PRELIMINARY

DRAFT

Failure Modes and Effects Analysis for the Oconee 1 Nuclear Power Station Makeup and Purification System

Prepared for the
Instrumentation and Controls Division
Union Carbide Corporation, Nuclear Division

by
Science Applications, Inc.
Systems Analysis Division

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1.0 INTRODUCTION

(To be included in next draft.)

2.0 SYSTEM DESCRIPTION

2.1 Makeup and Purification System Overview

The Makeup and Purification System consists of the piping and process equipment required to remove, