lvl. init. init. inputs.

K6A & K7A - Both must be energized to operate the "A" solenoids.

K9A & K10A - Energizes when "A" C.S. pump disch. pressure >145# or when "A" or "C" RHR pump discharge pressure >125#.

K24A & K25A - Energized during manual initiation.

Inhibit Switch - Prevents 2.5" & -132.5 Rx water level initiation input signal.

Timer Reset - Resets timer & will abort initiation.

Figure 10.2-2 ADS Auto-Init. & Man. Init. Logic "A" (B Similar)

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Chapter 10.3

Core Spray System

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10.3 CORE SPRAY SYSTEM

Learning Objectives

1. State the system's purpose.
2. Explain the major system flow paths.
3. Provide the purpose(s) of the major system components.
   - Pumps
   - Minimum flow valve
   - Injection valve
   - Testable check valve
   - Spargers
4. List the automatic initiation signals.
5. Explain the system's response to an automatic initiation signal.
6. Explain the interrelations this system has with the following systems:
   - Reactor Vessel System
   - Primary Containment System
   - ECCSs
   - Emergency AC Power Systems

10.3.1 Introduction

The purpose of the Core Spray System is to provide low pressure makeup water to the reactor vessel for core cooling under loss of coolant accident (LOCA) conditions.

The functional classification of the Core Spray System is that of a safety related system. Its regulatory classification is an engineered safety feature system.

The Core Spray System (Figure 10.3-1) consists of two separate and independent 100% capacity subsystems capable of delivering 4725 gpm at 274 psig discharge pressure. Each loop contains the following components: one low pressure pump, minimum flow line, test line, spray sparger, and the associated motor operated valves and instrumentation necessary to perform its purpose.

The Core Spray System delivers water from the suppression pool into the reactor vessel through spray nozzles mounted on spargers located directly above the fuel assemblies. Core cooling is accomplished by spraying water on top of the fuel assemblies. The water runs down the sides of fuel channels providing a heat sink for the heat radiated from the fuel rods. The heat removed by water evaporation within the fuel assemblies also provides some convection cooling.

The Core Spray System will automatically initiate upon receipt of either a level 1 reactor vessel water level signal or a high drywell pressure.

The system is provided with the means to periodically test the operational capability to the system. A minimum flow line is also provided to create a flow path to remove pump heat under situations where the discharge and test valves are closed. The motor operated valves automatically line up for the emergency mode of operation upon a system initiation when in the test mode.

The RHR and CS line fill system pumps maintain the CS and the other divisional RHR system filled with water from the suction of the CS pump to the injection isolation valve. This is done to reduce the water hammer hydraulic effect and decrease the delay time from initiation signal to actual water flow into the reactor vessel.

10.3.2 Component Description

The major components of the Core Spray System are discussed in the paragraphs which follow.

10.3.2.1 Suction Path

The normal water supply for the Core Spray System is provided by the suppression pool through a suction strainer into a 14 inch line with a motor operated suction valve to the suction of the pump. The suction valves have no automatic features.

When the reactor is shutdown, the core spray pump suction path can be manually transferred from the suppression pool to the condensate storage tank. With clean water from the condensate storage tank, a test can be conducted in which water can be sprayed on top of the core. This testing verifies the integrity of the spray pattern and removes any high level radioactive corrosion products from the spray spargers.

10.3.2.2 Core Spray Pumps

There is a total of two core spray pumps in the Core Spray System; one for each core spray loop. Each pump has a 100% loop flow capacity and is powered by an independent power source. Each core spray pump is a single stage centrifugal pump designed to deliver 4725 gpm at a reactor vessel pressure 274 psi greater than suppression pool pressure. Lubricating oil for the pump motors is cooled by the Reactor Building Service Water System. Power to the pump motors is supplied from the 4160 Emergency Distribution System.

10.3.2.3 Discharge Path

The main discharge path for the pumps goes through a discharge check valve, flow element and then to the discharge valves located just outside the primary containment. It then passes through penetrations in the containment and drywell walls.

Inside the primary containment, each discharge line has an air operated check valve to prevent reverse flow in the Core Spray System. The testable feature, which proves the valves operability, incorporates an air operator mounted on the valve. In addition, a motor operated bypass valve is provided to equalize around the air operated check valve prior to check valve opening. The valves are similar to those used by the High Pressure Coolant Injection System.

Downstream of the check valve is a manual isolation valve which isolates the discharge header so that maintenance can be accomplished. It also allows for independent hydrostatic testing of the discharge line and reactor vessel. A limit switch on this manual isolation valve provides an indication in the control room when the valve is full open. The discharge lines enter the reactor vessel approximately 180° apart. Once inside the reactor vessel, each line tees and is routed 90° horizontally. Each line is then directed downward along the vessel wall and then inward where it penetrates the shroud just above the core outlet plenum. After entering the shroud each line again tees to form two semicircular spray headers (spargers), shown in Figure 10.3-2.

10.3.2.4 Line Fill

The purpose of the line fill is to maintain the core spray system full of water, from the pump discharge check valves to the last normally closed valve in the injection path. With the system being maintained full of water, the probability of water hammer on system initiation is greatly reduced. The line fill pump supplies a Residual Heat Removal system loop and one Core Spray system loop with 15 gpm at 55 psig.

10.3.2.5 Motor Operated Valves

Each motor operated valve in the Core Spray System, is powered from the same electrical divisional power that supplies power to the pumps system (i.e.: System I from division I, System II from division II). All motor operated valves in both system I and II can be operated from the control room.

10.3.3 System Features and Interfaces

A short discussion of system features and interfaces this system has with other plant systems is given in the paragraphs which follow:

10.3.3.1 Normal Operation

During normal plant operation, the Core Spray System is in a standby status as indicated on Figure 10.3-1, ready for automatic initiation when required.

10.3.3.2 Automatic Initiation

The Core Spray System will automatically align valves and start pumps upon receiving either of the two initiation signals: level 1 reactor vessel water level or high drywell pressure.

The operation of the system in response to an initiation signal is as follows:

- The test line motor operated valves are closed and interlocked closed.
- If normal ac power is available the core spray pumps will start after a seven second time delay to prevent overloading the AC power system.
- When reactor vessel pressure decreases to a value of 465 psig, the injection valves receive a permissive to open signal.

Actual injection into the reactor vessel will begin when reactor pressure is reduced to less than pump shutoff head (333 psig) at the pump discharge.

- When injection flow reaches 650 gpm the minimum flow valve is signal to close. Flow will reach 4725 gpm when reactor pressure decreases to 113 psig above suppression pool pressure. The restricting orifice in the injection line prevents the CS pump from going into runout as the reactor further depressurizes.

10.3.3.3 Manual Override Features

With the system in operation following an automatic initiation, the operator, using procedures and his judgement, can override some of the automatic functions by turning the pump control switch to the off position or by throttling the discharge valve. Either of these actions produces the appropriate indication and alarms to inform the operator of his actions. Once the system is shutdown, by closing a discharge valve or stopping the pump(s), the system will not automatically restart unless the initiation logic is manually reset.

10.3.3.4 System Testing

During plant operation, periodic testing of the core spray pumps and valves are required to ensure the system will perform as designed. Surveillance testing of the core spray pumps is accomplished by recirculating the suppression pool water, via the test return line, to ensure required flow rates are obtainable. Surveillance testing of the motor operated valves is accomplished by cycling the valves and timing the stroke time, when required.

10 3.3.5 System Interlocks

The minimum flow valves automatically open on low flow (<650 gpm) and automatically close when flow exceeds 650 gpm. The test valves receive a continuous close signal whenever there is an initiation signal present. Discharge valves receives an open signals on system automatic initiation when reactor pressure is less than 465 psig. Once open following system automatic initiation, the inboard discharge valves can be throttled to adjust system flow.

10.3.3.6 Core Spray System Leak Detection

A detection system is provided to continuously confirm the integrity of the core spray piping between the inside of the reactor vessel and the core shroud. A differential pressure switch measures the pressure difference between the bottom of the core and the inside of the core spray sparger pipe just outside the reactor vessel. The principle of leak detection (Figure 10.3-3) is as follows. Normal operating reactor vessel pressures at full rated steam flow are such that:

- Pressure (1) is greater than (5) due to the jet pump driving force.
- Pressure (1) is greater than (2) & (3) due to the drop across the core.
- Pressure (3) is greater than (4) by ~7 psi due to the drop across the steam separators.
- Pressure (4) is greater than (5) by ~7" of water due to the drop across the steam dryer.

Thus under normal conditions, the low leg is reading above core plate pressure (2) and the high leg is reading separator inlet pressure (3) plus the height of the cooler water from the core spray piping to the differential pressure switch. This results in a normal reading at full power of ~3.5 psid.

If the Core Spray piping were to break outside of the shroud, the low leg would still read above core plate pressure (2) while the high leg would read pressure in the downcomer (5). The difference in pressure at full flow would be about 7 inches water gauge the pressure drop across the dryers and separators. An alarm sounds at 2 psid decreasing which indicates a possible pipe rupture outside the shroud.

10.3.3.8 System Interfaces

A short discussion of interfaces this system has with other plant systems is given in the paragraphs which follow:

Reactor Vessel System (Section 2.1)

The Core Spray System injection piping penetrates the reactor vessel and core shroud. The core spray spargers are mounted inside the core shroud.

Primary Containment System (Section 4.1)

The suppression pool, which is part of the Primary Containment System, is the normal suction for the core spray system. Additionally, the core spray minimum flow lines and full flow test lines are connected to the suppression pool.

Emergency AC Power System (Section 9.2)

The Core Spray System receives reliable electrical power for system operation from the Emergency AC Power System.

Reactor Building Service Water System (Section 11.2)

The Reactor Building Service Water System supplies cooling water to the core spray pump motors and the core spray room coolers.

10.3.4 Summary

Classification - Safety related system; Engineered safety feature system.

Purpose - To provide low pressure makeup water to the reactor vessel for core cooling under loss of coolant accident (LOCA)conditions.

Components - Suction path; core spray pumps; motor operated valves; discharge path; Keep fill line.

System Interfaces - Primary Containment System; Reactor Vessel System; Standby Auxiliary Power System; Reactor Building Service Water System

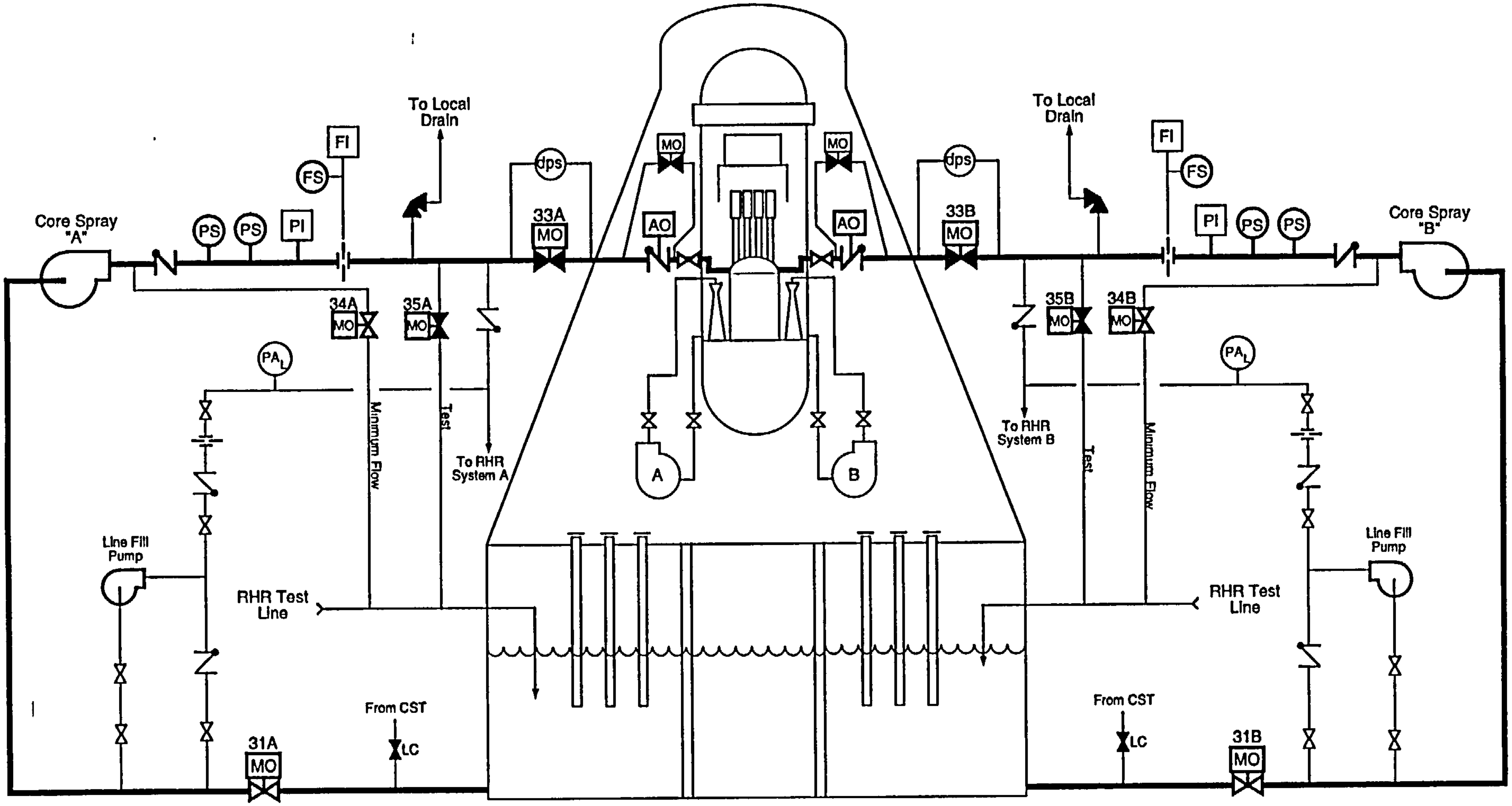


Figure 10.3-1 Core Spray Systems

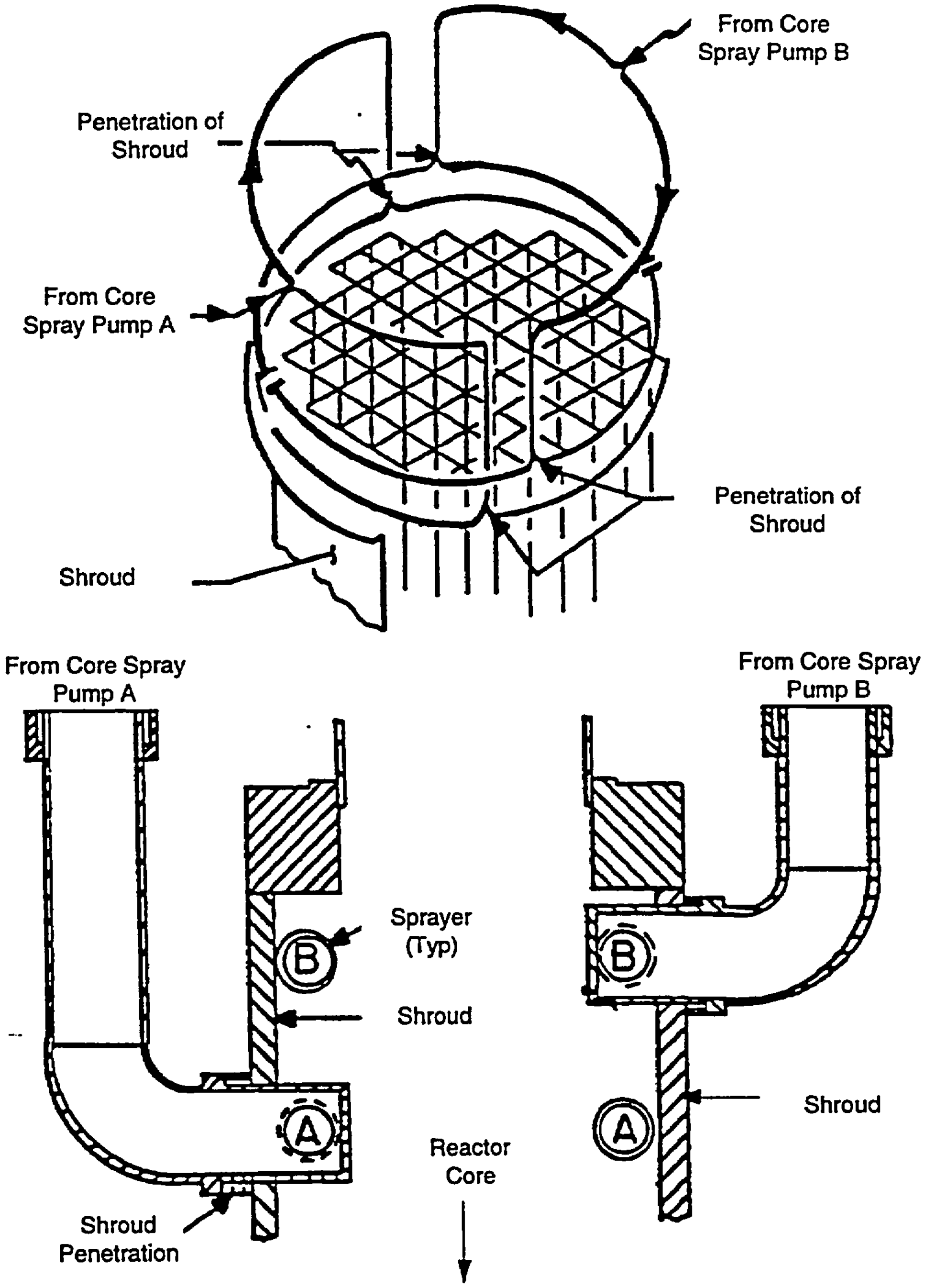
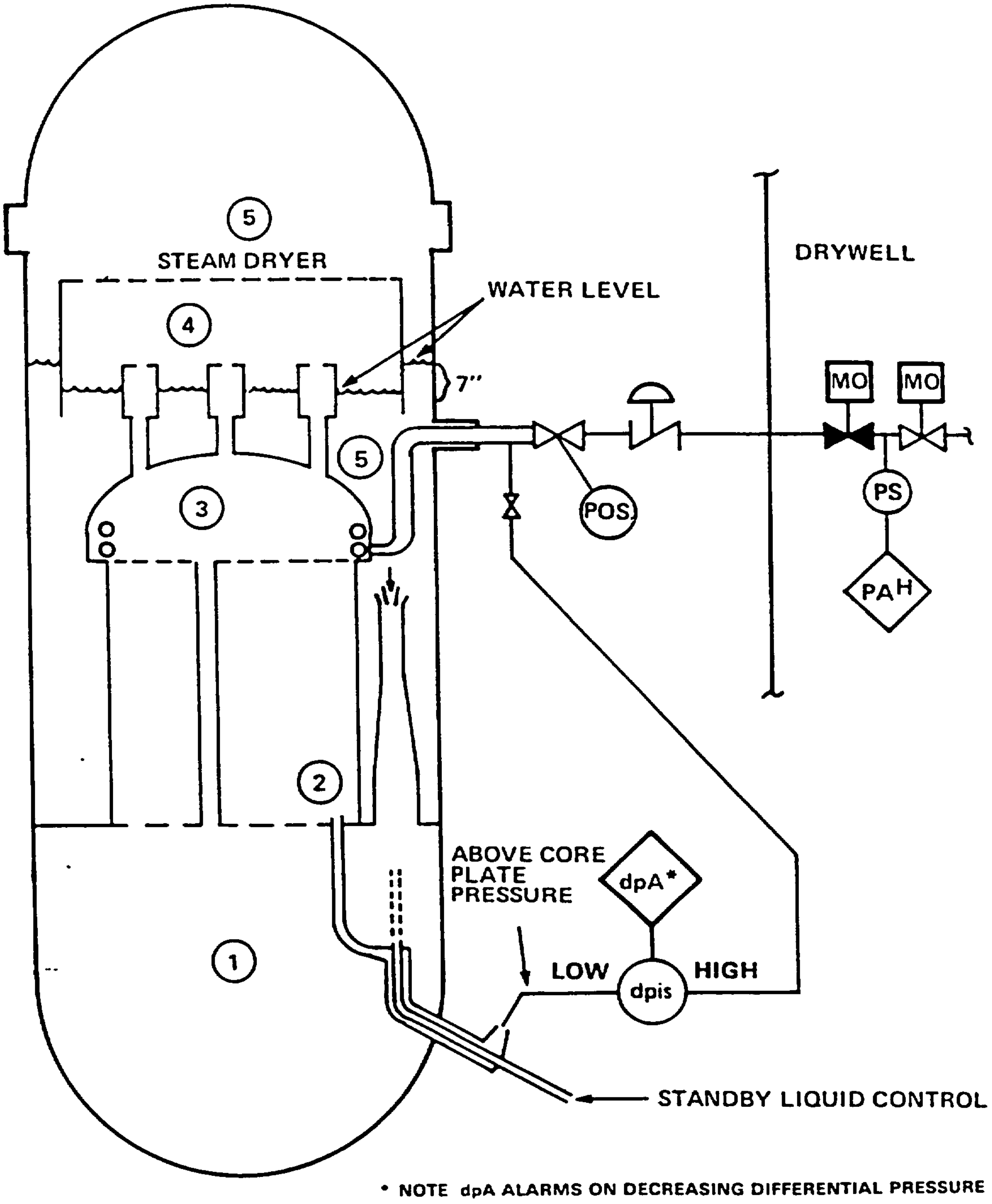


Figure 10.3-2 Vessel Internal Piping



* NOTE dpA ALARMS ON DECREASING DIFFERENTIAL PRESSURE

Figure 10.3-3 Core Spray System Pipe Break Detection Instrumentation

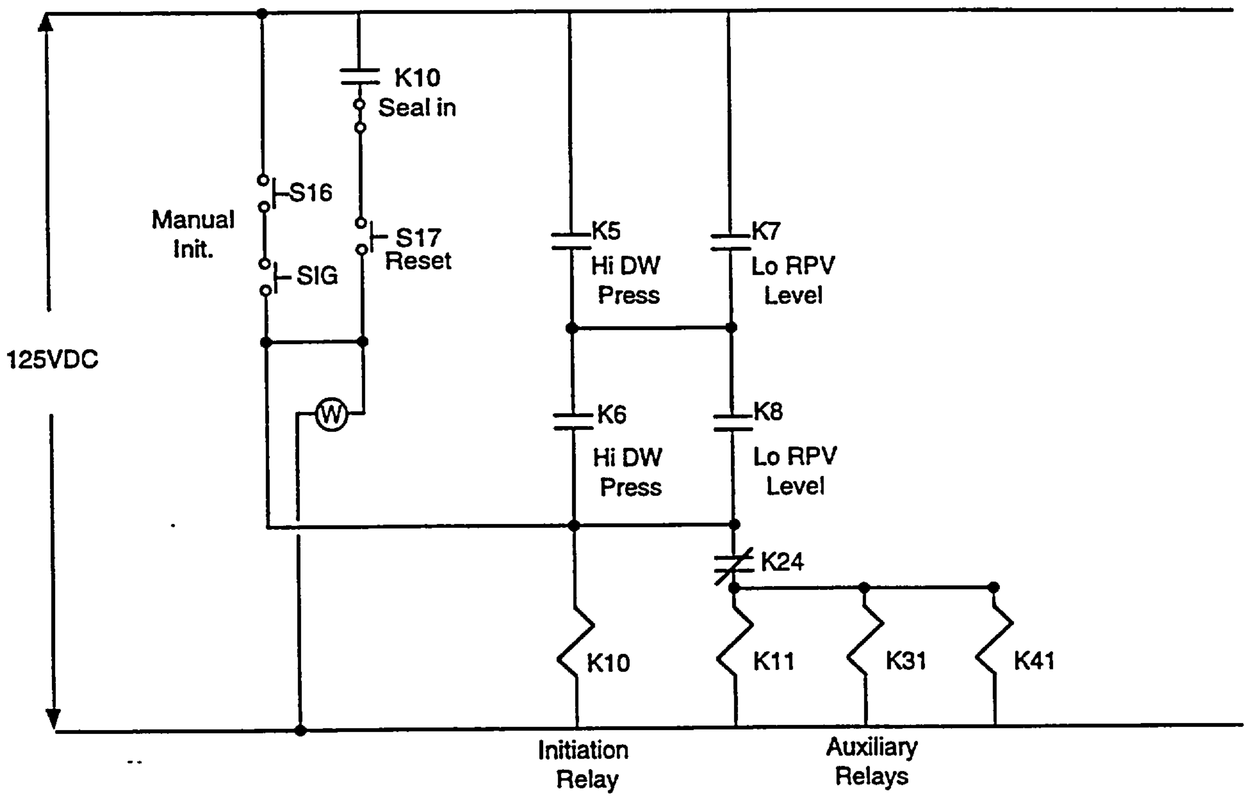


Figure 10.3-4 Core Spray Initiation Logic

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Chapter 10.4

Residual Heat Removal System

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10.4 RESIDUAL HEAT REMOVAL SYSTEM

Learning Objectives:

1. State the system's purpose.
2. Explain the purpose of the major system components.
    - Suction valves (suppression pool and shutdown cooling)
    - RHR pumps
    - Minimum flow valve
    - RHR heat exchanger
    - Containment spray spargers
    - Line fill
3. Explain the flow path for each mode of operation.
4. List the automatic and manual initiation signals for Low Pressure Coolant Injection Mode of operation.
5. Explain the interrelation this system has with the following systems:
    - Primary Containment
    - Reactor Vessel System
    - Other ECCSs
    - Emergency AC Power System

10.4.1 Introduction

The purposes of the Residual Heat Removal (RHR) System are:

Low Pressure Coolant Injection Mode

To restore and maintain desired water level in the reactor vessel following a Loss of Coolant Accident.

Containment Spray Mode

To condense steam and reduce airborne activity in the primary containment following a Loss of Coolant Accident.

Suppression Pool Cooling Mode

To remove heat from the suppression pool.

Shutdown Cooling and Head Spray Mode

To remove decay heat from the reactor core following a reactor shutdown and to remove residual heat from upper reactor vessel internals during a cooldown.

Steam Condensing Mode

To condense reactor steam and return the condensate back to the reactor vessel via the Reactor Core Isolation Cooling System.

Standby Coolant Supply Mode

To provide a means of flooding the primary containment.

Fuel Pool Cooling Mode

To provide fuel pool cooling when the capacity of the Fuel Pool Cooling and Cleanup system is not adequate.

The functional classification of the RHR System is that of a safety related system. Its regulatory classification is an Engineered Safety Feature (ESF) System.

The RHR System, shown in Figures 10.4-1 and 10.4-2, is a multipurpose system which has seven operational modes, each with a specific purpose. The RHR System consists of two separate and independent piping loops designated System I and System II. Each loop contains two pumps, one heat exchanger and associated piping, valves, and instrumentation.

The low pressure coolant injection (LPCI) mode is the dominant mode and normal valve lineup configuration of the RHR System. The LPCI mode operates automatically to restore and, if necessary, maintain the reactor vessel coolant inventory to preclude fuel clad temperatures in excess of 2200°F and subsequent energy release due to a metal-water reaction following a loss of coolant accident. During LPCI operation, the RHR pumps take water from the suppression pool and discharge to the reactor vessel via the Recirculation System's discharge piping.

The containment spray and suppression pool cooling modes of the RHR system are placed in operation by operator action. Containment spray is used to condense steam and reduce airborne activity in the primary containment following a loss of coolant accident. Suppression pool cooling is used to maintain suppression pool temperature within specified limits during normal plant operating conditions and to limit the temperature to <170°F following a loss of coolant accident. Water is pumped through the RHR heat exchanger to transfer heat from the suppression pool water to the Reactor Building Service Water System and then diverted for containment spray or suppression pool cooling.

The shutdown cooling and head spray mode is placed in operation during a normal reactor shutdown and cooldown. When reactor temperature/pressure has decreased to a sufficiently low value, the RHR System is placed in the shutdown cooling and head spray mode of operation. This mode is capable of completing the cooldown to 125°F in less than 20 hours and maintaining the water temperature below 125°F to accommodate refueling operation. Water is removed from the "B" recirculation loop suction piping, cooled by the RHR heat exchanger, and then discharged back to one of the recirculation loop discharge lines.

Steam Condensing mode is placed in operation when the reactor is isolated from its primary heat sink, the main condenser, and it is desirable to limit SRV operation for cooldown purposes. Steam is removed from the High Pressure Coolant Injection System steam supply line and directed to one or both of the RHR heat exchangers through pressure control valves and break down orifices. In the heat exchanger the steam is condensed and pumped back to the reactor vessel by the Reactor Core Isolation Cooling System.

The standby coolant supply mode provides an unlimited supply of water for flooding the primary containment if required for post loss of coolant accident recovery operations. Containment flooding is accomplished by connecting the designated Reactor Building Service water pump to the RHR System. Water is pumped into the reactor vessel and eventually spills out the break, filling the entire containment to a level above the reactor core.

The RHR System can also be used to augment the Fuel Pool Cooling and Cleanup (FPCC) System. The RHR heat exchangers are used to provide extra cooling capacity for spent reactor fuel in the event that the FPCC System is inadequate.

The System II loop can be used for any of the RHR System modes. The System I loop cannot be used for reactor vessel head spray or to augment the FPCC System.

10.4.2 Component Description

The major components of the RHR System are discussed in the paragraphs that follow.

10.4.2.1 Suction Strainers

Each RHR pump takes suction from the suppression pool. To prevent foreign objects in the suppression pool from entering the pump suction, strainers are located in the suction path from the suppression pool. The strainer, shown in Figure 10.4-2, utilizes perforated pipe of 0.125 inch holes aligned on 0.1875 inch staggered centers to prevent the introduction of foreign matter larger than 0.125 inch (1/4"). Although the suppression pool water quality will be monitored and controlled, debris resulting from accident conditions can be postulated to enter the suppression pool. The effective area of the strainer would be reduced as the strainer removes these objects from the suction flow path. To account for this decrease in area, the strainers are provided with adequate surface area so that the RHR pump will have adequate net positive suction head with 50 percent of the free strainer clogged. The large strainer area also results in low entrance velocities to minimize the entrainment of particles in the vicinity of the strainer.

Each strainer is located at least 5 feet below the high water level of the suppression pool. This location reduces the possibility of entrainment of small particles that tend to float on the pool surface. The heavier objects will tend to accumulate on the bottom of the pool and their size and weight should not be entrained in the suction flow path.

10.4.2.2 RHR Pumps

The four RHR pumps are vertically mounted, motor driven, centrifugal pumps. Each has a design flow rate of 10,000 gpm against 136 psig reactor pressure. Pump shutoff head is 238 psig. The pumps are sized on the basis of the flow required during the LPCI mode of operation. An orifice is installed on the discharge of each pump to prevent runout conditions.

The pumps are designed to handle water varying in temperature from 40°F to 350°F. Mechanical seals prevent leakage of water along the shaft. They are cooled by water from the pump discharge which flows through a centrifugal separator and a seal water cooler. The separator removes heavier than water solids and returns them to the RHR pump suction casing. The seal water cooler is a small heat exchanger supplied with cooling water by the Reactor Building Closed Loop Cooling Water System. A shaft bushing is designed to limit shaft leakage in the event of mechanical seal failure.

Each RHR pump is driven by a 2000 hp, 4.16 KV, 1800 rpm induction motor. The motor is designed to allow starting the pump with its discharge path open. Power to the pump motors is supplied from the Emergency AC Power System. RHR pump A from Division I 4160V, RHR pump B from Division II, and RHR pumps C and D from Division III. Sequencing of loads on the shutdown boards is automatically provided during automatic initiation conditions.

10.4.2.3 RHR Heat Exchanger

The RHR heat exchanger are vertical, inverted U-tube heat exchangers. The heat exchangers shell is carbon steel while the tubes and tube sheet cladding are copper nickel. The heat exchangers are sized on the basis of their required duty for the shutdown cooling mode of operation. Total heat transfer rate is designed to satisfy the requirements of shutdown cooling from 1025 psig reactor pressure to 125°F in 20 hours and maintain it there with a maximum projected service water temperature of 80°F. The RHR heat exchanger duties for the principal modes of operation are 41.4×10^6 Btu/hr (shutdown cooling), 89.3×10^6 Btu/hr (post LOCA) and 107.2×10^6 Btu/hr (steam condensing).

The shell and tube sides are provided with drain connections. The shell side is provided with a vent to remove noncondensible gases. A thermal relief valve on the shell side and a full flow relief valve on the steam supply line protect the shell side from over pressurization. The tube side is also protected by a thermal relief valve which will prevent over pressurization should the service water supply be isolated during RHR operation.

10.4.2.4 Motor Operated Valves

Each motor operated valve in the RHR system is operated by a 480 VAC motor. Power for system I of the RHR system receives power from the 480 VAC division I MCC. Division II 480VAC MCC provides power to system II of the RHR system.

The pump suction valves (F031A, B, C, and D) are 20 inch gate valves designed for a maximum of 70 psid across the valves. To operate in post LOCA conditions they must meet a minimum operating time of typically 90 seconds or less.

RHR pump minimum flow valves (F045A and B) are 4 inch gate valves designed to operate against a differential pressure of 500 psi differential pressure. These valves open to provide a discharge flow path for respective systems to prevent damage to the pumps in the event there is insufficient flow to keep the pump(s) cool. Each respective minimum flow valve automatically opens when one or both of the pumps in that loop start and flow is less than 2300 gpm for 10 seconds. Automatic closure of the valves occurs when flow reaches 2600 gpm.

LPCI injection valves consist of a normally open 24 inch angle globe (F036A and B) valve and a 24 inch normally closed gate valve (F037A and B). Each valve receives automatic open signals on system initiation signals combined with a reactor pressure less than 338 psig. The maximum allowed operating time must be rapid enough that LPCI flow is not delayed by valve opening time following a LOCA.

Shutdown cooling suction isolation valves (F048 and F047) are 20 inch gate valves. Each valve is capable of closing within 33 seconds.

10.4.2.5 Testable Check Valves

Air operated check valves are provided in each LPCI line downstream of the injection valves to prevent leakage from the reactor pressure vessel into the RHR System when the injection valves are open. The check valves are located inside the drywell and are not accessible during plant operation. The air actuators are provided to exercise the discs and ensure they are free to operate. The air actuators are NOT capable of closing the check valves and do not interfere with their operation, if LPCI is initiated.

10.4.2.6 Containment Spray Spargers

The containment spray spargers consist of 4 rings of pipe, two routed around the upper portion of the drywell and two routed around the upper portion of the suppression chamber. Each of the rings contains spray nozzles designed to produce water droplets with an average diameter of 400 microns and a maximum pressure drop across the nozzles of 40 psid. Each RHR system supplies one sparger in each location to ensure containment spray capability even with a failure of one RHR system. Each sparger ring ensures at least 90% coverage of the protected area.

10.4.2.7 Line Fill

The purpose of line fill is to maintain the RHR System full of water from the pump discharge check valves to the last normally closed valve in the injection path. With the system being maintained full of water, the probability of water hammer on system initiation is greatly reduced. Line fill water at approximately 50 psig is supplied by the line fill system with back up capability from the Condensate Transfer System. The line fill pumps are arranged in division with division I supplying Core Spray system I and RHR system I. The same would hold true for division II.

10.4.3 System Features and Interfaces

A short discussion of system features and interfaces this system has with other plant systems is given in the paragraphs which follow.

10.4.3.1 Normal Operation

During normal plant operation, the RHR System is in a standby status ready for LPCI initiation if required. Heat exchanger inlet outlet, and bypass valves are fully open. The suppression pool suction valve for each pump is open. Each RHR system is maintain pressurized and full by its respective loop level divisional pump. System I and II LPCI injection shutoff valves are open. All other valves in the various system flow paths are closed.

10.4.3.2 Infrequent Operation

Infrequent operation of the RHR System consists of operation in the suppression pool cooling mode, shutdown cooling and head spray mode, system testing or supplemental fuel pool cooling.

Suppression Pool Cooling

Suppression pool cooling is required to maintain the suppression pool water temperature within established limits. Cooling is usually required after RCIC or HPCI turbine operation, safety/relief valve testing, or high surrounding environment temperatures during the summer. To accomplish suppression pool cooling, reactor building service water flow is first established through the designated heat exchanger. Then the suppression pool cooling/spray shutoff valve is opened. Following the opening of the suppression pool cooling/spray valve, the RHR pump is started and flow is maintained by throttling the suppression pool cooling/test line isolation valve.

The flow path is from the suppression pool through the RHR pump(s), RHR heat exchanger(s), the full flow test line, and back to the suppression pool.

Shutdown Cooling and Head Spray Mode

The shutdown cooling and head spray mode of the RHR System is used to complete the cooldown process of the nuclear system after reactor pressure has decreased to within the capability of the RHR System. One of the RHR loops, System I or System II, may be taken out of its LPCI standby lineup when reactor pressure has been reduced to less than 125 psig. System II is preferred for use in the shutdown lineup because of its connection to the head spray line.

Prior to operating in the shutdown cooling and head spray mode, the system piping is flushed with reactor quality water to replace the high conductivity suppression pool water. To commence shutdown cooling, reactor building service water flow is established through the RHR heat exchanger as required to control the cooldown rate. The flow path for shutdown cooling is from the suction of the 'B' recirculation system loop, through the RHR pump(s), RHR heat exchanger(s), LPCI mode injection valves, and into the discharge of a Recirculation System loop.

The head spray line is used to divert approximately 500 gpm flow into the reactor vessel head region. The spray helps to promote a more uniform cooling of the reactor vessel head and mounting flange.

System Testing

During plant operation, periodic testing of the RHR pumps and valves are required to ensure the system will perform as designed. Periodic surveillance testing for the pumps require that its operation be checked for maximum obtainable flow rate and pump shutoff head. Flow rates are measured both through the heat exchanger and through the bypass valves.

Testing of the drywell spray requires elbow spool pieces be installed from the plant air system to the containment spray line. Actual water flow test is not performed due to the possibility of damaging equipment in the drywell. This test verifies flow through each spray nozzle.
Proper operation of the motor operated valves is verified during plant operation by cycling the valves through one cycle and timing them when required by technical specifications.

Steam Condensing Mode

After isolating the reactor from its primary heat sink, the main condenser, the RHR system steam condensing mode is used in conjunction with the RCIC System to remove decay heat and minimize the makeup water requirements. Decay heat raises the temperature and pressure of the reactor coolant until the safety/relief (SRVs) valves open. As the SRVs open to relieve pressure and decay heat in the form of steam, the water level in the reactor vessel decreases. The RCIC System is started to supply makeup water from the condensate storage tank to reactor vessel. Shortly after the RCIC system is started, the RHR System is lined up for steam condensing operation. One or both heat exchangers may be used, depending on the expected decay heat load.

To begin steam condensing mode operation, the heat exchanger shell side inlet and outlet valves are shut. The service water supply to the heat exchanger is placed in operation to provide cooling water flow. Heat exchanger level is lowered to about 50% by draining the heat exchanger to the suppression pool.

The level controller is placed in the manual mode and PCV-03 is opened about 10%. Condensate flow to the suppression pool from the heat exchanger is permitted by opening F044. The heat exchanger vent valves are throttled open to allow noncondensible gases to vent to the suppression pool. With the pressure controller set at zero, the steam inlet valve is slowly opened. Pressure setpoint is slowly increased to 50 psig, allowing steam pressure to force water from the heat exchanger to the suppression pool.

As level decreases, the level control valve is adjusted to maintain heat exchanger level at 50%. The pressure controller is placed in automatic mode and adjusted for the desired pressure.

When the RHR System outlet conductivity indicates adequate purity, the flow of condensate is shifted from the suppression pool to the RCIC pump suction. The level control valve is controlled by the lower of two signals, heat exchanger level or RCIC pump suction pressure. The suction pressure controller is normally set at 45 psig to prevent overpressurizing the RCIC pump suction piping. Level is adjusted to remove the desired amount of decay heat, either to maintain the plant in hot standby or to begin an abnormal cooldown. As heat exchanger level is decreased, more surface area of the tubes is exposed, thus allowing steam to condense at a faster rate. The RCIC pump flow controller is adjusted to about the same as the rate of condensation, thus maintaining a constant water level in the reactor. The higher pressure in the RCIC suction piping closes the check valve in the condensate storage tank suction line.

The flow path for the steam condensing mode is as follows:

- Reactor steam passes through the combined HPIC turbine/RHR heat exchanger steam line to the RHR heat exchanger.
- Steam is condensed in the heat exchanger, giving up its latent heat of vaporization to the service water system, and directed to the RCIC pump suction in the form of condensate.
- The RCIC system then delivers the fluid back to the reactor vessel via the feedwater piping.

Supplemental Fuel Pool Cooling

One of the most infrequent operations of the RHR System is fuel pool cooling. If large quantities of irradiated fuel are to be removed from the core, the decay heat load on the Fuel Pool Cooling and Cleanup System could be above its capacity. RHR System II may be aligned to supplement the FPCC System by closing the normal suppression pool suction valves and opening the FPCC suction valves.

The flow path for this mode is from the spent fuel pool to the RHR System suction piping, RHR pumps, RHR heat exchanger, and then back into the FPCC System return lines to the spent fuel pool. This flow path must be manually aligned from outside the control room.

10.4.3.3 Emergency Operation

Emergency operation of the RHR System consists of operation in the low pressure coolant injection (LPCI) mode, containment spray mode, or the standby coolant supply mode.

Low Pressure Coolant Injection Mode

The low pressure coolant injection (LPCI) mode of the RHR System comprises one of the emergency core cooling systems (ECCS). In the LPCI mode, the RHR Pumps take suction from the suppression pool. The injection valves open and if reactor pressure is less than the pump shutoff head, the check valves open allowing flow to the reactor vessel. If reactor pressure is above the pump shutoff head, the minimum flow valves open to allow sufficient flow to the suppression pool to cool the pumps. Water from the suppression pool, which is pumped into the reactor, eventually spills from the break which caused the LOCA and returns to the suppression pool; thus a closed loop is established for post accident cooling.

Both divisions of LPCI mode are initiated automatically by a one-out-of-two-twice logic madeup of low reactor water level and high drywell pressure. Automatic initiation occurs if a reactor vessel level 1 water level (-132.5") or primary containment (drywell) high pressure (+1.69 psig). Either initiation signal will start the system. Each of the initiating signals is sensed by four independent detectors arranged in a one-out-of-two twice logic, as shown in Figure 10.4-3. The instruments used to detect reactor vessel water level 1 and primary containment high pressure are the same ones used to initiate the other ECCS. Once an initiation signal is received by the LPCI control circuitry, the signal is sealed in until manually reset.

The overall operating sequence for LPCI following the receipt of an initiation signal is as follows:

- Without normal AC power RHR pumps A, B, and C start in 2 seconds followed by D in 7 seconds. RHR pump C and D both receive their power from Bus 103, thus due to the high starting currents one pump is started at a time to preclude overloading the bus. Initiation signal sealed in white light illuminates.
- The valves in the suction paths to the suppression chamber are maintained open so that no automatic action is required to line up suction.
- All motor operated valves on the discharge side of the pumps align to the LPCI mode. Minimum flow valves open with flow less than 2350 gpm.
- When nuclear system pressure has dropped to <338 psig, both LPCI injection valves automatically open allowing the LPCI pumps to inject water into the pressure vessel as the reactor pressure drops below the pump shutoff head (238 psig).
- When nuclear system pressure has dropped to <310 psig, the recirculation pump discharge valves in both loops of the effected unit start to close and are closed 33 seconds later.
- The LPCI system then delivers water to the reactor vessel via the recirculation loops to provide core cooling by flooding.
- As system flow increases above 2350 gpm the minimum flow valves close.

In the event of an automatic initiation signal while in the shutdown cooling and head spray mode or supplemental fuel pool cooling, the RHR System will not automatically realign for injection. The operator must secure the operation in progress and realign the RHR pump's suction to the suppression pool.

Manual Override Features

With the system in operation following an automatic initiation, the operator, using his own judgement, can override some of the automatic functions. He can stop RHR pumps and close injection valves (the outboard injection valves cannot be closed or throttled until after a 5 minute time delay).

Containment Spray Mode

The containment spray lineup must be manually initiated by the control room operator. If drywell spray is required, per Emergency Operating Procedures, and 10 minutes have elapsed the following actions must be performed:

- Place Containment Spray Valve manual Override key lock switch in the "MAN. OVVRD" position.
- Place the Containment Spray Valve Accident control switch to the "MAN." position and hold until the white override light illuminates.
- Open containment spray header isolation valve 38A(B).
- Throttle open containment header valve 39A(B).

Containment spray cannot be placed in service unless LPCI has been automatically initiated, drywell pressure is >1 psig and reactor vessel water level is >2/3 core height. Requiring the two permissive ensures the need for containment spray and ensures that the LPCI requirement has been satisfied.

Standby Coolant Supply Mode

Following a LOCA it may be necessary to flood the entire containment to a level above the top of the active fuel to facilitate removal of fuel from the reactor. Should this become necessary, the Reactor Building Service Water System can be connected to the RHR System by opening normally locked closed hand operated valves.

The flow path for containment flooding is from the reactor building service water pump into the outlet piping of the System II RHR heat exchanger. Once in the RHR System, flow can then be diverted to the suppression pool, reactor vessel, or containment spray.

10.4.3.4 System Automatic Isolation

The Nuclear Steam Supply Shutoff System, Group 2, provides signals to the shutdown cooling suction inboard and outboard isolation valves, the head spray inboard and outboard isolation valves and the LPCI inboard injection valve (if in shutdown cooling mode). In addition, the shutdown cooling suction inboard and outboard isolation valves and the head spray inboard and outboard isolation valves automatically close when reactor pressure is above 125 psig.

10.4.3.5 System Interlocks

To prevent inadvertent draining of the reactor vessel, the shutdown cooling suction valves are interlocked with the suppression pool suction valves. If the suppression pool suction valve is not fully closed, the shutdown cooling suction valve to that pump cannot be opened.

Each RHR pump controller is interlocked with all the shutdown cooling and suppression pool valves which can isolate the suction path for that pump. All the valves in at least one flow path must be fully open before that RHR pump can be started. If an RHR pump is running and a valve in its suction path is moved out of the fully open position, the pump trips.

The LPCI injection valves cannot be opened unless reactor pressure is less that 338 psig or one of the two valves is closed. The outboard LPCI injection valve is interlocked fully open for five minutes after LPCI initiation.

The test line isolation valves and containment spray valves interlock closed on a LPCI initiation and cannot be opened until the reactor vessel has returned to 2/3 core coverage. In addition, containment spray cannot be initiated until drywell pressure is above 1 psig. A manual override is provided for the 2/3 core coverage signal.

10.4.3.6 System Interfaces

A short discussion of interfaces this system has with other plant systems is given in the paragraphs which follow.

Recirculation System (Section 2.4)

The shutdown cooling and head spray mode suction is from the suction of the "B" recirculation loop. LPCI injection is into the discharge of both recirculation loops. Upon a LPCI initiation signal the recirculation pump discharge valves receive a permissive to close signal at 310 psig.

Reactor Vessel System (Section 2.1)

The head spray portion of the RHR system discharges into the reactor vessel.

Primary Containment System (Section 4.1)

The RHR System's normal suction path is from the suppression pool. Flow may also be returned to the suppression pool from the pump minimum flow lines, suppression chamber spray line or the test return lines. Redundant drywell spray spargers are supplied from the RHR system.

The standby coolant supply mode allows flooding the entire containment to an elevation above the core to allow fuel removal following a LOCA.

Nuclear Steam Supply Shutoff System (Section 4.4)

The NSSSS sends isolation signals to various RHR valves as part of its group 2 isolation logic.

Reactor Building Service Water System (Section 11.4)

The Reactor Building Service Water System supplies cooling water for the RHR heat exchanger and standby coolant supply mode water.

Fuel Pool Cooling and Cleanup System (Section 11.5)

System II of the RHR System may be used to assist in fuel pool cooling.

Emergency AC Power System (Section 9.2)

The Emergency AC Power System provides a reliable power source for RHR System operation.

Reactor Core Isolation Cooling (Section 2.7) System

The RCIC system removes water from the RHR heat exchanger, during steam condensing mode, and delivers it to the reactor vessel.

High Pressure Coolant Injection System (Section 10.1)

The HPCI system supplies steam to the RHR heat exchanger for steam condensing mode of operation.

Automatic Depressurization System (Section 10.2)

The ADS receives an open permissive signal when RHR pump discharge pressure is >125 psig.

Reactor Building Closed Loop Cooling Water System (Section 11.3)

The RBCLCW system provides cooling water to the RHR pump seals.

Condensate Transfer System (Section 11.6)

The condensate transfer system is used to flush the RHR system and act as a backup to the loop fill system.

10.4.4 Summary

Classification - Safety related system; Engineered safety feature system.

Purpose - To provide low pressure makeup water to the reactor vessel for core cooling under loss of coolant accident conditions. (Low Pressure Coolant Injection Mode)

To reduce primary containment pressure following a loss of coolant accident (LOCA). (Containment Spray Model)

To remove heat from the suppression pool. (Suppression Pool Cooling Mode)

To remove decay heat from the reactor core following a reactor shutdown and to remove residual heat from upper reactor vessel internals during a cooldown. (Shutdown Cooling and Head Spray Mode)

To provide a means of flooding the primary containment. (Standby Coolant Supply Mode)

Components - Suction path; pumps; heat exchangers; motor operated valves; testable check valves; containment spray spargers.

System Interfaces - Recirculation System; Reactor Vessel System; Primary Containment System; Service Water; Fuel Pool Cooling and Cleanup System; Emergency AC Power System; Automatic Depressurization System; High Pressure Coolant Injection System; Reactor Core Isolation Cooling System; Loop Fill System; Condensate Transfer System; Nuclear Steam Supply Shutoff System.

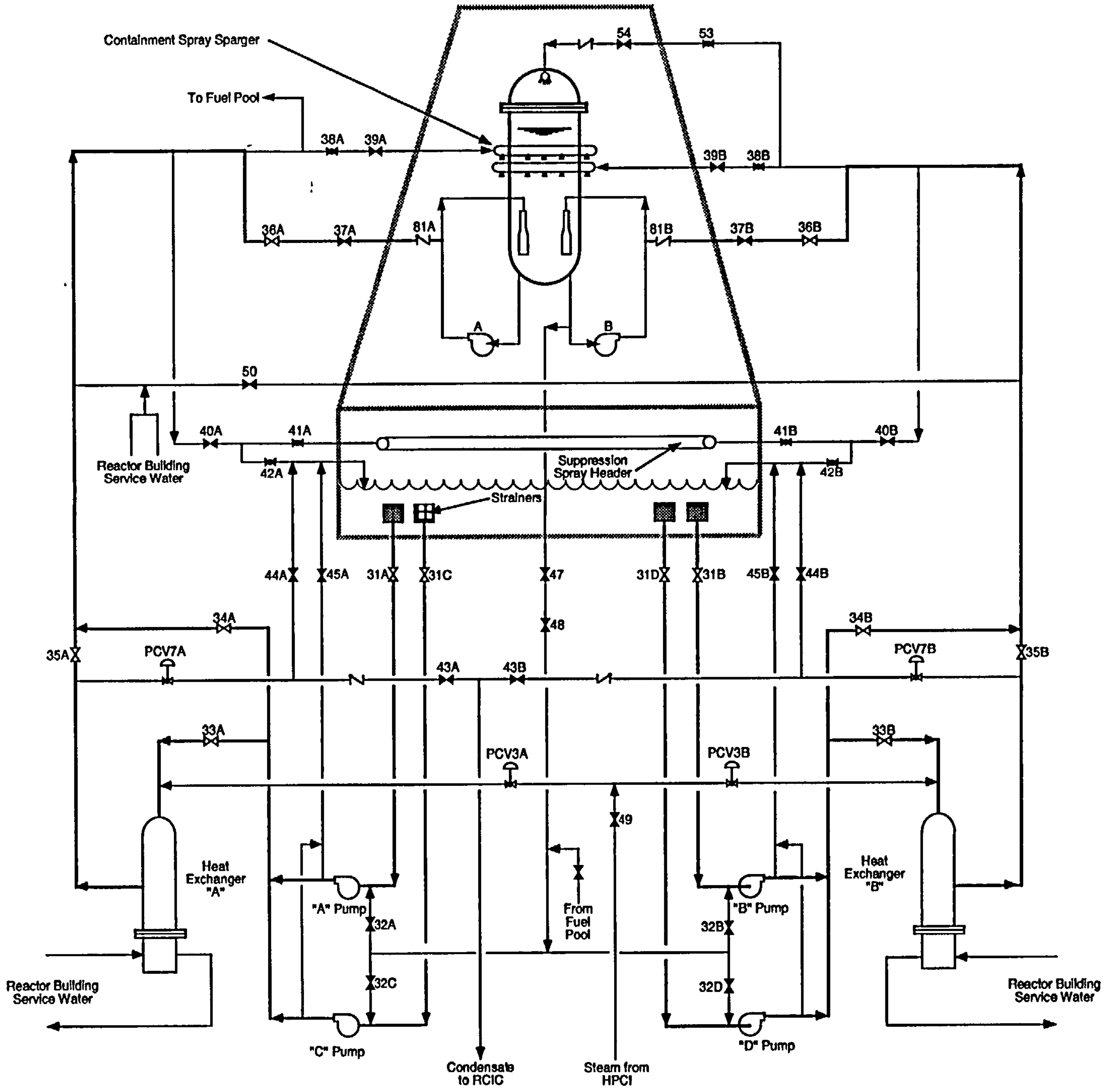

Figure 10.4-1 RHR System

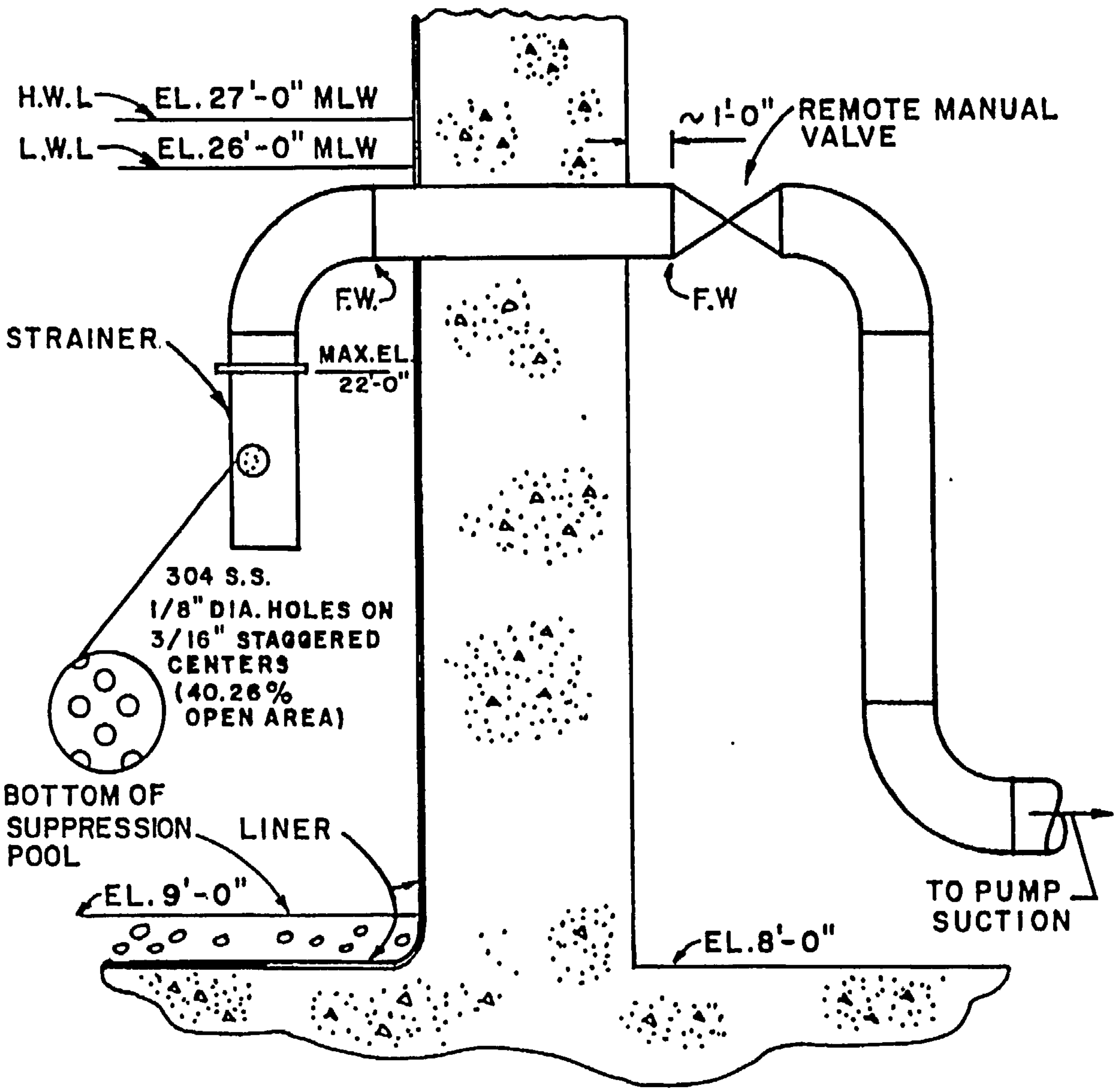

Figure 10.4-2 ECCS Suction Line Strainer

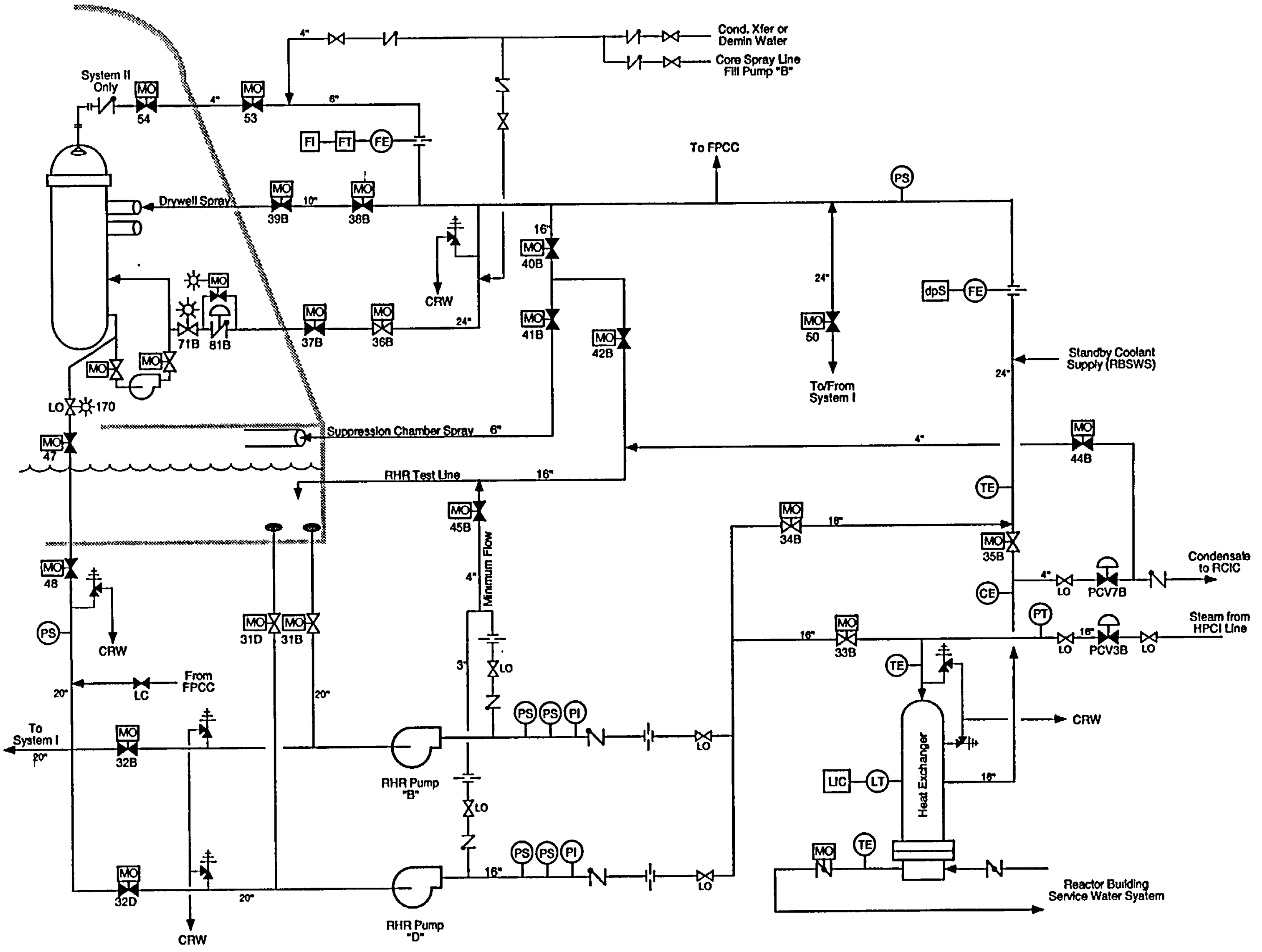

Figure 10.4-3 RHR System II

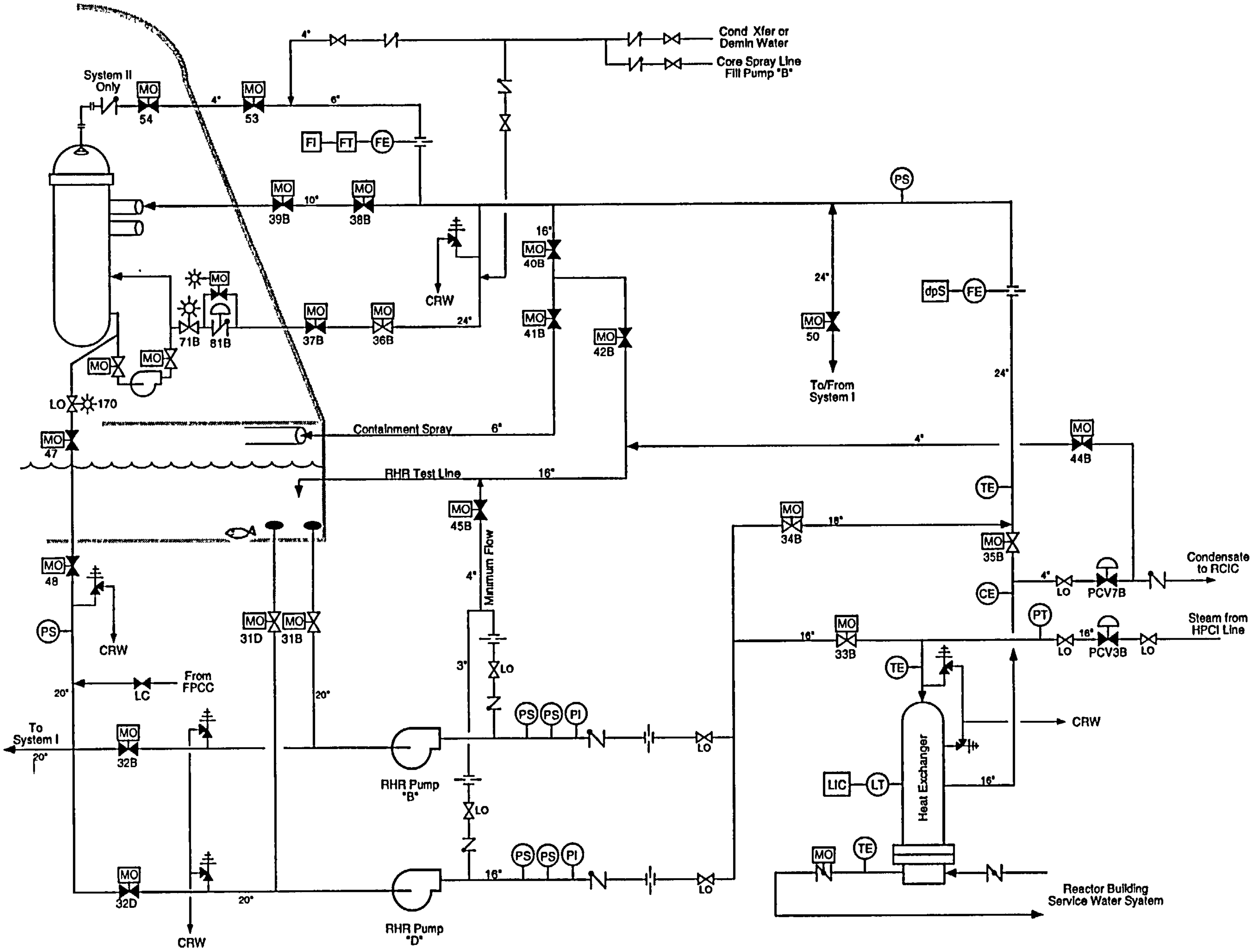

Figure 10.4-3 RHR System II

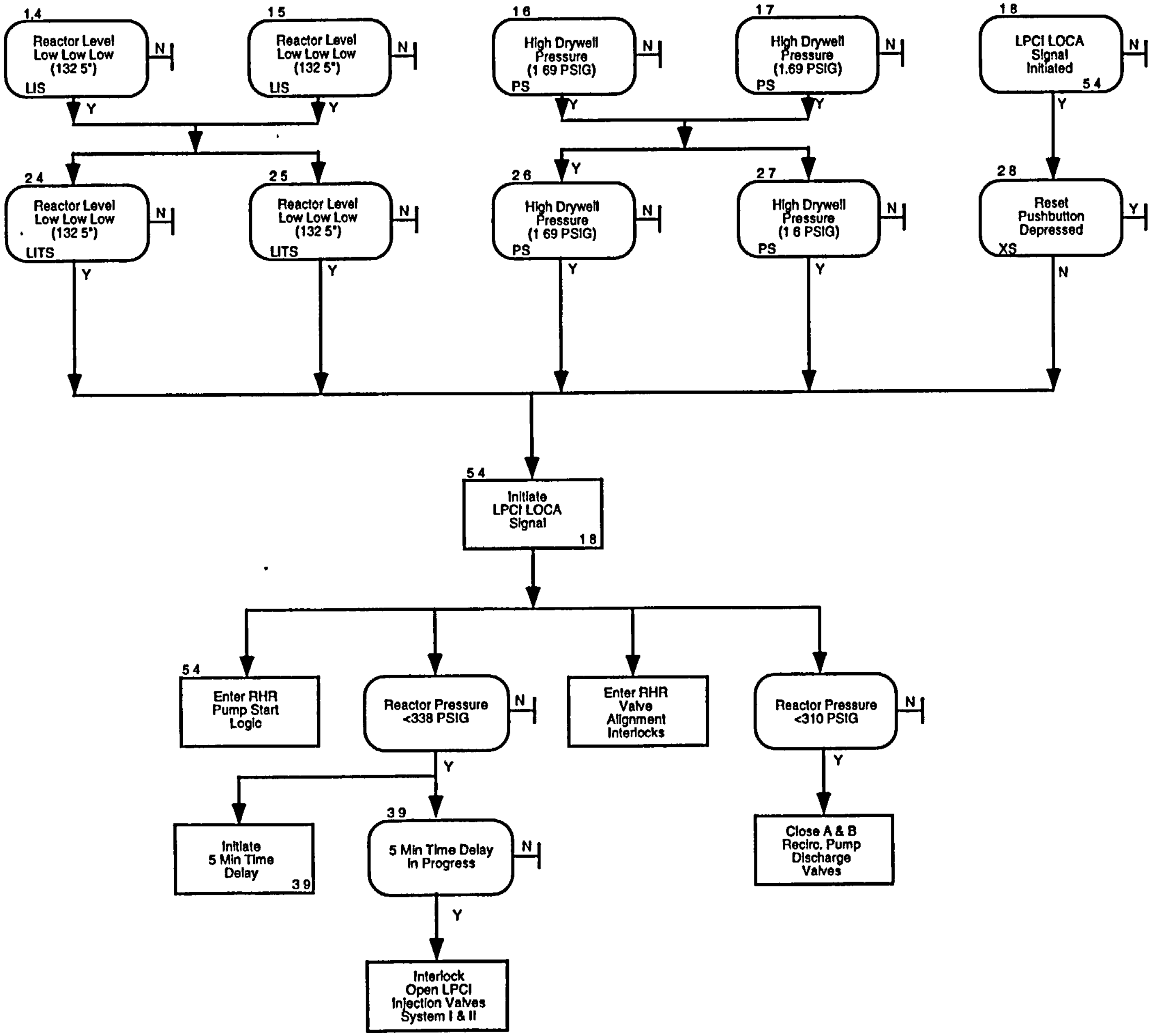

Figure 10.4-4 LPCI Automatic Initiation Logic

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Chapter 11.0

Water and Air Systems

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11.0 WATER SYSTEMS

The water systems necessary for plant operational support are discussed in this chapter. The water systems provide water supplies required by plant processes, auxiliary cooling functions necessary to support plant equipment, and cooling functions to remove decay heat for forced cooldown of the reactor. The cooling water provided may be from a variety of sources such as lakes, rivers, oceans, cooling towers, or cooling ponds.

11.0.1 Circulating Water System (Section 11.1)

The Circulating Water System (CWS) supplies cooling water to turbine condensers to reject heat from the steam cycle. The system also provides for dilution and dispersion of radioactive wastes released from the station.

11.0.2 Reactor Building Service Water System (Section 11.2)

The Reactor Building Service Water System (RBSW) transfer heat from the reactor building components to the Long Island Sound, and provide an emergency source of cooling water to the reactor vessel and spent fuel pool.

11.0.3 Reactor Building Closed Loop Cooling Water System (Section 11.3)

The Reactor Building Closed Loop Cooling Water (RBCLCW) System cools selected auxiliary equipment over the full range of plant operations. The RBCLCW System provides a closed cooling water loop between systems which are potentially radioactive and the service water system. This provides an additional barrier be tween the possibly contaminated systems and the service water discharged to the environment.

11.0.4 Turbine Building Service Water System. (Section 11.4)

The Turbine Building Service Water System (TBSW) supplies cooling water to non-safety related components located in the turbine building and rejects the heat to the Long Island Sound.

11.0.5 Turbine Building Closed Loop Cooling Water System (Section 11.5)

The Turbine Building Closed Loop Cooling Water System (TBCLCW) cools selected auxiliary balance of plant equipment located in the turbine building and transfers that heat load to the Turbine Building Service Water System.

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Chapter 11.1

Circulating Water System

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11.1 CIRCULATING WATER SYSTEM

Lesson Objectives:

1. State the system's purpose.
2. Explain how the system accomplishes its purposes.

11.1.1 Introduction

The purpose of the circulating water system is to provide cooling water for the station main condensers. Four circulating water pumps draw water from Long Island Sound via the intake canal and discharge the water to the main condensers where the water removes the heat of vaporization from the main turbine exhaust steam. The heated circulating water then passes to the discharge tunnel where it is returned to Long Island Sound through a multiport diffuser. Provisions are made in the system for backwashing individual quadrants of the main condenser and for priming and for removing air to ensure a completely water-filled system during operation. The system is controlled from the main control room on the balance of plant main control board 1H11*MCB-01.

11.1.2 System Description

Four motor-driven, vertical, wet pit pumps (1N71-P-063A,B,C,and D) mounted in the intake structure take suction from separate screenwell bays through individual traveling water screens. Each pump is provided with local discharge pressure indication and pressure transmitter which provides a computer point, and discharges through an expansion joint and a discharge isolation butterfly valve (MOV-031A,B,C,D). The discharge isolation valves are interlocked with their respective pumps to partially open prior to the pump start and close when the pump stops. Each discharge valve is powered from a different electrical source than its associated pump to ensure valve operability in the event of a pump trip due to loss of electrical power. The closed discharge isolation valves prevent backflow through idle pumps. Each pump is supplied with bearing cooling water and provided with a connection to the exhauster priming system. Bearing cooling water to the circulating water pumps is supplied from the service water system after being filtered by cooling water strainers

Each pump discharges into a 78 in. ID concrete-encased steel pipe which penetrates the south screenwell wall. The discharge lines leave the screenwell with a centerline elevation of 12 ft which is 8 ft below the yard ground surface. Immediately outside the screenwell, each circulating water pump discharge line is fitted with a 10 in. flanged pipe connection. This penetration provides both a means for the hypochlorination system to inject a sodium hypochlorlde solution into the flow stream to control marine growth, and air removal by the exhauster priming system. The individual discharge lines from pumps A and B combine into one 108 in. ID fiberglass line, with the discharge lines from pumps C and D combining into a separate 108 in. ID fiberglass line. The two lines parallel each other and travel underground approximately 200 ft across the yard to a point near the north side of the turbine building. Just before the 108 in. ID pipe splits back into 78 in. piping, near the plant access road, each 108 in. pipe is provided with a 30 in. diameter manhole with access given by a covered 5 ft square pit. Attached to the manhole cover is an air release and check valve arrangement, and a 3 in. connection for installing a transducer to be used during system testing. The air release valve allows for trapped air to escape to the atmosphere while at the same time preventing air from being drawn into the system during certain hydraulic transients.

Located under the North Plant Access Road are the pitot tube pits for each of the 108 in. circulating water legs. Each of the lines if provided with three 1 1/4 in. connections for insertion of pitot tubes to be used during flow measuring testing of the circulating water pumps. These connections are provided with gate valves for isolation when they are not in use. Outside the turbine building, each line branches into two 78 in. ID concrete-encased steel lines (four in all), one for each condenser quadrant. The four lines penetrate the turbine building north wall with a centerline elevation of 8 ft. As the lines penetrate the turbine building wall, they each expand from 78 in. to 84 in. ID piping. Immediately inside the turbine building, the inlet lines enter a concrete lined valve pit under the heater bay floor. Within the pit, each line contains an 84 in. butterfly condenser inlet isolation valve (MOV-032A,B,C,D) and two expansion joints.

Between each expansion joint, the line connects to the 96 in. ID condenser backwash line through another expansion joint and an 84 in. butterfly backwash isolation valve (MOV-034A,B,C,D). The vacuum priming system is connected to the backwash lines between each pair of backwash isolation valves. The backwash line then leaves the turbine building and runs east underground next to the north wall of the turbine building until lt meets the discharge tunnel. Approximately 20 ft from the point where the backwash line leaves the turbine building, connections are provided for a 6 in. vacuum breaker, and a 3 in. flanged connection for installing a pressure transducer to be used during system testing. That portion of the backwash piping inside the turbine building is provided with a dewatering sump and provides a point for service water being returned from the TBCLCW system to reenter the sound.

After making the connection to the backwash line and expansion joints, each condenser inlet line reduces back to 78 in. piping as the lines leave the pit area. Each line then passes under the heater bay and turbine building floor through concrete encased pipe for approximately 90 ft where it rises to meet the condenser inlet water boxes. A 30 in. diameter manhole through the heater bay floor provides access to each condenser inlet line and its dewatering sump. The inlet lines are connected to the water boxes through expansion joints. Each line is monitored just prior to the expansion joint by a temperature element which provides a computer point. In addition to the inlet temperature indication, the circulating water pressure at each condenser water box is monitored by a pressure transmitter which provides a computer point and indication of pressure in the main control room. The vacuum priming system is connected to the top of each condenser water box. Circulating water pumps A and B supply condenser lN21-E-051A and pumps P-063C and D supply condenser lN21-E-015B.

The condenser outlet water boxes, each monitored by a pressure transmitter, which provides a computer point, connected to the discharge tunnel through 78 in. lines. The lines then descend under the turbine building floor and travel approximately 30 ft where they penetrate the turbine building wall and enter the discharge tunnel.

Each line, upon leaving the condenser outlet water box, contains an expansion joint and a condenser outlet butterfly isolation valve (MOV-033A,B,C,D).

The outlet water boxes of condensers are connected to each other by a 78 in. ID line containing an expansion joint and a normally closed butterfly Isolation valve (MOV-035). These lines allow for reversal of flow through the condenser quadrants during backwashing operations.

The circulating water discharge tunnel is a 10 ft-6 in. high by 12 ft wide concrete structure which runs underground along the south wall of the turbine building. Access into the circulating water discharge tunnel is provided through a 30 in. manhole outside the turbine building. This manhole is near the south wall of the turbine building just west of the transformer area. Connected to the discharge tunnel are three connections from the service water system and a connection for admitting discharges from the waste regeneration neutralizing tank and the radwaste system sample tanks.

The tunnel turns north at the east end of the turbine building and passes under the radwaste building. The backwash line travels underground along the north wall of the turbine building and connects to the discharge tunnel. Approximately 88 ft. north of the radwaste building, there is a 30 in. manhole in the yard area providing access to the discharge tunnel, and a connection for the hypochlorination sample pump. The rectangular discharge tunnel transforms into a 144 in. ID diameter fiberglass pipe which travels approximately 1,000 ft north to connect to the outfall line which returns the circulating water to Long Island Sound. Near the above-mentioned manhole, the 144 in. ID pipe is provided with a connection to the vacuum priming system via air/water separator tank. Just prior to the meeting the outfall near the beach parking lot, the discharge line is provided with two temperature elements for use in determining circulating water system temperature rise, and a biological sampling station above the 30 in. manhole. There are also three flanged connections at the manhole, two of which are intended for later connection to a yard vacuum priming system if local air binding becomes a problem, with the third being used for connecting an air release and check valve assembly identical to the ones used on the condenser inlet piping.

Approximately 440 ft north of the radwaste building, a 66 in. ID warm water recirculation line is connected to the discharge line. The warm water recirculation line is directed to the intake canal to provide recirculation of a portion of the warm circulating water discharge to the intake canal water during periods of cold seawater temperatures. The line is provided with an expansion joint and a butterfly isolation valve (MOV-036), both of which are accessible via a concrete valve pit in the yard area. The warm water recirculation line is fitted with three blind flanged connections for future connection to a yard vacuum priming system in the event that local air binding becomes a problem. The recirculation line is capable of raising the intake water by 4 degrees F when four circulating water pumps are operating in the normal mode.

11.1.2.1 Circulating Water Vacuum Breakers

The circulating water system is susceptible to potential water hammer problems. Localized low pressure may reach vapor pressure following a flow decrease caused by an accidental pump trip or valve closure with resulting high pressures. Formation of vapor cavities retards the system flow and their subsequent collapse results in localized change of flow velocity, which ln turn causes high pressures capable of damaging the circulating water piping and discharge tunnel.

Vacuum breakers are utilized to admit air into the circulating water piping during conditions of potential vapor cavity formation to avoid the formation and subsequent collapse of vapor cavities in situations where the resulting pressure surges from collapsing of the vapor cavities would be unacceptable. The admission of air into the system increases the system pressure and breaks the siphon in the condenser and in the backwash line. Since the system is designed to operate with the condenser under siphonic conditions (condenser circulating water sections at less than atmospheric pressure), the entry of air will cause a rapid reduction of flow with subsequent loss of the system. For this reason, and because of the danger of water hammer due to the movement of slugs of entrapped air in the system, system interlocks are established to trip the remaining operating pumps when the vacuum breakers are open.

There are nine vacuum breakers installed in the circulating water system. Each vacuum breaker is a 6 in. air-operated valve designed to fail open on loss of air. When pump trip combinations in certain operating modes could potentially result in unacceptably high transient pressures, a signal is provided to open all nine valves. Once opened all valves remain open for 10 min. When a vacuum breaker opens on a condenser quadrant, the level control valve to the associated air/water separator tank will close avoiding a loss of the vacuum priming system. Normal operating procedures restrict starting of a circulating water pump until the vacuum breakers have closed and the system has been fully primed. However, in the event circulating water flow must be restarted immediately, a procedure entitled FAST PRIMING may be utilized.

11.1.2.2 Vacuum Priming

Vacuum priming of the circulating water piping and discharge tunnel is provided to prime the circulating water system conduits and remove as much air as possible from the condensers prior to start-up. It is also used to evacuate air which enters the system by inleakage or comes out of solution due to pressure reduction and heating during passage through the condenser, and thus prevent air binding. Air removal (creating a vacuum) allows the system to be primed with water due to the pressure differential between the system and atmospheric pressure and ensures that no pockets of air remain or accumulate in the system during operation. Air binding in the system would reduce the effectiveness of the system by reducing the flows. Accumulation of air in the higher elevation condenser tubes would result in decreased condenser performance.

The vacuum priming system consists of a vacuum priming tank and four rotary water ring vacuum priming pumps. The vacuum priming tank is connected to the circulating water system through individual water separator tanks. Two of the four vacuum pumps normally operate, with a third cycling to maintain the vacuum priming tank between 23.5 and 26.5 in. Hg vacuum. The low pressure of this tank is transmitted through the air/water separator tanks to the condenser water boxes, the circulating water piping and discharge tunnel. When the circulating water system is empty, the vacuum exhausts the air from the system, causing the piping to fill. As the air is removed, water from the circulating water piping will enter the vacuum priming lines and the air/water separator tanks. The water level in each water separator tank is maintained at 22 in. from the bottom, bend line of the tank by the modulation of the respective level control valve. This prevents any water from carrying over to the vacuum priming tank and seals in the vacuum at the top of the water separator tank.

11.1.3 Component Description

Only the major Circulating Water System components are discussed in the paragraphs which follow.

11.1.3.1 Circulating Water Pump/Motor

The circulating water pumps are vertical, one-stage, single-suction, open-impeller units, manufactured by Ingersoll-Rand. Each pump is designed for total head of 34.2 ft at 143,400 gpm. Required NPSH is 19 ft at design conditions and 36 ft at runout flow of 220,000 gpm. Each pump is driven by a vertical, squirrel cage, induction motor manufactured by the Electric Machinery Mfg. Company. Each motor is rated for 1,500 hp and rotates at 295 rpm. Each motor requires 3 phase, 60 Hz, 4,100 v power.

11.1.3.2 Vacuum Priming Units

Four identical vacuum priming units are provided. Each unit is manufactured by Nash Engineering Company. The units are rated for 780 cfm at 25 in. Hg vacuum. The units consist of a vacuum priming pump, pump driver, pump discharge separator tank, discharge silencer, and seal water heat exchanger. The components of each unit are mounted on a common base plate. Each unit is 90 1/2 in. long by 58 1/2 in. wide by 119.75 in. high and weighs 5,750 lb.

The units are installed in the turbine building at the 37 ft.-6 in. elevation.

11.1.4 Normal Operations

During plant power generation at any power level, the normal operating mode of the circulating water system is four circulating water pumps in operation supplying all four quadrants of the main condenser unit. The vacuum priming system removes any air in the condenser water boxes, piping, or discharge tunnel.

The circulating water system is prepared for start-up by using the vacuum priming system to prime the circulating water piping, condenser water boxes, and discharge tunnel. The exhauster priming system must be placed in operation just before the pumps are started to ensure that circulating water pumps and discharge piping are fully primed. All system valves with the exception of pump discharge valves, should be open during filling. when the vacuum priming system has drawn its maximum vacuum (approximately 25 in. Hg), the piping and discharge tunnel will be completely water filled. The warm water recirculation valve, and backwash valves must be closed, and bearing cooling water must be established to all the pumps. After bearing cooling has been in operation 15 min, the circulating water pumps are started one at a time. Two minutes must elapse between a pump discharge valve reaching the fully open position and the starting of another pump.

11.1.5 System Interfaces

The interfaces this system has with other plant systems are discussed in the paragraphs which follow.

11.1.5.1 4160V Normal Distribution System (Section 9.1)

The electrical distribution system provides all the electrical power requirements for the Circulating Water System.

11.1.5.2 Service Water System (Section 11.1)

The Service Water System is physically connected to the Circulating Water System, for normal return to the Long Island Sound.

11.1.5.3 Liquid Radwaste System (Section 8.2)

The Liquid Radwaste System is physically connected to the Circulating Water System, this can be a means of discharging liquid radwaste to the Sound.

11.1.5.4 Service and Instrument Air System (Section 11.8)

The Service and Instrument Air System provides air for pneumatically operated valves.

11.1.5.5 Chemical Feed and Sampling System (No section in manual)

The Circulating Water System receives chemicals from the Chemical Feed System for the purpose of removing algae and preventing tube fouling in the main condensers.

11.1.6 BWR Differences

The design of the system described in this section is specific to one plant. The function of the Circulating Water System is performed by similar systems at all facilities. However the arrangement of pumps, heat loads, and water sources varies from plant to plant.

11.1.7 Summary

Classification: Power Generation System

Purpose: The purpose of the circulating water system is to provide cooling water for the station main condensers

Components: Pumps, Motors, Vacuum Priming Unit

System Interfaces: Electrical Distribution, Service and Instrument Air System, Service Water System; Process Sampling System, Plant Chemical Feed System, Liquid Radwaste System.

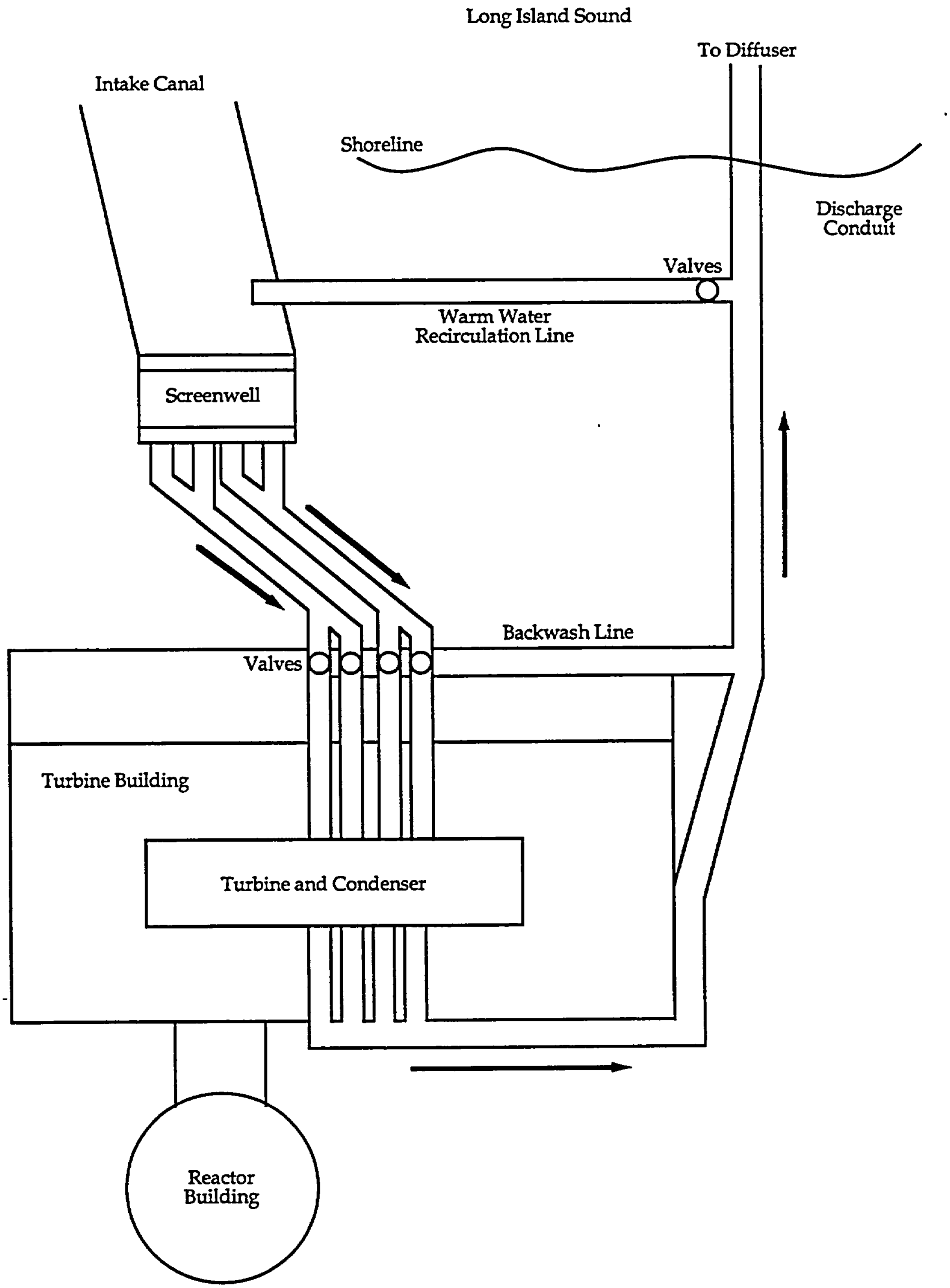

Figure 11.1-1 Circulation Water System Overview

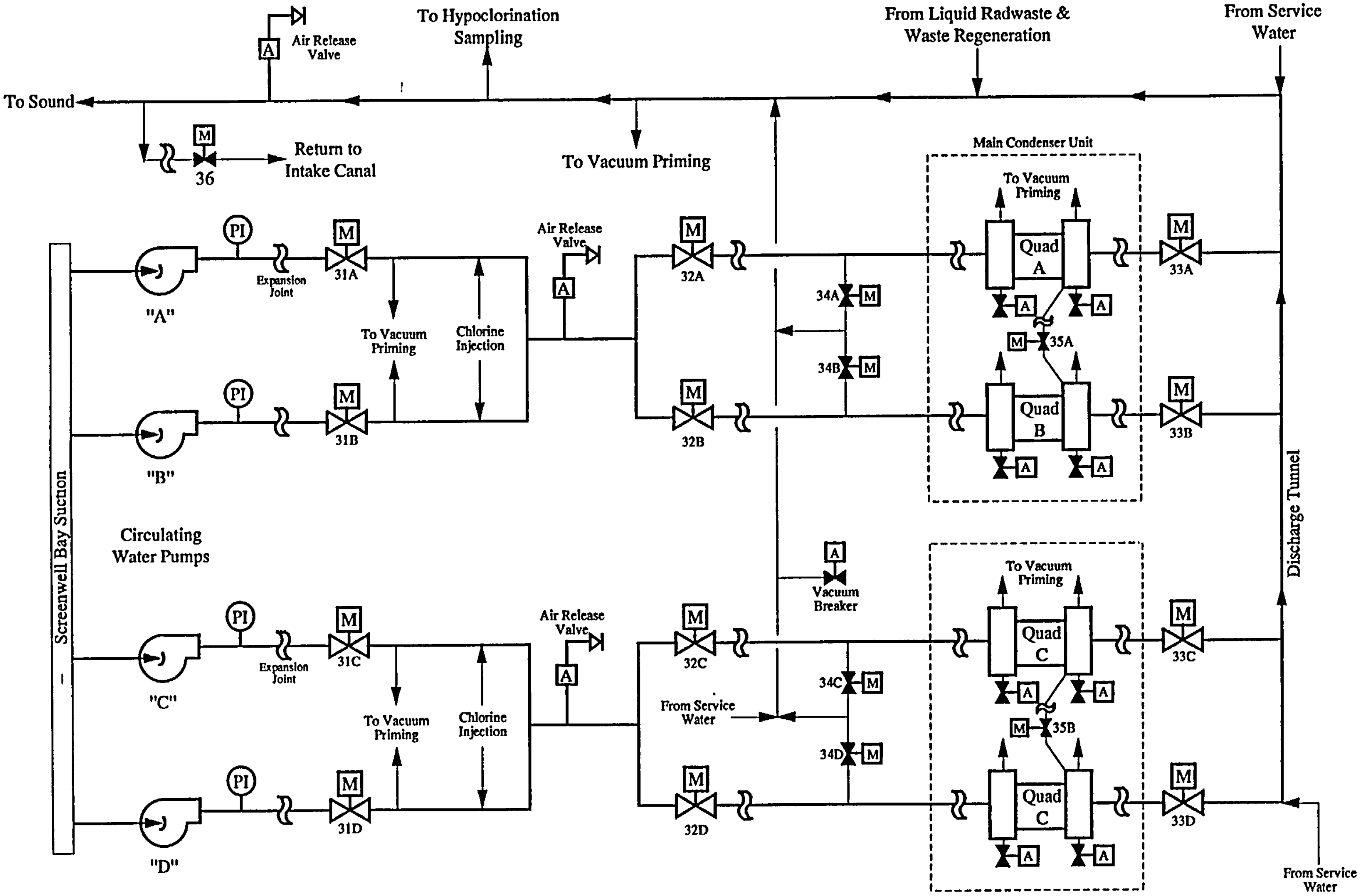

Figure 11.1-2 Circulating Water System (N42)

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Reactor Building Service Water System

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11.2 Reactor Building Service Water System

Lesson Objectives:

1. State the system's purpose.
2. Explain how the system accomplishes its purposes.
3. Describe the systems response to a loss of coolant accident.

11.2.1 Introduction

The purpose of the Reactor Building Service Water System (RBSW) is to transfer heat from the reactor building components to the Long Island Sound, and provide an emergency source of cooling water to the reactor vessel and spent fuel pool. The RBSW incorporates two independent cooling water flow paths supplying safety related systems that require cooling water during accident conditions, therefor it is classified as an engineered safety feature system. The major components of the RBSW system are shown in figure 11.2-1.

11.2.2 System Description

The Reactor Building Service Water System (RBSW) is divided into two loops which supply safety related components. Loads on the two loops are redundant to ensure that at least one set of the nuclear safety related components is supplied in the event of a single service water component failure.

Four service water pumps take suction from the screenwell. Each pump shares a screenwell with a circulating water pump. Each pump discharges through a motor operated discharge valve (MOV-31A,B,C, and D), which is open 25°when in the closed position, a bypass butterfly valve around the discharge valve is normally closed. All four pump discharge lines combine in a common header. Two normally open isolation valves (MOV-32A and B) are located in the common discharge and automatically close during LOCA or loss of emergency bus voltage conditions to split the RBSW system into two independent loops. Table 11.2-1 list the heat loads on the individual RBSW loops.

The warm RBSW from each component is returned to the circulating water system discharge tunnel. A radiation monitor draws a RBSW sample off of each RHR heat exchanger outlet and returns the sample to the same piping. The radiation monitor will detect inleakage of radioactive materials from the RHR system and be indicated in the main control room. Service water to the ultimate cooling connection and the spent fuel pool, if injected, would not be returned to the discharge tunnel but be retained in the reactor building.

11.2.3 Component Description

The major components of the Reactor Building Service Water system are described in the paragraphs that follow.

11.2.3.1 RBSW Pumps

The Reactor Building Service Water pumps are vertically mounted, two stage, centrifugal, rated at 8600 gpm @ ~70 psig. The pumps are driven by a 450 Hp, 4160 VAC, 3 phase, induction electric motor.

11.2.3.2 RBSW Strainers

Each RBSW pump has its own discharge strainer. The strainers are self cleaning, electric motor driven, and automatically backwash to the trash sump.

11.2.4 System Features and Interrelations

System operation and interrelations between this system and other plant systems are discussed in the paragraphs that follow.

11.2.4.1 Normal Operations

During non accident conditions the RBSW system normally has one pump per loop (A or C and B or D) operating and supplying RBSW to the following components:

- One of two RCBCLCW booster heat exchanger.
- One of two RBCLCW heat exchanger.
- One of four RBSVS and CRAC chilled water condensers.
- RBNVS chilled water condenser.

The warmed water from the system is directed to the circulating water discharge tunnel and out to the Sound.

11.2.4.2 Loss of Preferred Power

On a loss of preferred power all running RBSW pumps will trip. After the emergency diesel generators have restored power to the emergency buses, the following events automatically occur:

- The discharge valves of any previously operating RBSW pump shuts.
- When the associated discharge valve is shut, each RBSW pump that has its control switch in AUTO,will start, except the bypassed C or D RBSW pump (the division III pumps, C/D, have a selector switch to bypass the auto start feature of the selected pump (C or D). This feature ensures the DIV III diesel LOOP/LOCA service load limit of 3300 Kw in not exceeded).

A. 7 seconds following bus reenergization, if no LOCA exist
or
B. 12 seconds following bus reenergization, if a LOCA signal exist

- The pump discharge valve opens 20 seconds after the associated RBSW pump starts.
- Emergency diesel engine cooler outlet isolation valves (AOV-16A, B, and C) open for each operating diesel engine.

Following realignment of the motor operated valves to there proper LOCA/LOPP position. each loop of RBSW will supply the following components:

- One RBCLCW heat exchanger.
- Two RBSVS and CRAC chilled water condensers.
- The cooler associated with each operating emergency diesel engine.
- One RBCLCW booster heat exchanger if lined up by operator.
- One RHR heat exchanger if lined up by the operator.

11.2.4.3 Loss of Coolant Accident

Upon a receipt of a LOCA signal, the following automatic actions occur:

- If cross connected, TBSW is isolated (MOV-35A and B close).
- The RBNVS chilled water system is isolated from RBSW (MOV-36A, B, and C close).
- RBCLCW booster heat exchanger service water flow is isolated (MOV-129 A and B close).
- RHR heat exchanger service water flow is isolated (MOV-34 A and B close).
- Service water is admitted to both RBCLCW heat exchanger (MOV-37 A and B open), if closed.
- RBSW splits into two redundant loops (MOV-32 A and B close).
- Each nonoperating RBSW pump with its control switch in AUTO, except the bypassed C or D RBSW pump, will start 12 seconds after the initiation of the LOCA signal.

11.2.4.4 Loss of Station Air System

Upon loss of station air system the emergency diesel engine cooler outlet isolation valves (AOV-16 A, B, and C) fail open. With the engine coolers supplied with cooling water, an additional RBSW pump may have to be started to prevent the operating pump(s) from tripping on over current.

11.2.4.5 System Interfaces

A short discussion of interfaces this system has with other plant systems is given in the paragraph which follow.

4160V Emergency Distribution System (Section 9.2)

The RBSW pumps and motor operated valves receive power from the Emergency Power System , and the RBSW supplies cooling water to the Emergency Diesel Generator Engines.

Service & Instrument Air System (Section 11.8)

The emergency diesel engine outlet valve (AOV-16A, B, and C) receive air for valve movement from the Station Air System.

Circulating Water System (Section 11.1)

The Circulating Water System shares the screenwell suction pits with the RBSW. The CWS also provides a discharge path for return water of the RBSW to the Long Island Sound.

11.2.5 Summary

Classification:	Safety related system.
Purpose:	To transfer heat from the reactor building components to the Long Island Sound, and provide an emergency source of cooling water to the reactor vessel and spent fuel pool.
Components:	Pumps, Strainers,Pipes, and Valves
System Interfaces:	Emergency Power System, Station Air System, Circulating Water System.

Table 11.2-1 RBSW Load List

Reactor Building Service Water Loop "A"

- RHR A heat exchanger
- RBCLCW A heat exchanger
- RBCLCW A booster heater exchanger
- Emergency diesel engine A, B, and C coolers
- RBSVS and CRAC chilled water system A
- RBNVS chilled water system
- Emergency water supply to the reactor vessel
- Emergency water supply to the spent fuel pool

Reactor Building Service Water Loop "B"

- RHR B heat exchanger
- RBCLCW B heat exchanger
- RBCLCW B booster heater exchanger
- Emergency diesel engine A, B, and C coolers
- RBSVS and CRAC chilled water system B
- RBNVS chilled water system
- Emergency water supply to the reactor vessel
- Emergency water supply to the spent fuel pool
- RBSW/TBSW cross connect.

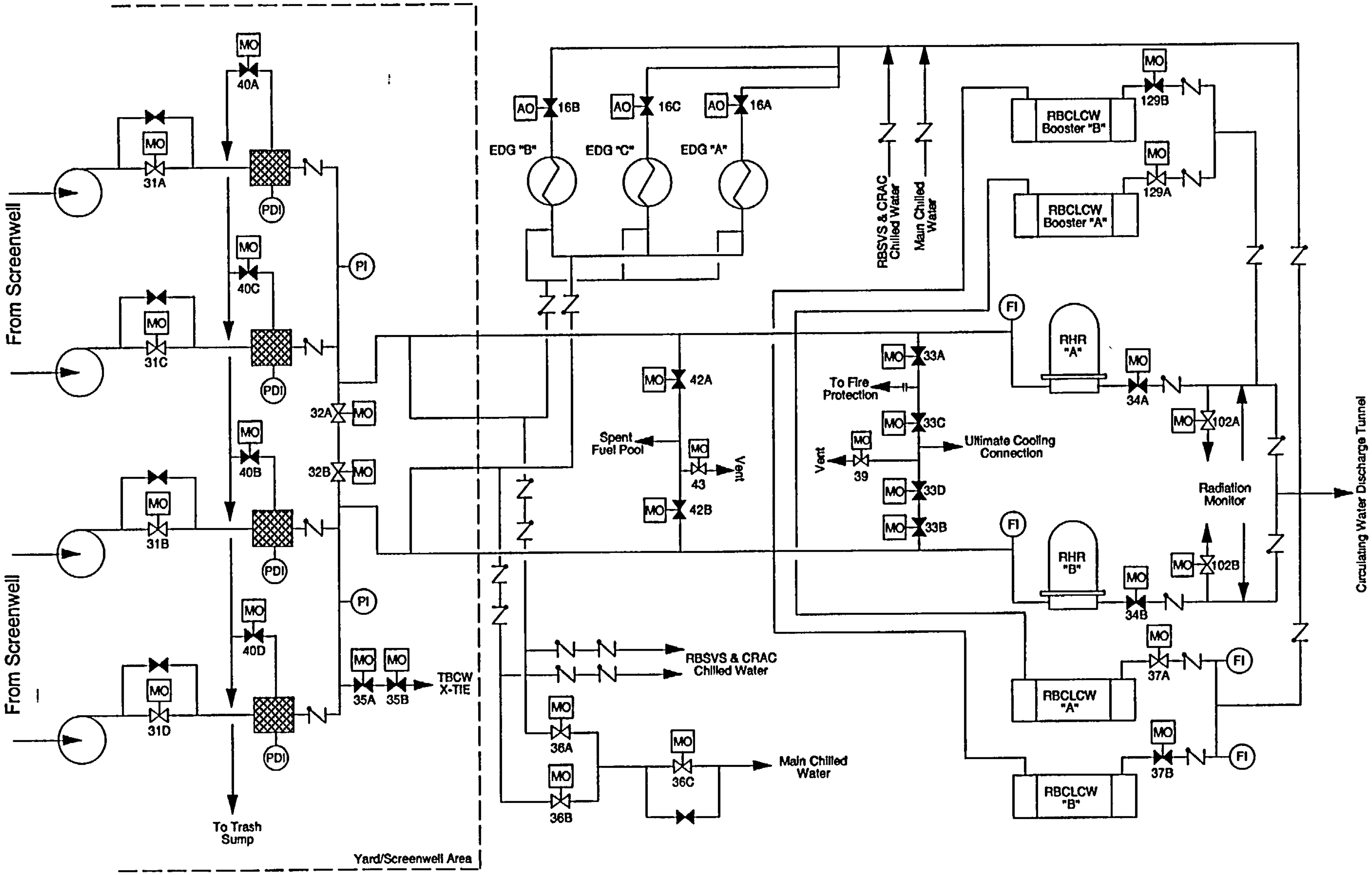

Figure 11.2-1 Reactor Building Service Water System

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Chapter 11.3

Reactor Building Closed Loop Cooling Water System

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11.3 Reactor Building Closed Loop Cooling Water System

Lesson Objectives:

1. State the system's purpose.
2. Explain how the system accomplishes its purposes.
3. Describe the systems response to a Loss of Coolant Accident.

11.3.1 Introduction

The purpose of the Reactor Building Closed Loop Cooling Water System (RBCLCW) is; to transfer heat from the components cooled by RBCLCW to the Reactor Building Service Water System via heat exchangers, provide cooling water to reactor auxiliary equipment and other miscellaneous reactor building equipment during normal operation, and provide nuclear safety related systems with a redundant means of cooling during an accident condition in order to accomplish and maintain a safe shutdown.

11.3.2 System Description

The Reactor Building Closed Loop Cooling Water System is a redundant, closed loop system providing nuclear safety and non-nuclear safety related equipment with a reliable source of cooling water. The system is divided into four loops, two serving safety related components, Figure 11.3-1, and two serving non-safety related components, Figure 11.3-2. Loads on the safety related loops are redundant to ensure that at least one half of the nuclear safety related components served by RBCLCW are supplied in the event of a single RBCLCW component failure. Since the safety related components are themselves redundant, sufficient equipment to establish and maintain a safe shutdown will remain operable. Loads on the non-safety related loops supply auxiliary components that are not required to operate during accident conditions. The two non-safety related loops automatically isolate during an accident. Two of three 50% capacity circulating pumps take suction from a common suction header and discharge to a common discharge header. The common discharge header serves the four system loops, two safety related loops, "A" and "B", and two non-safety related loops, "A" and "B", a list of system or components cooled can be found in Table 11.3-1.

Each non-safety related loop return line ties into its associated safety related loop return piping. The safety related loop returns to the inlet of an RBCLCW heat exchanger. The two heat exchangers are cross connected on both the inlet and outlet sides. During normal operations, only one RBCLCW heat exchanger is in service. The two heat exchangers discharge to a common suction header supplying the three RBCLCW pumps. Two RBCLCW head tanks connect to the common pump suction header to provide a surge reservoir and ensure that sufficient net positive suction head (NPSH) is available to the pumps.

Between the RBCLCW heat exchangers and the common pump suction, two additional RBCLCW circulating water pumps (reactor recirculation pump M/G set fluid coupling cooler cooling water pumps) take suction and supply the recirculation pump M/G set fluid coupling oil coolers. Normally, only one pump operates. The discharge of the fluid coupling oil coolers is returned to the cross connected RBCLCW heat exchanger inlet. During normal (non-accident) conditions, the system operates with all loops cross connected, two main RBCLCW pumps operating, one recirculation pump M/G set fluid coupling cooler cooling water pump operating, one RBCLCW heat exchanger in service, and one RBCLCW booster heat exchanger in service.

11.3.3 Component Description

Only the major Reactor Building Closed Loop Cooling Water System components are discussed in the paragraphs which follow.

11.3.3.1 Reactor Building Closed Loop Cooling Water System Pumps/Motors

The RBCLCW circulating water pumps are; 50 % capacity each, double suction; single stage, centrifugal pumps, rated at 1600 gpm flow at 165 ft. head. The motor that drives the pumps are; 100 Hp, 480 VAC, 3 phase, 60 Hz, induction motors rated at 120 amps full load current.

11.3.3.2 Recirculation Pump Cooling Water Circulating Pumps/Motors

The Recirculation pump M;G set fluid coupling cooler cooling water circulating pumps are; 100% capacity each, single stage centrifugal pumps, rated at 1600 gpm flow at 118 ft. head. The motors that drives the pumps are; 75 Hp, 480 VAC, 3 phase, 60 Hz., induction motors rated at 88 amps full load current.

11.3.3.3 Reactor Building Closed Loop Cooling Water Heat Exchangers

The RBCLCW heat exchangers are; single pass, counter flow, shell and tube type. Service water supplies the shell side at a pressure less than RBCLCW system pressure. Each heat exchanger is 100% capacity. Outlet temperature is controlled by mixing heat exchanger outlet flow with heat exchanger bypass flow.

Temperature control valves in the bypass line and outlet line modulate to maintain return water to the pump suction at 91°F.

11.3.3.4 Reactor Building Closed Loop Cooling Water Head Tank

The RBCLCW head tank is designed to provide a system surge volume and satisfy pump net positive suction head (NPSH) requirements. Makeup water is automatically provided by the demineralized water system.

11.3.3.5 Radiation Monitor

The inlet to the radiation monitor is located on the common pump discharge header. the monitor is designed to detect the inleakage of radioactive contaminants due to the failure of a cooler served by the system. The outlet of the radiation monitor is returned to the common pump suction header.

11.3.3.6 Pressure Control Valve

The pressure control valve connect the common pump suction header and the common pump discharge header to maintain a constant differential pressure of 70 psid across the system loads. During one and two pump operation, discharge header pressure is normally 65-68 psig and the pressure control valve is closed. Maintenance of a constant differential pressure insures that individual coolers can be valved in and out of service without affecting the remainder of the loads.

11.3.3.7 Booster Heat Exchangers

The RBCLCW booster heat exchangers are each 100% capacity and provide additional cooling for; drywell air unit coolers, CRD pump gear oil coolers, CRD pump bearing coolers and drywell equipment drain cooler. Outlet temperature is controlled by mixing heat exchanger outlet flow with heat exchanger bypass flow. Temperature control valves in the bypass and outlet lines modulate to maintain a constant supply temperature to the supplied loads.

11.3.4 System Features and Interrelations

System operation and interrelations between this system and other plant systems are discussed in the paragraphs that follow.

11.3.4.1 Normal Operations

Two of the three circulating pumps take a suction from a common suction header and discharge to a common discharge header, the third is in automatic, available to start immediately to replace one of the operating pumps, should it trip. A pressure control valve (PCV-71) connects the discharge header to the suction header and maintains a constant differential pressure of 70 psid across the system loads. During normal system operation with two pumps running, the discharge header pressure is approximately 65-68 psig and thus the pressure control valve is shut. The radiation monitor draws suction from the pump discharge header and returns water to the pump suction header. the monitor will detect inleakage of radioactive contaminants. The common discharge header contains two normally open isolation valves (MOV-32 A and B) that automatically close during an accident to split the system into two independent loops.

The non-safety related loops each contain two normally open isolation valves (Loop A: MOV-33 A and B, Loop B: MOV- 34 A and B) that automatically close during an accident to isolate the non-safety related loads form the system. At the operators discretion, the recirculation pump coolers in each safety related loop may be isolated by closing MOV-35 and 36 in the A loop and MOV-47 and 48 in the B loop.

The RWCU non-regenerative heat exchangers can be supplied by either non-safety related loop. However, only one loop should be valved in at a time (manual isolation valves).

The two non-safety related loop s return lines tie into their respective safety related loop return lines. Air operated check valves (AOV-293 and 294) automatically close during an accident to isolate the non-safety related loops.

Each of the two safety related loop return lines supplies an RBCLCW heat exchanger. Each heat exchanger inlet line is provided with an isolation valve (MOV-42 A and B) that automatically opens during an accident to insure that each heat exchanger is in service. The two heat exchangers inlet lines are cross connected through two normally open isolation valves (MOV-41 A and B). the isolation valves automatically close during an accident to split the two safety related loops into totally independent flow paths. During normal plant operations, the two cross connection isolation valves and one of the heat exchanger inlet valve are open. Thus only one heat exchanger is in service. During an accident, both inlet valves are open and both cross connect valves are closed resulting in independent loop operations with a heat exchanger in each loop. Temperature control valves in each heat exchanger outlet (TCV-1 W and Y) and each heat exchanger bypass (TCV-1 X and Z) modulate to maintain a constant pump suction water temperature of 91°. The common pump suction line contains two normally open isolation valves (MOV-31 A and B) that close during an accident to split the two safety related headers into independent loops.

Two head tanks connect to the common pump suction line to provide a surge volume and ensure sufficient pump NPSH is available.

Between the RBCLCW heat exchanger outlets and the common pump suction header, a second cross connect line connects the two heat exchanger outlets. This cross connect supplies suction to two 100% capacity RBCLCW pumps (recirculation pump M/G set fluid coupling cooler cooling water pumps) that supply cooling water to the recirculation pump M/G set fluid coupling coolers. One pump normally operates. Four normally open isolation valves (MOV-43 A and B and MOV-44 A and B) automatically close during an accident to isolate the recirculation pump M/G set fluid coupling coolers from the two safety related RBCLCW loops. The operating pump automatically trips on low suction pressure at 10 psig. The return line from the recirculation pump M/G set fluid coupling coolers ties into the common inlet to the RBCLCW heat exchangers. An air operated check valve (AOV-282) in the return line automatically closes during an accident to isolate the return line from the safety related loops.

11.3.4.2 Loss of Preferred Power

The RBCLCW system pumps are powered from the emergency buses. If the emergency buss should experience a loss of normal power the pumps will stop and the motor operated valves will remain in their current position.

After the emergency buses have been reenergized the following should occur;

- RBCLCW pumps A and B will automatically start. Pump C cannot be started for a period of ten minutes following the restoration of power to the emergency buses. If the "C" pump must be started, wait ten minutes and then place the control switch in PULL-TO-LOCK followed by AUTO-AFTER-START.
- The RBCLCW heat exchanger inlet valves (MOV-42 A and B) automatically open if not already open.

When normal power is restored, verify that one M/G set cooler cooling water pump is operating and the other is in standby.

11.3.4.3 Loss of Coolant Accident

One of the purposes of the RBCLCW system is to provide nuclear safety related systems with redundant paths of cooling water during an accident condition. In order to accomplish this purpose when the system receives a LOCA signal (High Drywell Pressure or Low Low Reactor Water Level) the following actions will occur:

- RBCLCW pump discharge cross connect valves (MOV-32 A and B) <u>close</u>
- Non-safety related loops A and B isolation valves (MOV-33 A and B & MOV-34 A and B) <u>close</u>
- Return isolation check valves (AOV-282, 293, and 294) <u>close</u>

- Heat exchanger inlet and outlet cross connect valves (MOV-41 A and B & MOV-31 A and B) close

- Recirculation pump M/G set fluid coupling cooler cooling water pump suction valves (MOV-43 A and B & MOV-44 A and B) close, which causes the pumps to trip on low suction pressure.

- Heat exchanger bypass line temperature control valves (TCV-002 X and Z) close

- Heat exchanger inlet and outlet valves (MOV-42 A and B & TCV-001 W and Y) open

11.3.4.4 Loss of Station Air

The RBCLCW system can sustain a loss of station air and still perform its intended function. The following actions take place on a loss of service air:

- Heat exchanger and booster heat exchanger bypass temperature control valves (TCV-1X and Z and TCV-304X and 305X) fail open

- The head tanks level control valves (LCV011 A and B) fail open

- Heat exchanger and booster heat exchanger bypass temperature control valves (TCV-1X and Z & TCV-304Y and 305Y) fail close

In order to optimize the system performance after a loss of station air manual operator action is required. The head tank level control valves have to be isolated and tank level must be maintain by manual bypass valve operation. Manual control of heat exchanger and booster heat exchanger outlet temperatures between 60 and 100°F by using the manual handwheel associated with the failed temperature control valves.

11.3.4.5 System Interfaces

A short discussion of interfaces this system has with other plant systems is given in the paragraphs which follow.

4160V Emergency Distribution System (Section 9.2)

The RBCLCW pumps and motor operated valves receive power from the Emergency Power System.

Service & Instrument Air System (Section 11.8)

The heat exchangers temperature control valves and the head tank makeup valve receive motive air from the station air system.

Reactor Building Service Water System (Section 11.2)

The Reactor Building Service Water System is the heat sink for the Reactor Building Closed Loop Cooling Water System.

11.3.5 Summary

Classification:

Safety Related System

Purpose:

The purpose of the Reactor Building Closed Loop Cooling Water System (RBCLCW) is; to transfer heat from the components cooled by RBCLCW to the Reactor Building Service Water System via heat exchangers, provide cooling water to reactor auxiliary equipment and other miscellaneous reactor building equipment during normal operation, and provide nuclear safety related systems with a redundant means of cooling during an accident condition in order to accomplish and maintain a safe shutdown.

Components:

Pumps, heat exchangers, booster heat exchangers, temperature control valves, head tanks, radiation monitors, and pressure control valve.

System Interfaces:

Emergency Power System, Station Air System, and Reactor Building Service Water System.

Table 11.3-1 RBCLCWS Load List

Safety Related Loop "A"

- Fuel Pool Cooling Heat exchanger A
- RHR Pump A & C Seal Coolers
- Recirculation Pump A Seal Coolers
- Recirculation Pump A Bearing Cooler
- Recirculation Pump A Motor Winding Coolers

Safety Related Loop "B"

- Fuel Pool Cooling Heat exchanger B
- RHR Pump B & D Seal Coolers
- Recirculation Pump B Seal Coolers
- Recirculation Pump B Bearing Cooler
- Recirculation Pump B Motor Winding Coolers

Non-safety Related Loop "A"

- RWCU Pump A & B Coolers
- RWCU Non Regen Heat Exchanger
  - Can be supplied by either non-safety related loops (manual valves)
- Booster Heat Exchanger A
  - Drywell air unit cooler A.
  - CRD pump A gear oil cooler.
  - CRD pump A bearing cooler.
  - Drywell equipment drain cooler.

Table 11.3-1 RBCLCWS Load List (Cont.)

Non-safety Related Loop "B"

- Reactor Water Recirculation Sample Cooler
- Reactor Sample Panel
- RWCU Non Regen Heat Exchanger (optional)
- Auxiliary Boiler sample coolers
- Booster Heat Exchanger B
  - Drywell air unit cooler B
  - CRD pump B gear oil cooler
  - CRD pump B bearing cooler

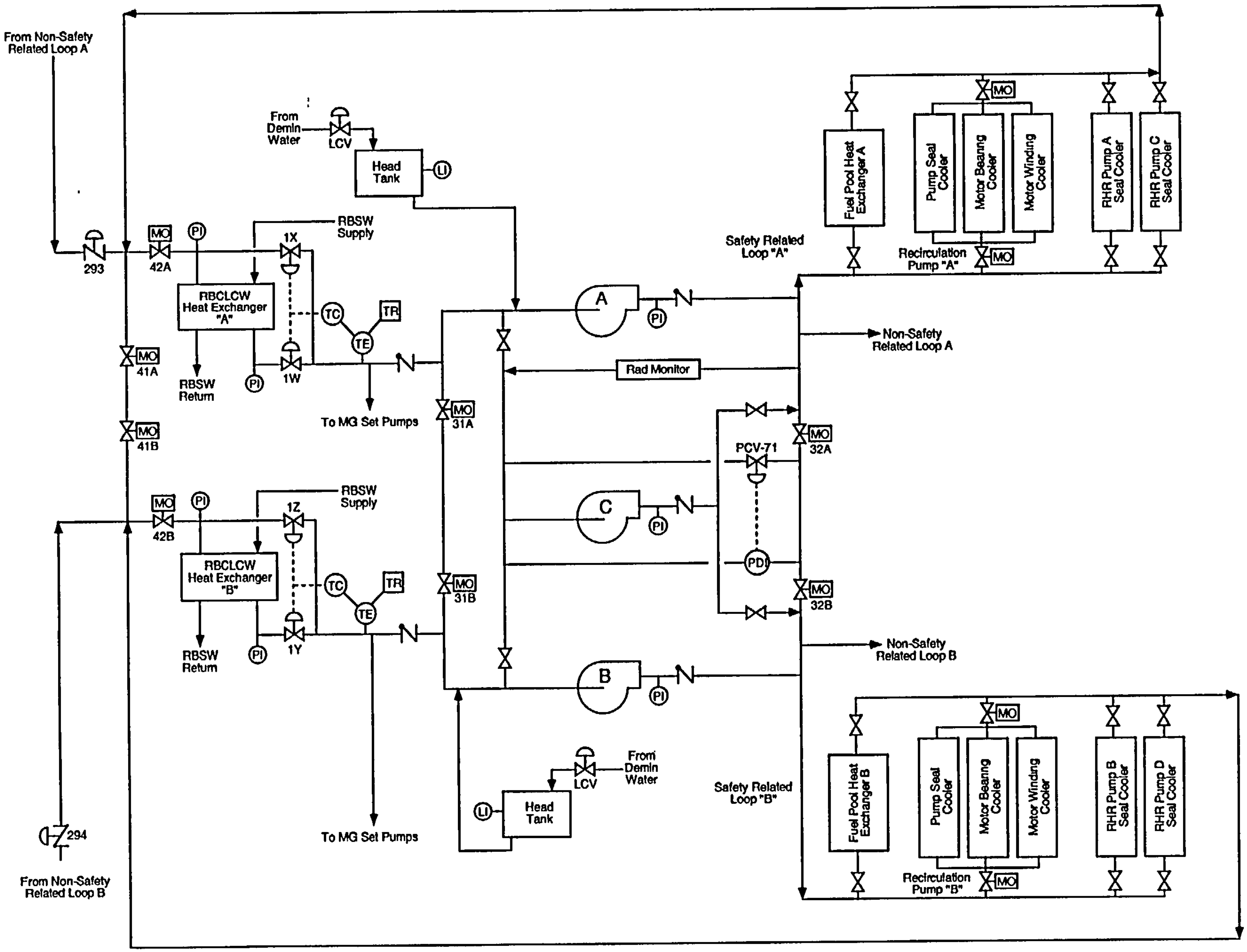

Figure 11.3-1 Reactor Building Closed Loop Cooling Water System (Safety Related Loops)

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Chapter 11.4

Turbine Building Service Water System

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11.4 Turbine Building Service Water System

Lesson Objectives:

1. State the system's purpose.
2. Explain how the system accomplishes its purposes.

11.4.1 Introduction

The purpose of the Turbine Building Service Water System (TBSW) is to transfer heat from non-safety related components in the turbine building to the Long Island Sound. The major components of the TBSW system are shown in figure 11.4-1.

11.4.2 System Description

The Turbine Building Service Water System (TBSW) supplies non-safety related components in the turbine building. The system pumps takes water from the screenwell. Normally two of the three pumps are running discharging into a common discharge/supply header via MOV-112 A, B, and C , each discharge valve is bypassed by a normally open butterfly valve which provides for system fill prior to discharge valve opening. The common discharge header supplies two motor operated, self cleaning, strainers that are arranged in parallel. Either strainer can be isolated by an inlet isolation valve (MOV-113 A or B). The outlet of the two strainers combine to form a single header that supplies TBSW to the following components and systems:

- Screen wash pump motor oil cooler.
- Circulating water pump bearing cooling water supply.
- Circulating water system fish retention pool.
- Vacuum priming pump seal coolers
- Vacuum priming drain tank level control valve.
- TBCLCW heat exchanger.

The TBSW supply to the TBCLCW heat exchangers is controlled by isolation valves (MOV-111 A and B) on the outlet of the heat exchangers. the outlets of the two TBCLCW heat exchangers combine in a single return line containing a single normally open isolation valve (MOV-120). A bypass line around the isolation valve accommodates the TBSW return from the vacuum priming pump seal coolers. The combined TBCLCW heat exchanger and vacuum priming pump seal cooler return line discharges to the circulating water system backwash discharge piping. TBSW from the circulation water pump bearing coolers and the fish retention pool is returned to the screenwell.

11.4.3 Component Description

The major components of the Turbine Building Service Water system are described in the paragraphs that follow.

11.4.3.1 TBSW Pumps

The Turbine Building Service Water pumps are vertically mounted, single stage, centrifugal, rated at 800 gpm @ ~50 psig. The pumps are driven by a 350 Hp, 4160 VAC, 3 phase, induction electric motor.

11.4.3.2 TBSW Strainers

The TBSW pumps have two common discharge strainer. The strainers are self cleaning, electric motor driven, and automatically backwash to the trash sump.

11.4.4 System Features and Interrelations

System operation and interrelations between this system and other plant systems are discussed in the paragraphs that follow.

11.4.4.1 Normal Operations

During normal operations the TBSW system has two pump operating supplying service water to the components cooled by the system. The third pump in normally aligned to the standby mode of operation.

11.4.4.2 Loss of Power

The TBSW pumps and valves are powered by normal AC power system. Upon a loss of normal AC power the all running pumps will stop and all motor operated valves will fail as is.

11.4.4.3 System Interfaces

A short discussion of interfaces this system has with other plant systems is given in the paragraph which follow.

4160V Normal Distribution System (Section 9.1)

The TBSW pumps and motor operated valves receive power from the Normal Power System .

Circulating Water System (Section 11.1)

The Circulating Water System shares the screenwell suction pits with the TBSW. The CWS also provides a discharge path for return water of the TBSW to the Long Island Sound.

11.4.5 Summary

Classification:
Power Generation system.

Purpose:
To transfer heat from the turbine building components to the Long Island Sound.

Components:
Pumps, Strainers,Pipes, and Valves

System Interfaces:
Normal Power System, Circulating Water System.

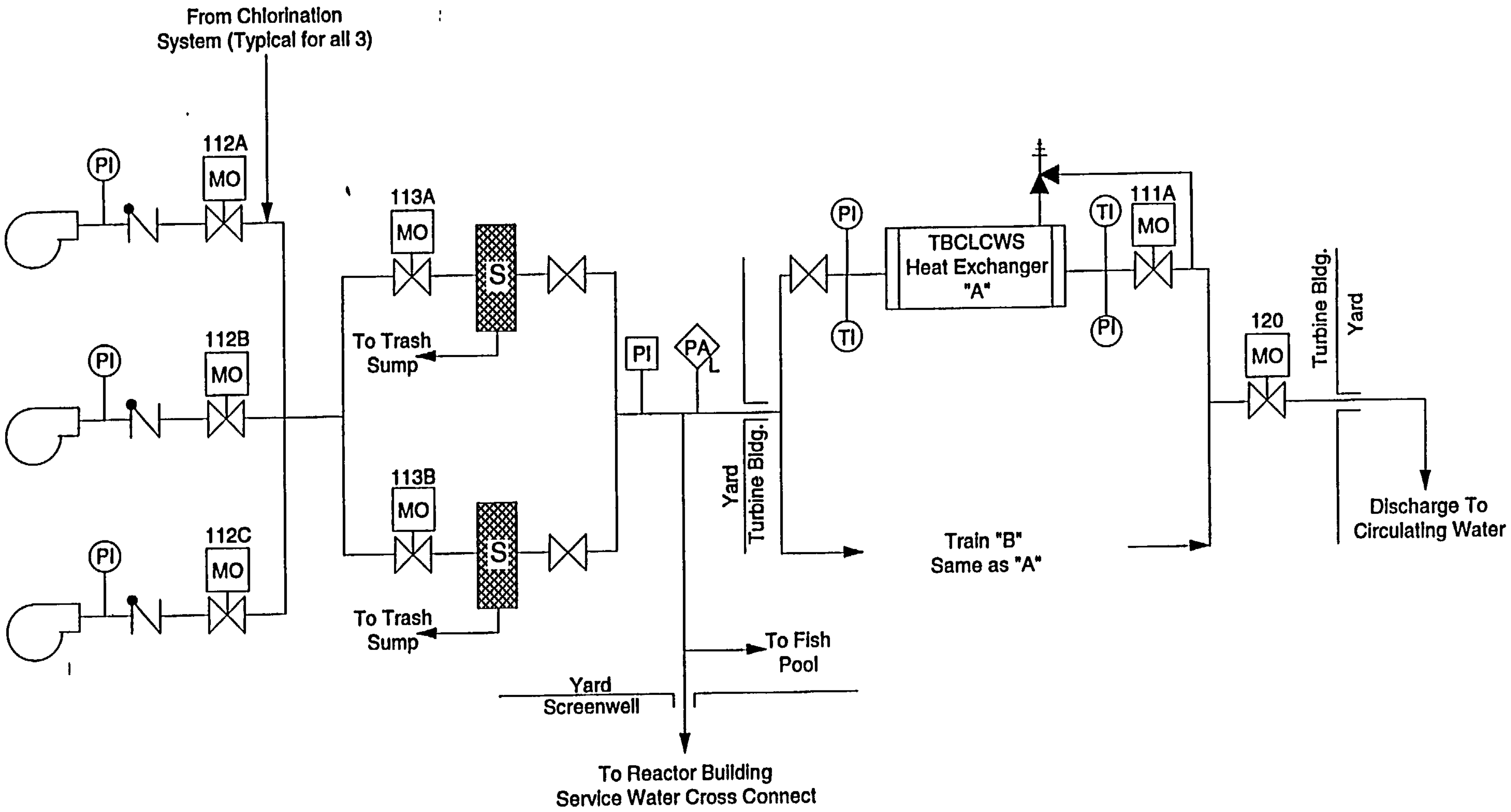

Figure 11.4-1 Turbine Building Service Water System

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Chapter 11.5

Turbine Building Closed Loop Cooling Water System

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11.5 Turbine Building Closed Loop Cooling Water System

Lesson Objectives:

1. State the system's purpose.
2. Explain how the system accomplishes its purposes.

11.5.1 Introduction

The purpose of the Turbine Building Closed Loop Cooling Water System (TBCLCWS) is to transfer heat from non-safety related components in the turbine building, radwaste building, and service building to the Turbine Building Service Water System. The major components of the TBCLCWS system are shown in figure 11.5-1.

11.5.2 System Description

The Turbine Building Closed Loop Cooling Water System (TBCLCWS) is a closed loop piping system consisting of two full-capacity centrifugal pumps, two full-capacity heat exchangers, a surge tank, two motor-operated pump discharge isolation valves and automatic system temperature and pressure control valves. The system is shown in Figure 11.5-1. The piping loop is routed throughout the turbine, office and service, and radwaste buildings, providing cooling water to the components listed in Table 11.5-1. Manual isolation valves are provided at each cooler and heat exchanger on the inlet and outlet sides to allow for isolation and maintenance.

11.5.3 Component Description

The major components of the Turbine Building Closed Loop Cooling Water system are described in the paragraphs that follow.

11.5.3.1 TBCLCW Pumps

The TBCLCW pumps are single stage, double suction horizontally mounted pumps, rated at 17.8 Kgpm @ 85 psig. The impeller is a double suction closed type cast in one piece. Both sleeve and thrust bearings are of the oil lubricated ball bearing type, a splash type oil lubrication system is provided. No external oil cooling system is required. The pumps are driven by a 1000 hp, 4.16kv, 3 phase, 60Hz, squirrel cage induction motor.

11.5.3.2 TBCLCW Surge Tank

A 1,680 gal. surge tank is located above the pump suction manifold. Connected to the pump suction manifold, the tank will reduce pressure surges, permit thermal expansion of loop water, provide a low pressure inlet for makeup water, ensure the minimum NPSH for the system pumps, and provide a method for detecting and measuring leakage. Makeup water is automatically supplied from the demineralized water system

11.5.3.3 TBCLCW Pressure Control Valve

Pressure transients caused by placing coolers in the system in or out-of-service, are compensated for automatically by pressure control valve PCV-92. This valve is located in the recirculation line connecting the TBCLCW heat exchanger discharge manifold to the TBCLCW pump common suction header. Increased in system pressure cause the pressure control valve to open, thereby permitting recirculating flow around the TBCLCW pumps to increase, maintaining a constant discharge pressure.

11.5.3.3 TBCLCW Temperature Control Valve

A heat exchanger bypass line containing automatic temperature control valve (TCV-001) is provided from the pump discharge header to the cooling water heat exchanger discharge header. Closed loop cooling water discharge temperature is maintained at a constant 95°F by modulation of bypass flow around the heat exchanger.

11.5.4 System Features and Interrelations

System operation and interrelations between this system and other plant systems are discussed in the paragraphs that follow.

11.5.4.1 Normal Operations

During normal operation one of the TBCLCW pumps is operating with the other pump in standby. If the operating pump should trip, the standby pump will start, the discharge valve of the starting pump will automatically open 10 seconds after the standby start.

11.5.4.2 Abnormal Operations

The TBCLCW system does not receive power from the emergency buses. Upon total loss of offsite power, the TBCLCW pumps will stop, the motor operated valves will fail as is and the system will no longer supply cooling water to any components.

11.5.4.3 System Interfaces

A short discussion of interfaces this system has with other plant systems is given in the paragraph which follow.

4160V Normal Distribution System (Section 9.1)

The TBCLCW pumps and motor operated valves receive power from the Normal Power System .

Turbine Building Service Water (Section 11.4)

The Turbine Building Service Water System cools the TBCLCW system.

11.5.5 Summary

Classification:

Power Generation system.

Purpose:

To transfer heat from the turbine building components to the Turbine Building Service Water system.

Components:

Pumps, Pipes, and Valves

System Interfaces:

Normal Power System, Turbine Building Service Water system.

Table 11.5-1 TBCLCWS Load List

Turbine Building

Station Air compressor
Condensate booster pump lube oil coolers
Condenser air removal pump sealing water cooler
Geerator leads cooler
Reactor feed pump turbine lube oil coolers
Hydrogen coolers
Offgas desuperheater condensers
Offgas drain coolers
Electro-Hydraulic Control coolers
Condensate pump motor bearings
Condenser air removal pump lube oil coolers
Generator stator cooling unit
Exciter alternator cooler
Main turbine lube oil coolers
Sample system coolers
Offgas glycol skid freon condensers
Offgas loop seal cooling jackets
Low conductivity drain tank coolers

Radwaste Building

Waste evaporator
Sample system coolers
Regenerant evaporator
Radwaste vent glycol chillers

Office and Service Building

O & SVB air conditioning condenser

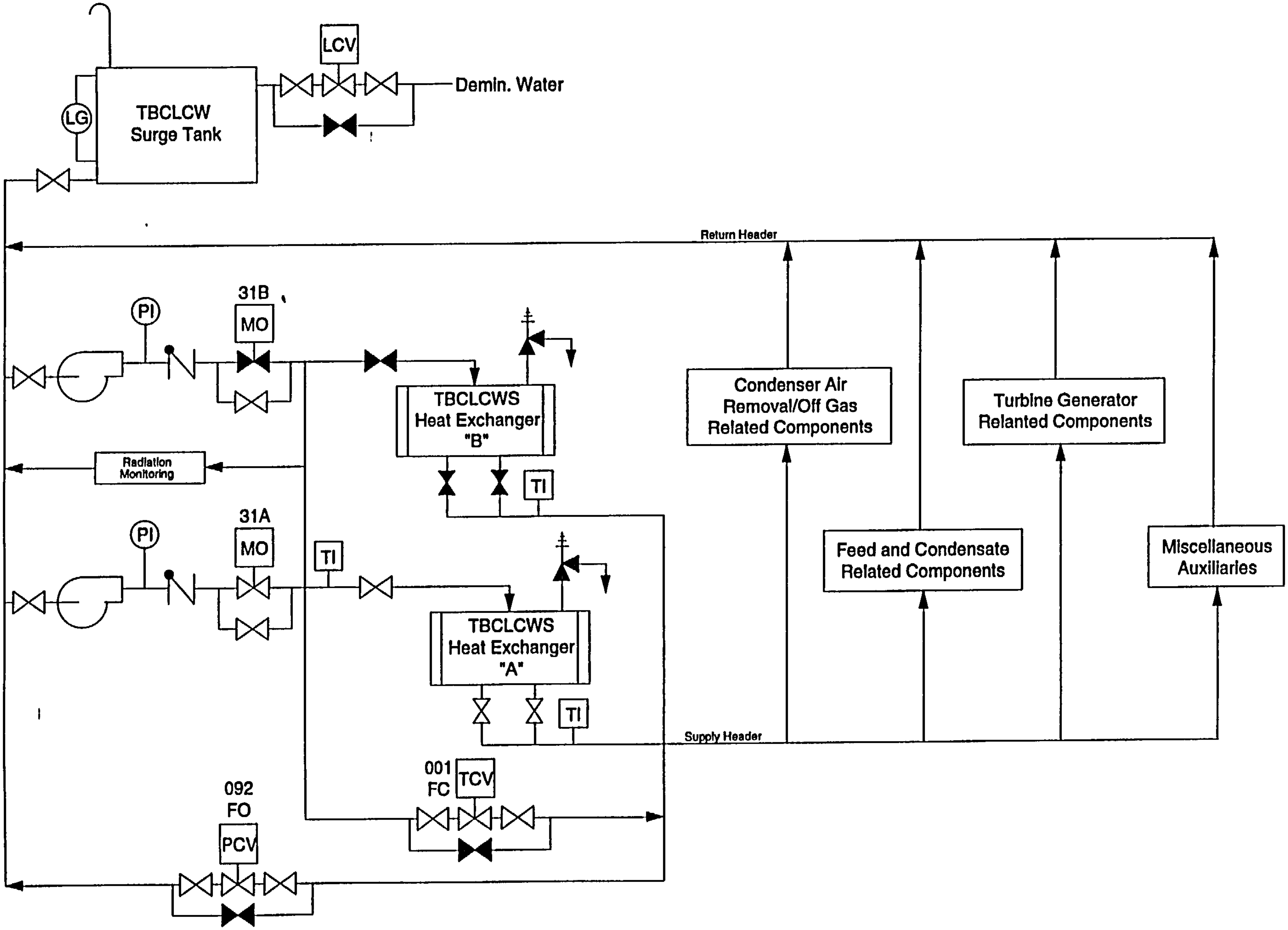

Figure 11.5-1 Turbine Building Closed Loop Cooling Water System

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Chapter 11.6

Condensate Transfer and Storage System

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11.6 CONDENSATE TRANSFER AND STORAGE SYSTEM

11.6.1 Introduction

The Condensate Transfer and Storage (CTS) System stores and distributes reactor quality water for the main steam cycle and for numerous auxiliary systems. It also maintains a minimum of 150,000 gallons for the Reactor Core Isolation Cooling (RCIC) System and the High Pressure Coolant Injection (HPCI) System.

The functional classification of the Condensate Transfer and Storage System is that of a power generation system.

11.6.2 System Description

The Condensate Transfer and Storage System consists of two condensate transfer pumps, a normal supply pump, a condensate storage tank, a freeze protection heater, pipes, valves, and instrumentation to accomplish the system purpose. The supply header from the condensate storage tank supplies water to the condensate transfer pumps, the normal supply pump, the Control Rod Drive Hydraulic System pumps, and the condenser makeup. A separate connection to the condensate storage tank is used to supply water for the High Pressure Coolant Injection (HPCI) System and Reactor Core Isolation Cooling (RCIC) System. There is another tank connection for various return lines.

11.6.3 Component Description

The major components of the Condensate Transfer and Storage System are discussed in the paragraphs that follow and are shown in Figure 11.6-1.

11.6.3.1 Condensate Storage Tank

The condensate storage tank (CST) is a carbon steel tank, 50 feet in diameter and 35 feet high. It has an effective capacity of 500,000 gallons and is vented to the atmosphere. It is located outdoors, inside a concrete dike, next to the turbine building. The dike has the capacity to retain all of the potentially contaminated condensate should the tank rupture or leak. All of the tank connections are above the tank connection for the RCIC and HPCI header to ensure that there is 150,000 gallons of water for their operation. The CST provides the required static head for the suction of the condensate transfer pumps and the normal supply pump.

11.6.3.2 Normal Supply Pump

The normal supply pump runs continuously; its minimum flow requirements are ensured by an automatic minimum flow valve and a return line to the condensate storage tank. This line is sized for the pump's minimum flow requirements and a heater for winter freeze protection of the storage tank. The pump is rated at 330 gpm at 220 feet total discharge head (TDH).

11.6.3.3 Condensate Transfer Pumps

The condensate transfer pumps are used to supply makeup water to various auxiliary systems. The pumps are rated at 1000 gpm at 225 feet TDH. The pumps are normally off, and one will start automatically if the system flow reaches 330 gpm. If the demand on the system is in excess of the capacity of the running pump, the second pump starts to handle the required needs of the system. As system flow decreases, the second pump drops off the line.

11.6.3.4 Freeze Protection Heater

The freeze protection heater is a two pass heat exchanger. Its purpose is to heat condensate quality water and recirculate it back to the CST to prevent freezing. It contains 124 square feet of heat transfer area. The heater has a design flow rate of 150 gpm, a design pressure of 150 psig for the shell and 100 psig for the tubes, and a design temperature of 190°F inlet and 150°F outlet. The heat source for the freeze protection heater is the plant hot water system.

11.6.4 System Features And Interrelations

A short discussion of system operation and interrelations between this system and other plant systems is given in the paragraphs that follow.

11.6.4.1 System Operation

During normal operation, the only continuous users of condensate will be the main steam cycle (gravity feed) and radwaste pump seals (pumped). The demand of the remaining consumers of condensate will be intermittent for short periods and mostly at flows less than 500 gpm. This means that one 1000 gpm condensate transfer pump will be able to meet most normal demands. For normal operation, the system is entirely automatic.

The pumped discharge portion of the system is sized to provide a fast flush of the Residual Heat Removal (RHR) System (2000 gpm) or a fast fill of the containment upper pool (2000 gpm). These two operations cannot be done simultaneously. If either of these two operations are in process, other pumped discharge uses must be curtailed.

Makeup water is supplied to the condensate storage tank by the Demineralized Water System whenever CST level is abnormally low. Table 11.6-1 provides a listing of Condensate Transfer and Storage System outputs and flow rates.

11.6.4.2 System Interrelations

The Condensate Transfer and Storage System has interrelates with various plant systems as described in the paragraphs that follow.

11.6.4.2.1 Condensate And Feedwater System (Section 2.7)

The condensate storage tank acts as a surge tank for the Condensate and Feedwater System by accommodating changes in steam cycle water requirements. The hotwell level is maintained by a makeup or dump flow of up to 3000 gpm through makeup control valves. Makeup water requirements should be less than 0.5% of the steam cycle feedwater flow or 120 gpm average. Gravity and vacuum in the condenser are used to transfer the water from the CST.

CTS water is supplied to the cleanup or polishing section of the Condensate and Feedwater System for processing and regeneration of the condensate demineralizer resins.

A gravity feed line is provided to a condensate seal water system which provides water for sealing condensate pumps and various condensate valve stems.

11.6.4.2.2 Control Rod DriveHydraulic System (Section 2.4)

The CST provides a gravity drain suction line to the Control Rod Drive Hydraulic (CRDH) System pumps.

The CRDH pump minimum flow and test lines are routed back to the CST.

11.6.4.2.3 High Pressure Core Spray System (Section 10.1)

The High Pressure Core Spray (HPCS) System pump gets its normal suction from the CST. This suction path is via a line shared with the Reactor Core Isolation Cooling System and is sized for simultaneous operation of these two systems. A HPCS pump test return line also taps into the CST.

11.6.4.2.4 Reactor Core Isolation Cooling System (Section 2.7)

The Reactor Core Isolation Cooling (RCIC) System pump gets its normal suction from the suction line shared with the HPCS pump. An RCIC pump test return line taps into the HPCS pump test return line which taps into the CST.

11.6.4.2.5 Residual Heat Removal System (Section 10.4)

CTS water is supplied to the Residual Heat Removal (RHR) System for flushing. Flushing is required to purge the stagnant water (which could be suppression pool water) from the RHR System lines before placing the RHR System in the shutdown cooling mode on a normal or abnormal plant cooldown.

11.6.4.2.6 Reactor Water Cleanup System (Section 2.8)

CTS water is supplied to the Reactor Water Cleanup (RWCU) System for filling, precoating, and backwashing of filter demineralizer resins.

11.6.4.2.7 Primary Containment System (Section 4.1)

Periodic, infrequent makeup water is supplied to the suppression pool by the CTS. During a refueling outage, water from the upper containment pool is drained to the main condenser hotwell for temporary storage. The same path can be used to refill the upper containment pool using the condensate pumps. The CTS provides an alternate method of filling the upper containment pool by pumping water from the CST.

11.6.4.2.8 Fuel Pool Cooling & Cleanup System (Section 12.1)

CTS water is supplied to the Fuel Pool Cooling and Cleanup (FPCC) System for filling, precoating, and backwashing of filter demineralizer resins and for spent fuel pool makeup.

11.6.4.2.9 Liquid Radwaste System (Section 8.2)

CTS water is supplied to the Liquid Radwaste System (LRS) for filling, precoating, and backwashing of filter demineralizer resins and filter aids. Water is also required for infrequent flushing of radwaste piping systems during equipment maintenance and after each use of piping systems handling solids. LRS water which has been processed so that it is of reactor quality is returned to the CST for reuse.

11.6.5 BWR Differences

Minor differences may exist in the CTS between facilities of product lines BWR/2 through BWR/6, but the system purpose and majority of components served are similar.

11.6.6 Summary

Classification - Power generation system

Purpose - To store and distribute reactor quality water for the steam cycle and various auxiliary systems, to provide a minimum amount of water for HPCS and RCIC Systems

Components - Condensate storage tank, normal supply pump; condensate transfer pumps; freeze protection heater

System Interrelations - Condensate and Feedwater System, CRDH System, HPCS System, RCIC System, RHR System, RWCU System, Primary Containment System, FPCC System, Liquid Radwaste System

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Chapter 11.7

Demineraliqed Water System

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11.7 DEMINERALIZED WATER SYSTEM

11.7.1 Introduction

The Demineralized Water System provides a source of demineralized water to various plant systems and components.

The functional classification of the Demineralized Water System is that of a power generation system.

11.7.2 System Description

The Demineralized Water System consists of a clearwell tank, activated carbon filters and demineralizers, associated water storage and transfer equipment, and regeneration facilities. The clearwell tank receives station service water, as required, and provides suction for the clearwell transfer pumps.

The clearwell transfer pumps discharge directly to the activated carbon filters (Figure 11.7-1). The activated carbon filter effluent discharges to the demineralizers and to the domestic water storage tank (Figure 11.7-2).

Demineralized water is discharged to the demineralized water storage tank which provides suction for the demineralized water transfer pumps and jockey pump. The tank will provide storage capability for approximately a 12 hour supply without makeup, based on a mean annual requirement of 130 gpm. The demineralized water jockey pump will maintain the distribution header in a filled and pressurized condition. Any additional requirements will be met by the demineralized water transfer pumps.

11.7.3 Component Description

The major components of the Demineralized Water System are discussed in the paragraphs that follow.

11.7.3.1 Clearwell Tank

The untreated water which will be processed by the Demineralized Water System is supplied by the Station Service Water System. This untreated water is stored in the 10,000 gallon capacity clearwell tank. Level is maintained within the tank by a level controller which operates the level control value located in the supply line from the Station Service Water System. Water is removed from the tank by two clearwell transfer pumps.

11.7.3.2 Clearwell Transfer Pumps

The clearwell transfer pumps are centrifugal, horizontal, motor driven pumps with a capacity of 270 gpm each at a differential head of 190 feet of water. The pumps are controlled using local handswitches. Normally one pump is running continuously; the other pump is in the standby condition. A minimum flow valve is provided to maintain flow through the operating pumps. If there is an excessive demand on the system, a flow switch will start the standby pump.

11.7.3.3 Activated Carbon Filters

The water from the clearwell transfer pumps passes through two, parallel, activated, carbon filters. Each filter contains 125 ft3 of filter material and can pass 250 gpm. After passing through the filters, the water passes through a pressure control valve. Before the pressure control valve, a line taps off to supply water to the domestic water storage tank.

11.7.3.4 Demineralizers

The demineralizer section is comprised of two ion exchanger trains each with a cation ion exchanger and an anion ion exchanger. Both the anion and cation exchangers are layered, bead resin type, ion exchangers, with a capacity of approximately 200 ft3 for each anion bed and approximately 150 ft3 for each cation bed. Normally, both ion exchanger trains are in service except during periods when one of the trains is being regenerated.

11.7.3.5 Demineralized Water Storage Tank

The water discharged from the ion exchanger trains is piped into the demineralized water storage tank, which is a 100,000 gallon stainless steel structure located in the yard area adjacent to the water treatment building. The tank has a storage capacity of about 12 hours' water supply without makeup. This is based on the annual water requirements of 130 gpm. Level indication is provided by a local level indicator. The level transmitter is also used for high/low level alarms as well as to regulate the flow of water through the demineralizers.

11.7.3.6 Demineralized Water Jockey Pump

The demineralized water jockey pump operates continuously to maintain the demineralized water header filled and pressurized. The jockey pump is a centrifugal pump rated at 70 gpm with a discharge head of 132 feet of water.

11.7.3.7 Demineralized Water Transfer Pumps

Any flow requirements beyond the capacity of the jockey pump are met by the demineralized water transfer pumps. These pumps operate in response to a signal from a flow switch on the line to the distribution header. Normally, one transfer pump is in the automatic mode, the other is in the standby mode. The pump in the automatic mode will start when flow demand exceeds the capacity of the jockey pump. If the flow requirement approaches the combined capacity of the jockey pump and the transfer pump then the standby transfer pump will start. As flow decreases, the standby pump and then the automatic pump will automatically stop sequentially. A minimum flow line is provided from the common discharge header back to the demineralized water storage tank. Each transfer pump is rated at 165 gpm with a discharge head of 132 feet of water.

11.7.4 System Features And Interrelations

A short discussion of system operation and interrelations with other plant systems is given in the paragraphs that follow.

11.7.4.1 System Operations

The makeup supply to the system is controlled in response to the water level in the clearwell tank. The operation of the clearwell transfer pumps is controlled by the water level in the clearwell tank and system flow requirements. Normally, one pump will be operating continuously, the other will be on standby. The starting and stopping of the standby pump is controlled by high and low discharge flows, respectively. A minimum flow line with flow valve is provided for pump protection. This valve opens in response to a low discharge flow and passes at least 10% of rated flow for one dump.

Normally, both activated carbon filters are in service. Backwashing is performed manually on one filter at a time, leaving the other in service.

The makeup to the domestic water storage tank is controlled in response to the water level in the tank.

The process flow through the demineralizer trains is controlled in response to the water level in the demineralized water storage tank with provisions for manual override at the control panel.

The supply water pressure to the demineralizers is regulated to 70 psig ± 5% by a pressure control valve in the common inlet header.

The operation of the demineralized water transfer and jockey pumps is controlled by the water level in the demineralized water storage tank and the water distribution requirements. The jockey pump operates continuously to maintain water pressure in the distribution header and to supply the continuous demands by auxiliary steam and chlorination systems. Both transfer pumps operate in response to distribution header flow requirements. Either pump may be selected for primary operation with the other in standby. The standby pump operates in response to higher flow set points than the primary pump.

The demineralized water jockey and transfer pumps supply the distribution header which supplies water to the following systems or components:

- Condensate Storage Tanks (CST)
- Fuel Pool Cooling and Cleanup (FPCC) System
- Auxiliary Steam System
- Closed Cooling Water (CCW) System
- Standby Liquid Control (SLC) System
- Diesel Generators
- Condensate and Feedwater System
- Sampling Stations
- Liquid Radwaste System
- Residual Heat Removal (RHR) System
- Offgas System
- Standby Service Water System (SSWS)
- Turbine Building Cooling Water (TBCW) System

Demineralized water lines which penetrate the auxiliary building and the containment have isolation valves which are automatically closed on auxiliary building and containment isolations, respectively.

Eventually, both the cation and anion resins become saturated with ions and will no longer demineralize the plant service water to the required effluent conditions. Then regeneration of the cation and anion resins is necessary to restore the resins to their original ion exchanging capacity. In regenerating the resin, the object is to replace the ions which the cation and anion resins have removed (for example Na and C1-) with their original radicals (hydronium H+ and hydroxyl OH-). This restores the resins to their original ion exchanging capacity. The harmful ions, Na+ and C1-, are carried away as waste.

Sufficient redundancy is incorporated in the Demineralized Water System design to permit regeneration and normal maintenance while still supplying a flow rate of 150 gpm.

11.7.4.2 System Interrelations

The Demineralized Water System has interrelations with various plant systems as described in the paragraphs that follow.

11.7.4.2.1 Station Service Water System (Section 11.1)

The Station Service Water System supplies makeup water to the clearwell tank.

11.7.4.2.2 Service And Instrument Air System (Section 11.8)

The Service and Instrument Air System provides air for the operation of valves and instruments within the Demineralized Water System.

11.7.4.2.3 Nuclear Steam Supply Shut off System (Section 4.4)

The Nuclear Steam Supply Shutoff System provides signals for automatic isolation of the demineralized water header.

11.7.5 BWR Differences

Minor differences exist in the demineralized water systems between facilities of product lines BWR/2 through BWR/6. However, the system purpose and majority of components served are fairly standard.

11.7.6 Summary

Classification - Power generation

Purpose - Provide a source of demineralized water to various plant systems and components

Components - Clearwell tank, clearwell transfer pumps, carbon filters, demineralizers, storage tank, jockey pump, transfer pumps

System Interrelations - Station Service Water System, Service Instrument Air System; Nuclear Steam Supply Shutoff System

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Chapter 11.8

Service and Instrument Air System

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11.8 SERVICE AND INSTRUMENT AIR SYSTEM

11.8.1 Introduction

The purpose of the Service and Instrument Air (SIA) System is to provide a continuous supply of compressed air of suitable quality and pressure for instruments, controls, and station use and to supply instrument air to the safety/relief valves and primary containment vacuum relief valves during all modes of plant operation including a loss of coolant accident.

The functional classification of the Service and Instrument Air System is that of a power generation system, although some components are safety related.

11.8.2 System Description

The Service and Instrument Air System is shown in Figures 11.8-1, 11.8-2, and 11.8-3. If the system air pressure in either of the units decays below the setpoint of the valves, the valves automatically close to isolate the two unit systems and allow the one not losing pressure to operate. A total of three centrifugal air compressors are used to supply the service and instrument air requirements of units 1 and 2. Two compressors are operated simultaneously to meet normal air requirements for both units; the third compressor is maintained in the standby mode.

Aftercoolers are located in the air piping downstream of each compressor. The aftercoolers reduce the temperature of the compressed air. Each compressor is also served by an air receiver which provides a reserve surge capacity to the air supply system.

The system is maintained at a constant air receiver pressure with local reduction as required. The two compressors normally maintaining the system pressure automatically load and unload as receiver pressure cycles.

The system is designed with two separate and identical 100% capacity divisions that are connected at multiple points to increase system redundancy.

Service air which is not required to be dry is taken off the air receiver discharge piping. Service and instrument air which must be dry is supplied after being processed by the refrigeration air dryers and further processed by the desiccant air dryers and after filters.

The two full capacity booster air compressors receive air from the instrument air distribution header for the reactor area and supply air at an increased pressure to the primary containment vacuum relief valves and the safety/relief valves.

11.8.3 Component Description

The major components of the service and instrument air system are discussed in the paragraphs that follow.

11.8.3.1 Service and Instrument Air Compressors

The SIA compressors are designed to supply all of the service and instrument air requirements for a single unit. The compressors are of a multistage, oil-free, centrifugal, electric motor driven design and are capable of supplying a minimum of 1000 scfm at 125 psig and 1800 rpm. Air intake is through an air filter silencer which filters particles from process air. Air is drawn into the compressor suction through a flow control valve which is automatically positioned by a compressor control circuit. A blowoff valve and silencer are located directly after the compressor unit but before the aftercooler.

Each compressor and aftercooler is cooled by water from the Closed Cooling Water (CCW) System with backup water supply from the Standby Station Service Water System (SSWS).

Each compressor has its own self contained control panel complete with three position, pull-to-lock, control switches; automatic control trip circuitry; and off normal condition annunciators.

11.8.3.2 Air Receiver

Air leaving the main SIA compressors at 125 psig is piped to one of two 300 ft3 air receivers. These air receivers provide sufficient surge reserve capacity to maintain system pressure for a time sufficient for the compressor in the standby mode to start and load. The SIA air receivers are designed for pressures of 150 psig and tested at 225 psig.

11.8.3.3 Refrigeration Air Dryers and After Filters

The refrigeration air dryers, function to reduce the dew point of instrument air to less than 35°F at 125 psig or -14°F at atmospheric pressure. The refrigeration air dryers operate continuously to dry at least 1400 scfm at 125 psig and 110°F while maintaining outlet pressure above 122 psig and a maximum pressure drop of 3 psid. At the outlet of the refrigeration air dryer are air filters which function to remove dirt and any other contaminants from the process air. Power for the refrigeration air dryers is from the Normal Auxiliary AC Power System.

11.8.3.4 Desiccant Air Dryers

The desiccant air dryers remove moisture from instrument air in order to minimize corrosion within piping and valves. These dryers are of a dual tower design. Each tower is capable of drying at least 600 scfm to a dew point of -45°F at atmospheric pressure which satisfies all of the dry air requirements of a single unit. One tower is used to dry process air; the other tower undergoes desiccant reactivation or moisture purging. Drying is accomplished with 645 lbs of alumina type desiccant material supported by a stainless steel screen in each tower.

11.8.3.5 Booster Instrument Air Compressors

The two unit 1 booster instrument air compressors are each 100% capacity units which increase the pressure of instrument air from 100 psig to between 145 psig and 150 psig at a rate of 15 scfm. These booster compressors are reciprocating, heavy duty, V-belt driven, non-lubricating compressors with teflon piston rings. Each compressor has a tube and shell type air cooled intercooler and aftercooler.

11.8.4 System Features and Interrelations

A discussion of system operation and interrelations with other plant systems is given in the sections that follow.

11.8.4.1 System Operation

The SIA System is normally operated with one of the SIA compressors and one of the booster instrument air compressors in unit 1 in continuous service and the other SIA and booster compressors in the standby mode.

The SIA compressor which is in the automatic mode loads and unloads automatically as receiver pressure cycles between low and high pressure setpoints of 120 and 130 psig, respectively. In the load portion of the cycle, the pneumatic valve on the compressor inlet is open, the blowoff valve is closed, and the compressed air is discharged through the after cooler to the air receiver. In the unload portion of the cycle, the pneumatic valve on the compressor inlet is closed and the blowoff valve is open.

The booster instrument air compressor is normally controlled and operated in the same manner as the main SIA compressor, but unloads, and loads at high and low booster instrument air receiver pressure.

There are air operated gate valves outboard of the containment penetrations and check valves on the inboard side of each penetration for each SIA System line that penetrates the containment.

In the event of a complete loss of SIA supply pressure, the plant undergoes a rapid automatic shutdown. Upon loss of air to the scram pilot valve air header, the scram valves open and fully insert all control rods.

11.8.4.2 System Interrelations

The Service and Instrument Air System interrelates with various other plant systems as described in the paragraphs that follow.

11.8.4.2.1 Closed Cooling Water System (Section 11.4)

The closed cooling water system supplies the SIA system with normal cooling water for compressor and after cooler cooling.

11.8.4.2.2 Standby Service Water System (Section 11.5)

The Standby Service Water System acts as a backup source of cooling water upon loss of the CCW System.

11.8.4.2.3 Normal Auxiliary AC Power System (Section 9.1)

Power for the SIA System is from the Normal Auxiliary AC Power (NAACP) System.

11.8.5 BWR Differences

Minor differences exist in the SIA System between facilities. However, the system purpose and majority of components served are fairly standard.

11.8.6 Summary

Classification - Power generation system

Purpose - To provide a continuous supply of compressed air of suitable quality and pressure for instruments, controls, and station use, to supply air to the safety/relief valves and primary containment vacuum relief valves during all modes of plant operation including a LOCA

Components - Compressors, receivers, air dryers and after filters, booster compressors

System Interrelations - Closed Cooling Water System, Standby Service Water System, Normal Auxiliary AC Power System

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Chapter 12.0

Plant Support Activities

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12.0 PLANT SUPPORT ACTIVITIES

12.0.1 Introduction

This chapter covers the systems which are used from the time new fuel comes on site until irradiated fuel leaves the site for remote storage. Included in this material are the Refueling and Vessel Servicing System, the Fuel Transfer System, and the Fuel Pool Cooling and Cleanup System.

12.0.2 Fuel Pooling and Cleanup System (Section 12.1)

The Fuel Pool Cooling and Cleanup (FPCC) System is provided to remove heat from, and achieve purity and clarity in, the cask pool, fuel storage pool, fuel service pool and fuel transfer pool in the fuel building and the upper containment pool, separator storage pool, storage pool, and transfer pool in the containment.

12.0.3 Fuel Transfer System (Section 12.2)

The Fuel Transfer (FT) System is provided for transferring fuel assemblies, control rod blades, and other small irradiated items from the reactor building transfer pool to the fuel building transfer pool, and for transferring new fuel from the fuel building to the reactor building.

12.0.4 Refueling and Vessel Servicing System (Section 12.3)

The Refueling and Vessel Servicing System provides the facilities and equipment for handling and storage of new and spent fuel, for vessel refueling, and for servicing of reactor vessel internal components.

12.0.5 Typical Refueling Outage

In the process of refueling and servicing a reactor, about 400 separate operations may be performed. This is only an order of magnitude and is given to illustrate the fact that with such a large number of operations, an efficient and safe refueling servicing procedure is strongly dependent on planning, preparation, and performance.

Before each outage, every step needs to be planned; specific tasks need to be assigned to each person who will perform each of the various operations.

Certain sequences of steps are performed at every refueling outage. During each stage, these sequences are refined to provide the safest, most efficient method of performing the function. The planning includes equipment inspection before starting as well as periodic checks of equipment during operations.

During a typical outage the following major tasks might be required:

- Remove 25% of the core fuel assemblies.
- Shuffle 25% of the core fuel assemblies.
- Reload 25% of the previously channeled new fuel assemblies.
- Replace a few control rod blades.
- Replace several of the incore instrument assemblies.
- Accomplish in vessel sipping of fuel assemblies as required.
- Perform routine service work as required.

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Chapter 12.1

Fuel Pool Cooling and Cleanup System

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System Figures

12.1 FUEL POOL COOLING AND CLEANUP SYSTEM

Learning Objectives:

1. State the purposes of the fuel pool cooling and cleanup system and describe how the system accomplishes its purpose.
2. Describe the design features of the fuel pool cooling and cleanup system which prevent inadvertently lowering the water level in the spent fuel pool.

12.1.1 Introduction

The Fuel Pool Cooling and Cleanup (FPCC) System maintains the fuel storage pool and separator storage pool at an acceptable temperature and removes dissolved and suspended solids. Removal of these solids is required to maintain the pools within acceptable activity limits and to maintain the necessary water quality to store, transfer, and service the reactor internals and fuel assemblies.

The functional classification of the FPCC System is that of a safety related system.

The purposes of the Fuel Pool Cooling and Cleanup (FPCC) System are:

1. To remove decay heat released from the spent fuel elements.
2. To maintain water quality for refueling activities and storage of spent fuel.
3. To provide shielding to reduce radiation levels on the refueling floor.

The FPCC System (Figure 12.1-1) consists of pumps, heat exchangers, filter/demineralizers, diffusers, tanks, and storage pools. The FPCC System is a closed loop system, removing water from the spent fuel storage pool via skimmer surge tanks and then returning the water at a lower temperature and of reactor quality. FPCC pumps take suction on skimmer surge tanks and discharge to heat exchangers where heat is removed by the Reactor Building Closed Loop Cooling Water System. From the heat exchangers the water is forced through filter/demineralizers and back to the fuel storage pool. The fuel storage pool then flows over weirs and back into the skimmer surge tanks.

During refueling operation, the reactor well and dryer separator pit are flooded to facilitate fuel transfer operation and storage of the dryer and separator. Water is then diverted so that the reactor well receives a small portion of the system flow.

12.1.2 Component Description

The major components of the FPCC System are discussed in the following paragraphs and are shown in Figures 12.1-1 through 12.1-5.

12.1.2.1 Dryer-Separator Storage Pit

The purpose of the dryer-separator storage pit (Figure 12.1-1) is to provide underwater storage for the steam dryer and shroud head/steam separators assemblies during a refueling outage.

The pit is constructed of re-enforced concrete with a stainless steel liner. The area between the stainless steel liner and concrete liner (annulus area) drains to the reactor building floor drain sump through "tell-tale" sight glasses.

Because the pit can be drained through the reactor well via its bottom drain, a raised step at the bottom of the pit, between the pit and the reactor well is provided. The raised step provides two functions: First, if the pit is drained through the reactor well, particulate matter from the pit is prevented from entering the reactor well. Secondly, a 6" layer of water over the shroud head is assured, keeping the shroud head covered thereby keeping the radiation levels on the refueling floor low.

There is a spray system installed around the perimeter of the upper edges of the dryer separator pit. Usually several hours elapse between removal of the steam dryer and the time that the shroud head is ready to lift. During this time, the steam dryer will dry off and the attached crud tends to release airborne radioactivity. This would result in having to wear respiratory equipment to be able to work on the refueling floor. To prevent this from happening, the dryer-separator pit is equipped with adjustable spray spargers and nozzles which are connected by hose to the clean demineralized water transfer system. The sprays are directed at the steam dryer and keep it wet while flooding the pit and removing the shroud head.

12.1.2.2 Reactor Well/Cavity

The reactor well, Figure 12.1-2, provides a space which can be flooded to permit fuel movement underwater to and from the reactor vessel. Its construction is similar to the dryer-separator pit.

During normal plant operation the reactor well is dry and three layers of semicircular shield plugs are used to reduce the refueling floor radiation levels. The normal reading on top of the shield plugs directly over the reactor at 100% power is approximately 1 mr/hr. Removable shield plugs are also provided in the opening between the reactor well and the fuel pool and between the reactor well and the dryer-separator pit.

Reactor well isolation valves provide isolation of the free return line to the reactor well and are normally open during refueling when the reactor well is flooded. They will automatically close on low-low level in the skimmer surge tanks.

12.1.2.2.1 Refueling Bulkhead

The refueling bulkhead, Figure 12.1-3, in conjunction with two bellow seals provides a water tight barrier to permit flooding above the reactor and prevent water from entering the drywell. It is a flat circumferential plate rigidly fixed to the inside of the drywell. It contains ventilation duct hatches which allow the drywell cooling system to cool, as well as the area above the bulkhead (within the drywell head) during normal plant operation.

The reactor vessel to refueling bulkhead seal accommodates the differential expansion that occurs between the reactor vessel and the drywell during reactor heatup and cooldown. This seal is a cylindrical, one piece stainless steel bellows. One end is welded to a special skirt provided on the reactor vessel, the other end is welded to the refueling bulkhead. Any leakage past the seals is detected by a flow indicating switch which alarms in the control room.

The drywell to reactor building seal accommodates the differential expansion that occurs between the drywell and reactor building concrete during plant heatup and cooldown. Its construction is similar to the reactor vessel to drywell seal.

12.1.2.3 Fuel Storage Pool

The fuel storage pool provides for storage and cooling of spent fuel, spent control rods, and other irradiated core internals. The pool is 41' long, 33' wide and 38'9" deep with a capacity of 385,000 gallons. The pool is constructed of reinforced concrete with a stainless steel liner.

12.1.2.3.1 Pool Gates

Two rubber gasketed gates are used to permit draining of the reactor well and dryer-separator pit during normal plant operation while still maintaining the normal fuel pool water level. The gates are held in place by lugs on the wall of the fuel pool and are dogged down from the refueling floor to assure a leak tight seal. The slot between fuel pool and reactor well is only deep enough to permit passage of a fuel bundle when carried by the refueling bridge fuel grapple in the full up position. This assures adequate water coverage of the spent fuel in the unlikely event that the reactor well is drained without the fuel pool gates in place. Approximately 3' of water will be available above the spent fuel in this case.

The area between the reactor well and spent fuel pool gates is normally drained and lined up to a flow indicating switch to detect leakage past the first spent fuel pool gate.

12.1.2.3.2 High Density Fuel Storage Racks

The old fuel storage racks had a storage capacity of 1080 fuel assemblies. The present installation consists of storage modules composed of fuel storage tubes arranged in 13 x 13 and 13 x 17 arrays. The total pool capacity of fuel assemblies is supplied by fourteen modules of 13 x 13 and five modules of 13 x 17. There are five extra positions for defective fuel storage and 370 temporary storage locations. The new racks are seismic category I structures.

The rectangular fuel storage tube is fabricated by forming an outer and inner sheet of 304 stainless steel sandwich around a core of aluminum clad Boral (a B_4C dispersal in aluminum). The inner and outer walls of the storage tube are welded together at each end, which isolates the aluminum clad Boral from direct contact with fuel pool water. Except for the Boral and aluminum, all structural material used in fabrication of the new modules is type 304 stainless steel.

The module design is free-standing, transferring shear forces to the pool slab through friction resistance provided by the normal force of the weight of the module through the support columns resting on the pool floor liner. Analysis ensures that only a small sliding will occur from earthquake motions.

Swelling has been detected in boral racks caused by leaks in the tubes, which allow water to enter the tubes. The water results in corrosion of the aluminum cladding, which generates hydrogen. To prevent a buildup of hydrogen within the tubes which could cause swelling, holes are drilled in the top of the tubes.

12.1.2.4 Skimmer Weirs and Surge Tanks

Water is removed from the reactor well and the fuel pool through skimmer weirs (Figure 12.1-4). The weir plates are adjustable over a 3" range. This sets the pool water level. Skimmer surge tanks are provided to accept overflow from the reactor well and/or fuel pool. The skimmer surge tanks provide an adequate supply of water to the suction of the fuel pool cooling pumps and act as a surge tank to handle the water displaced by the largest piece of equipment that will be immersed into or removed from the pools (spent fuel shipping cask).

A long slot on the end of the fuel pool nearest the skimmer surge tank provides additional overflow capacity to the surge tank when large objects are rapidly placed in the fuel pool.

The skimmer surge tanks filter out any large foreign particles to protect the fuel pool cooling pumps through removable screens that are installed at the top of each tank. Access to the screens are through hatches over the skimmer surge tanks on the operating floor. The tank levels are kept the same by an equalizing line between them.

12.1.2.5 FPCC Pumps

The Fuel Pool Cooling Pumps provide forced circulation of water through the fuel pool cooling heat exchangers and filter/demineralizers and back to the pool.

There are two horizontal, centrifugal, 600 gpm pumps. One pump is normally on line and is controlled from a local panel near the pumps or from the radwaste control panel. To handle the maximum normal heat load, both pumps are required to be operating. The pumps are powered from 480V shutdown boards.

12.1.2.6 Heat Exchangers

The FPCC heat exchangers, located downstream of the FPCC pumps, are used to transfer the heat from the pools to the Reactor Building Closed Loop Cooling Water (RBCLCW) System. Each of the two heat exchangers is capable of removing half of the decay heat generated from an average discharge of spent fuel. FPCC water flows through the shell side of the heat exchangers while service water flows through the tube side.

12.1.2.7 Filter/Demineralizers

The filter/demineralizers remove suspended and dissolved solids, by filtration and ion exchange, to maintain the clarity and purity of the refuel pool water within acceptable limits. The design capacity of each filter/demineralizer unit permits one complete water volume change per day.

Since each filter/demineralizer can operate independently of the other, one unit can be removed from service for precoating, backwashing, or maintenance without diminishing normal system capability. During refueling operations and other periods of poor water quality, it is possible to place both units on line to provide filtration and demineralization capability at twice the normal rate. The filter/demineralizer units are of a pressure precoat type similar to the Reactor Water Cleanup System filter/ demineralizers.

12.1.2.8 Diffusers

Diffusers are used to slow down the velocity of water returning to the reactor well and fuel storage pools. The placement of the diffusers in the pools is designed to distribute the return water as efficiently and with as little turbulence as possible. The diffuser piping incorporates check valves to prevent the pool water from being siphoned out of the pool and uncovering the irradiated fuel.

12.1.3 System Features and Interfaces

A short discussion of system features and interfaces this system has with other plant systems is given in the paragraphs which follow.

12.1.3.1 Pool Ventilation

Ventilation ducts are located around the perimeter of the pool at an elevation just above the skimmer weirs. Their purpose is to evacuate air from directly over the surface of the pool to keep the airborne radiation level to a minimum and to keep the refueling floor relative humidity as low as possible.

12.1.3.2 System Operational Summary

The FPCC System is designed to prevent excess radiation to personnel, and to maintain the water in the spent pool at <150°F. The FPCC System can maintain the fuel pool temperature <138°F when removing the maximum normal heat load with the RBCLCW water at 100°F.

Normally, the spent fuel pool is full and the dryer-separator pit and reactor well are empty. One fuel pool cooling pump is running with one heat exchanger and a filter/demineralizer in service with the bypass valves closed. Makeup will occasionally be required due to evaporation.

Upon receiving a skimmer surge tank low level alarm, the fuel pool can manually be filled using the condensate transfer pumps and water from the condensate storage tank. Overfilling the pool will overflow into the ventilation ducting and from there into the reactor building.

In preparation for refueling, the reactor well shield plugs are removed along with the drywell head, the reactor vessel head insulation, and RPV head spray and level column lines. The reactor vessel head is removed and the steam dryer assembly is moved (dry) to the dryer-separator storage pit. Using the dryer separator pit spray, the dryer is kept wet.

Approximately 430,000 gallons of reactor grade water is required to fill the reactor well and dryer-separator pit. This water (for the reactor well and dryer-separator pit) is transferred to and from the main condenser hotwell.

After filling the reactor well and dryer-separator pit with water stored in the main condenser hotwell using a condensate pump (through the feedwater spargers), the shroud head is transferred to dryer-separator pit and the fuel pool gates are removed. When water clarity is adequate, refueling operations are begun.

During refueling operations, there will be a net inflow of water into the reactor well from the Control Rod Drive (CRD) System, if the CRD hydraulic system is in operation. This water is rejected by either the Reactor Water Cleanup System (Section 2.8) drain flow regulator or the fuel pool cooling reject line.

There are no connections to the fuel pool which can allow drainage of the pool below the bottom of the fuel transfer canal from the reactor well.

NOTE: The only way to drain the pool is to use a portable sump pump.

For high heat loads, both pumps and both heat exchangers are used. With one demineralizer in service, all flow above 550 gpm is routed through the demineralizer bypass valves. For high suspended matter or high dissolved matter content, two filter/demineralizers may be used with two pumps and two heat exchangers, or one heat exchanger and one filter/demineralizer. During refueling operations, fuel pool cooling circulation to the reactor well may be used as needed using the reactor well supply valve.

A connection is provided between the FPCC System and the Residual Heat Removal (RHR) System (Section 10.4) to permit the use of the RHR heat exchangers to cool the fuel pool(s) in the event the FPCC System is not capable of maintaining water temperature within specified limits.

12.1.3.3 System Interlocks

A low-low level in the skimmer surge tanks will cause the following automatic actions:

(a) Filter/Demin bypass valves will automatically open.
(b) Filter/Demin inlet valves will automatically close.
(c) Reactor well inlet valves will automatically close if open.

The filter/demineralizer flow control valve will automatically close on filter/demineralizer high ΔP.

The drain valve to the condenser will automatically close if gate seal or drywell seal leak rate is high.

12.1.3.4 System Interfaces

A short discussion of interfaces this system has with other plant systems is given in the paragraphs which follow.

12.1.3.4.1 Condensate and Feedwater System (Section 2.6)

Makeup water to the pools is supplied by the condensate storage tank. Following refueling, the condensate storage tank provides a place to reject water to. The hotwell provides a place to gravity drain the pools following refueling.

12.1.3.4.2 Secondary Containment System (Section 4.2)

The reactor building ventilation system is used to draw off air from the top of the pool and exhaust it to the reactor building exhaust stack or to the Reactor Building Standby Ventilation System when the normal ventilation path is isolated.

12.1.3.4.3 Residual Heat Removal System (Section 10.4)

The Residual Heat Removal System can be used to aid the FPCC System in the removal of decay heat.

12.1.3.4.4 Reactor Building Closed Loop Cooling Water System (Section 11.3)

The Reactor Building Closed Loop Cooling Water System provides the cooling media for the FPCC System heat exchangers.

12.1.4 Summary

Classification

Safety related system.

Purpose

To remove decay heat released from the spent fuel elements.

To maintain necessary water quality to store, transfer, and service the reactor internals and fuel assemblies.

To minimize radioactive corrosion and fission product buildup.

Components

Dryer-Separator Pit; Reactor Wall; Fuel Storage Pool; Skimmer Weirs and Surge Tanks; FPCC pumps; heat exchangers; filter/ demineralizers; diffusers.

System Interfaces

Condensate and Feedwater System; Secondary Containment System; Residual Heat Removal System; Reactor Building Closed Loop Cooling Water System.

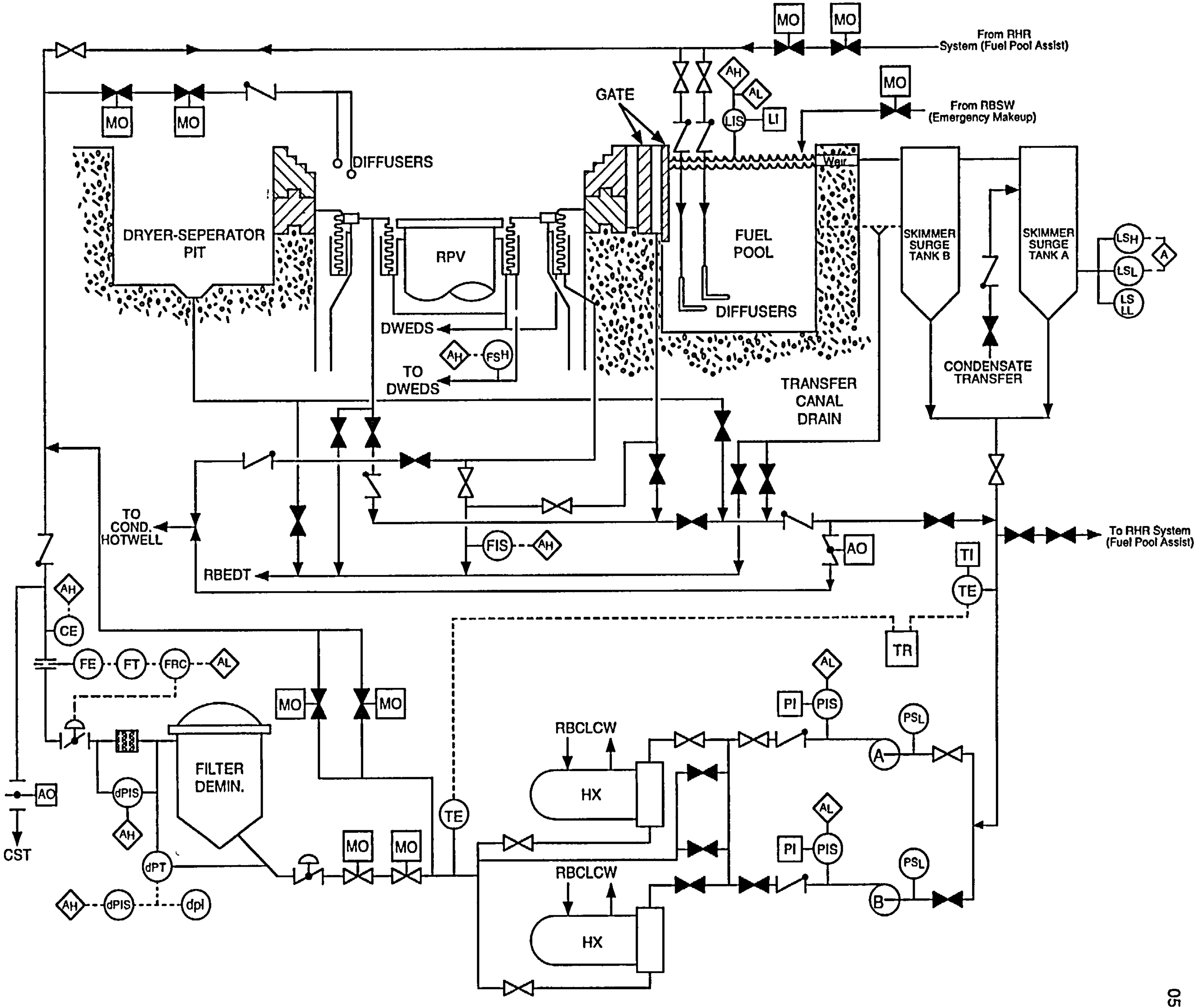

Figure 12.1-1 Fuel Pool Cooling and Cleanup System

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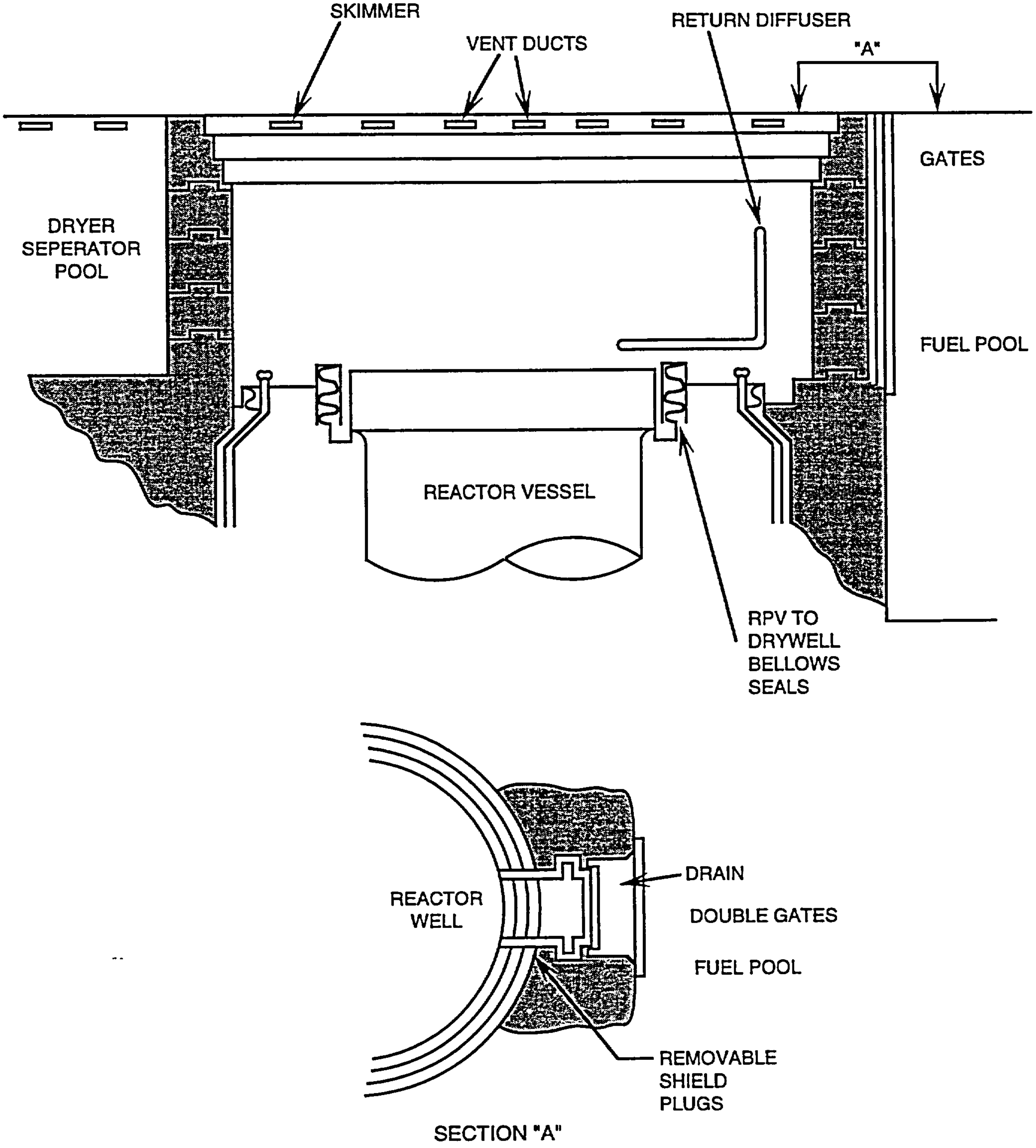

Figure 12 .1-2 Reactor Cavity and Refueling Bulkhead

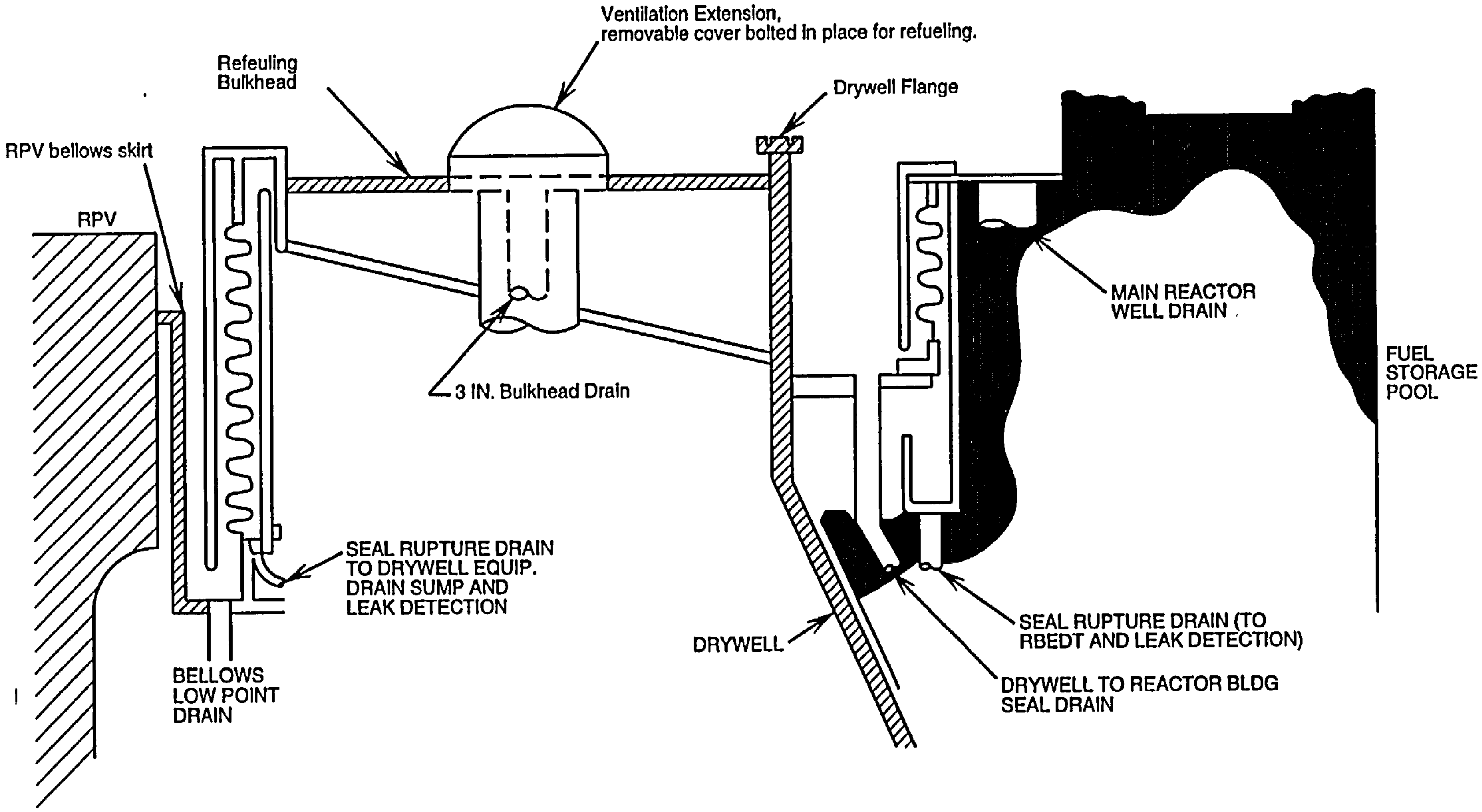

Figure 12.1-3 Refueling Bulkhead and Associated Bellows

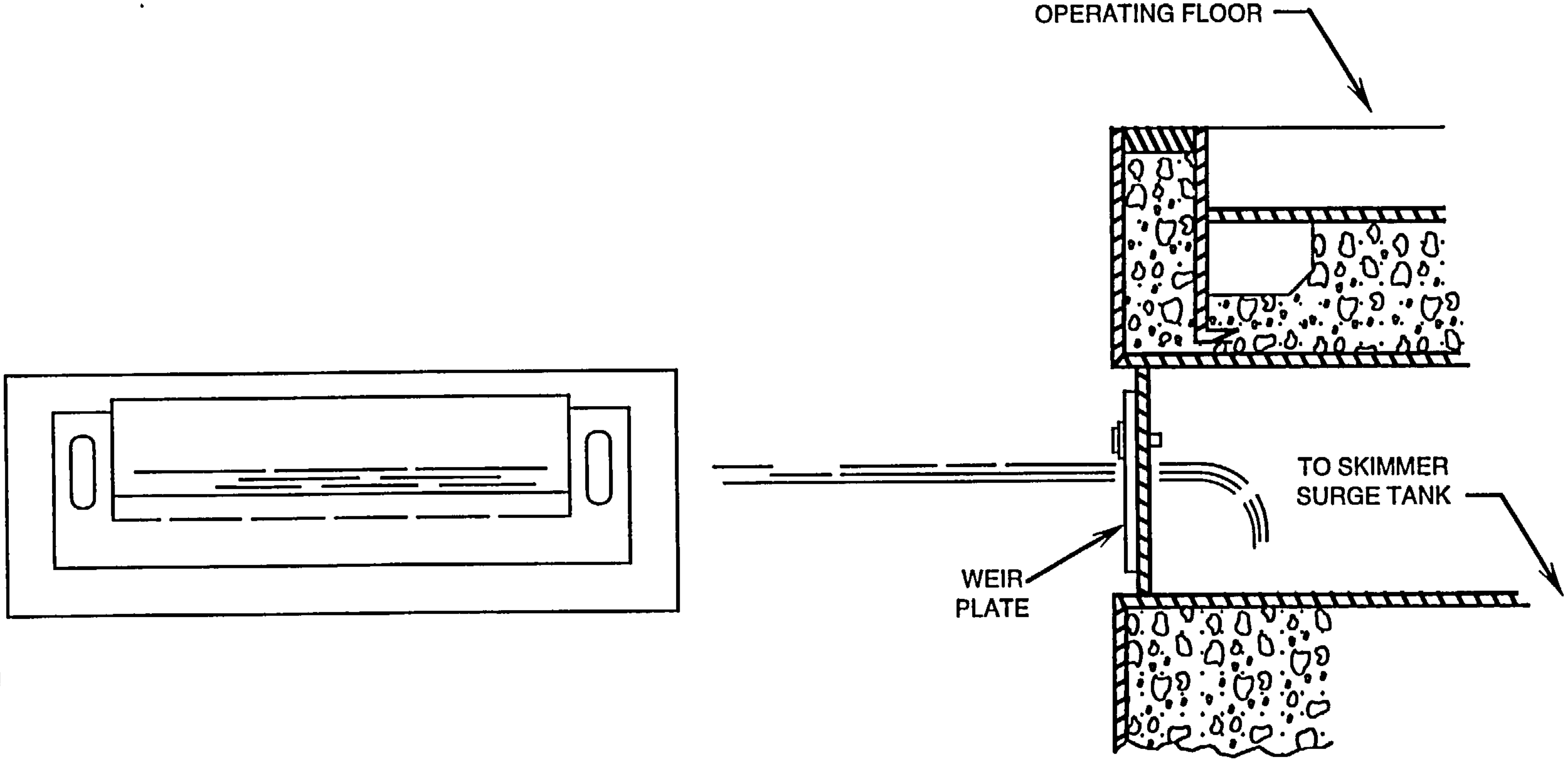

Figure 12.1-4 Fuel Pool Skimmer Weir

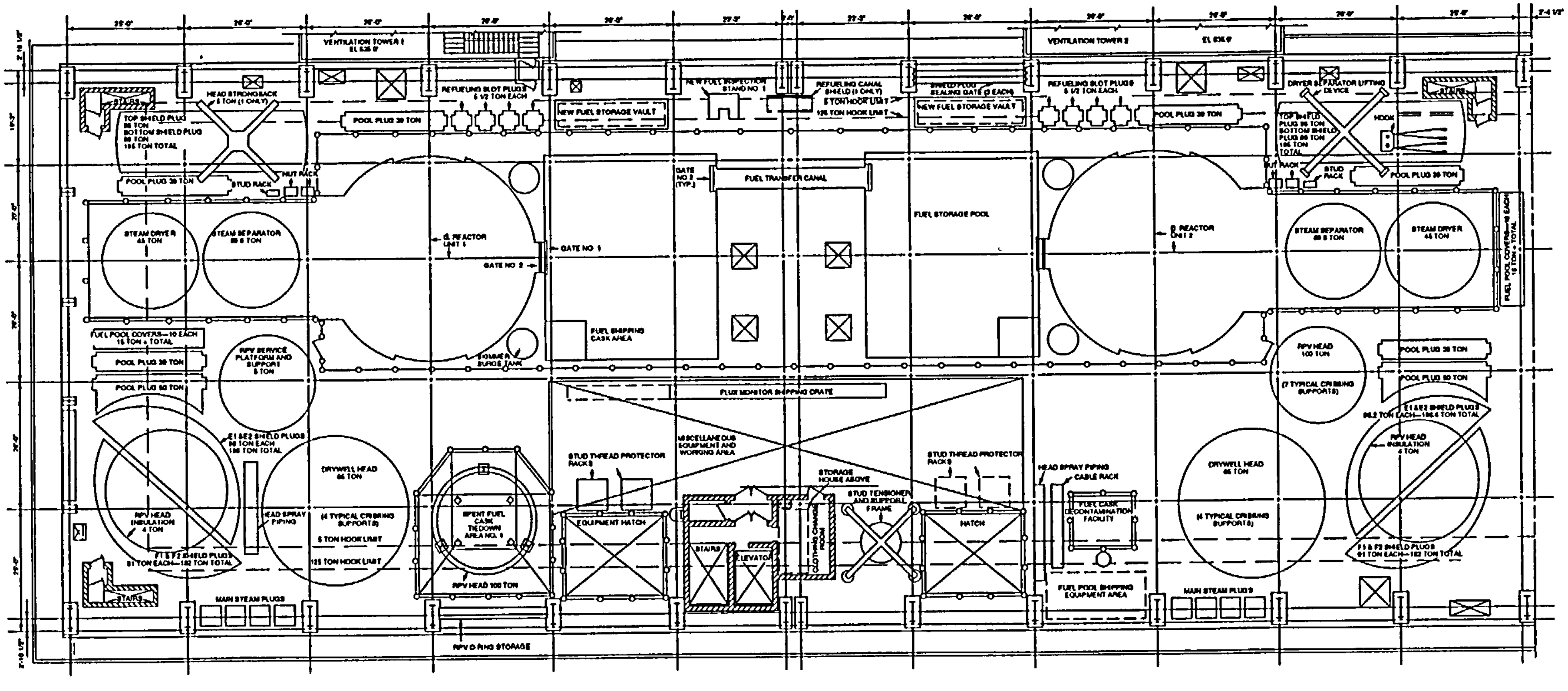

Figure 12.1-5 Typical Dual Unit Refueling Floor Arrangement

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Chapter 12.2

Fuel Transfer System

Table of Contents

12.2 FUEL TRANSFER SYSTEM

12.2.1 Introduction

The Fuel Transfer (FT) System transfers fuel assemblies, control rods, and other small irradiated items from the containment transfer pool to the fuel building fuel transfer pool and transfers new fuel from the fuel building to the containment. Also, portions of the FT System within and immediately adjacent to the containment vessel perform a containment isolation function when the FT System is not in use.

The functional classification of the FT System is that of a power generation system.

12.2.2 System Description

The FT System, shown in Figure 12.2-1, provides facilities to move spent fuel, control rods, defective fuel containers, and other small radioactive equipment between the reactor building and the fuel building. The FT System is an integral part of the plant refueling and reactor servicing maintenance program. The FT System is used only during refueling operations when the reactor is shut down. The FT System consists of an inclined water filled transfer tube, upending devices to allow carrier loading and unloading, a winch for raising or lowering the carrier, components for maintaining the primary containment boundary during reactor operation, two hydraulic power supply units, and a control system for automatic or manual operation of the transfer equipment.

The transfer tube provides a sealable, enclosed path for the carrier which is lowered and raised by means of a winch assembly. The motorized winch, located on the containment refueling floor, uses two cables attached to the follower on the lower end of the carrier to raise the carrier from the fuel building to the reactor building and to control the carriage descent velocity. A hydraulically actuated upender is provided in each pool for rotating a portion of the carrier to the vertical position for loading and unloading, and to the inclined position for transfer. The containment isolation assembly includes a blind flange and a bellows that connects the containment penetration sleeve to the assembly. The blind flange provides containment isolation during reactor operation.

12.2.3 Component Description

The major components of the Fuel Transfer System are discussed in the paragraphs that follow.

12.2.3.1 Fuel Transfer Tube

The fuel transfer tube is a fixed installation which connects the containment transfer pool, through penetrations, with the fuel building fuel transfer pool. The tube passes through the containment pool floor, containment vessel, shield building, and fuel building at an angle of 31° to the vertical. The transfer tube provides a sealable, enclosed path for the carrier which is lowered and raised by means of a winch assembly. The transfer tube is a pipe assembly which is suspended between two flexible seals or bellows. The transfer tube is a 24 inch diameter stainless steel pipe with a T-shaped track welded inside, and has a 34 inch diameter outer guard pipe. The T-shaped track serves as a guide for the carrier. At the containment pool, the transfer tube connects to the pool penetration and to a sheave box. Connected to the sheave box is a 24 inch flap valve, a vent pipe, cable enclosures, and a fill valve. In the fuel building pool, the transfer tube connects to a 24 inch gate valve. A bellows connects from the fuel building penetration to the gate valve and transfer tube to prevent water entrapment between the tube and penetration. A drain line with a motor operated valve is connected to the transfer tube just above the fuel pool water for water level control in the tube. The drain line is able to drain 1000 gallons of water by gravity to the Fuel Pool Cooling and Cleanup System drain tank within 2 minutes.

12.2.3.2 Upenders

The two hydraulically actuated upenders, one in the containment transfer pool and one in the fuel building fuel transfer pool, are mechanisms which push the tilt tube into the vertical position for fuel loading or unloading, and return it to the inclined position for the transfer between buildings. The upenders are located at both ends of the transfer tube. The upenders are mounted on pivot arms which permit them to be raised to a vertical position for loading and unloading the carrier. The upenders are stainless steel, curved sections, hinged at the bottom with a T-shaped track welded to the concave side. Each upender is contained in guide arms which provide support and guidance for the upender cradle during motion. A hydraulic cylinder is used to move the upenders to the vertical position and return them to the inclined position.

12.2.3.3 Carrier

The carrier consists of a 16 inch diameter stainless steel tilt tube and a follower. The follower remains in the inclined position; the tilt tube can be tilted into the vertical position to load or unload fuel assemblies. The tilt tube provides an enclosure for the transferable inserts.

Two inserts are provided for the tilt tube. One insert handles two fuel assemblies; the second accommodates control rods, defective fuel storage containers and other small items. When the upenders are raised to a vertical position, the tilt tube tilts with the upender while the follower maintains the inclined attitude, either in the sheave box enclosure or the pivot arm frame, depending upon the location of the tilt tube. The tilt tube is coupled to the lower section, the follower, by means of a pivot lug and stop assembly. Both the tilt tube and the follower are fitted with wheel housings containing axially opposed wheels. The vertical and horizontal wheels ride on the T-shaped track to maintain proper carrier alignment. The follower also includes the pivot bar assembly to which the redundant wire lifting ropes from the winch is attached.

12.2.3.4 Sheave Box

The stainless steel sheave box is mounted in the bottom of the reactor building transfer pool. The sheave box is a multipurpose device which not only provides a means to open and close the end of the tube, but also connects to the cable enclosure pipe and the fill valve. The sheave box encloses the cable sheaves which keep the twin wire ropes from the winch in proper parallel alignment with the carrier. The sheave box also provides a vent connection for venting to the winch head.

12.2.3.5 Winch

The winch is mounted at the refueling floor level in the containment and is used to raise the carrier from the fuel building and to control the descent from the reactor building.

The winch consists of a motor operated gear connected to a dual cable drum assembly. The winch motor receives 480V power from the Standby Auxiliary AC Power System.

The winch motor has provisions for two speed operation (60 ft/ min and 5 ft/min) and controls acceleration and deceleration each time a start or stop is made. The changes from high to low speed are accomplished by regenerative braking. The controls for accomplishing this function are automatic rather than manual. Two holding brakes, each capable of holding 150% of the winch design load, prevent cable movement when power is removed from the winch drive motor.

12.2.3.6 Containment Isolation Assembly

The containment isolation assembly is used by the FT System to isolate the containment during normal operation. The containment isolation assembly includes a blind flange and a bellows which connects from the containment penetration sleeve to the transfer assembly. When the FT System is placed in operation, the containment isolation assembly is disassembled and the blind flange is replaced with an open faced gasket. The manually operated gate valve is provided to isolate the reactor building pool water from the transfer tube so the blind flange can be installed. A hand operated hydraulic system (hand pump) is provided to compress the bellows to permit installation of the blind flange. The containment isolation assembly is shown in Figure 12.2-2.

12.2.3.7 Hydraulic Power Supply Unit

A hydraulic power supply unit (HPSU) is provided in each building to actuate the hydraulic cylinders attached to the upenders, the fill valve, the flap valve, and the gate valve. The fuel building hydraulic power supply unit is designed to operate the lower upender and the gate valve cylinders; the reactor building HPSU is designed to operate the upper upender, the flap valve, and the fill valve cylinders. The HPSU consists of a pump and 7.5 hp motor which forces demineralized water from the return reservoir through a ball check valve to the 10 gallon capacity accumulator. Each unit is mounted near the applicable transfer pool, and hydraulic lines feed hydraulic cylinders. The accumulator pressure is used to drive the hydraulic cylinders. A relief valve is provided for overpressure protection of the pump and accumulator. During normal operation, the pump starts during the cylinder stroke and stops when the accumulator is fully charged. The accumulator is sized to store enough high pressure fluid to fully stroke the upender cylinder in the event of a power failure. A two way, normally closed solenoid valve is used to dump the accumulator and high pressure lines at the end of the refueling operation or for unit maintenance.

12.2.4 System Features and Interrelations

A short discussion of system features and interrelations between this system and other plant systems is given in the paragraphs that follow.

12.2.4.1 Normal Operation

During normal plant power operation, the FT System stands idle. All space heaters remain on during the idle period.

12.2.4.2 Infrequent Mode of Operation

The FT System operates only when the reactor is in the refueling mode. To transfer spent fuel or other items from the containment to the fuel building, the tilt tube and upender are moved to the vertical position. At this point, the sheave box and the manual gate valve are open; the fill valve, the hydraulic gate valve, and the drain valve are closed. The hydraulic cylinder is actuated to push the upender and tilt tube to the vertical position. Fuel, control rods, or other items are loaded or unloaded from the tilt tube. The hydraulic cylinder is actuated to pull the tilt tube into the inclined position for transfer.

The carrier is lowered by gravity down the transfer tube to a point about 2 feet above the lower gate valve where it is stopped automatically. The sheave box cover (flap valve) is closed by the hydraulic cylinder. The drain valve is opened to allow the water in the cable enclosure, sheave box, and tilt tube to drain to the FPCC System drain tank. The water is drained to the level of the water in the fuel building fuel transfer pool. Each transfer operation results in no more than 1000 gallons of water being drained from the containment transfer pool and returned to the FPCC System. The lower gate valve is opened, and the winch is actuated to allow the carrier to move downward until it is stopped and supported by the pivot arm framing.

The hydraulic cylinder is actuated to push the lower upender and tilt tube to the vertical position, where the tilt tube is loaded or unloaded. The hydraulic cylinder is then actuated to push the lower upender and tilt tube back to the inclined position. The winch is actuated and pulls the carrier to a position approximately 2 feet above the gate valve, where it is automatically stopped. The gate valve and drain valve are closed; the fill valve is opened. The sheave box cover (flap valve) is opened when level sensors indicate that the transfer tube, sheave box, vent pipe, and cable enclosures are filled with water. The carrier is then pulled to the reactor building transfer pool. After the transfer operations are completed, the carrier is stored in the reactor building transfer pool on the upper upender. The transfer operation cycle time, including the time to operate the upenders at the ends of the tube, takes no longer than 16 minutes to complete.

12.2.4.3 Emergency Operation

During a loss of preferred power (LOPP) or loss of coolant accident (LOCA), the Standby Auxiliary AC Power System disconnects all non-ESF loads from the three divisional buses. The disconnected loads can be manually reset by the operation during an LOPP, but cannot be reconnected as long as a LOCA signal is present. All motors associated with the FT System are non-ESF.

12.2.4.4 System Interrelations

A short discussion of interrelations between this system and other plant systems is given in the paragraphs that follow.

12.2.4.4.1 Fuel Pool Cooling and Cleanup System (Section 12.1)

The Fuel Pool Cooling and Cleanup (FPCC) System is used to maintain the fuel building and containment pools below a maximum temperature and at a acceptable level. One thousand gallons of water are drained from the FT System transfer tube into the FPCC System drain tank during each transfer cycle. In addition, the fuel transfer pool supplies the same volume to the transfer tube during the cycle.

12.2.4.4.2 Refueling and Vessel Servicing System (Section 12.3)

The Refueling and Vessel Servicing System is used to inspect and handle new and spent fuel, to remove and assemble fuel channels, and to load and unload fuel, control rods, and other small items into and out of the tilt tube.

12.2.4.4.3 Standby Auxiliary AC Power System (Section 9.2)

The Standby Auxiliary AC Power System supplies power to the winch motor, gate valve motor, drain valve motor, HPSU motors, space heaters, and relay panels.

12.2.5 BWR Differences

The discussion in this section is typical for a BWR/6 product line plant with the reference Mark III Containment design. BWR/6 plants with the alternate Mark III Containment design, such as Grand Gulf, have a horizontal fuel transfer system. This system is not applicable for product lines other than the BWR/6.

12.2.6 Summary

Classification - Power generation system

Purpose - To transfer fuel assemblies, control rods, and other small irradiated items from the containment transfer pool to the fuel building transfer pool and to transfer new fuel from the fuel building to the containment (Portions of the FT System provide a containment isolation function when the FT System is not in use)

Components - Fuel transfer tube, upenders, carrier, sheave box, winch, containment isolation assembly, hydraulic power supply unit

System Interrelations - FPCC System, Refueling and Vessel Servicing System, SACPS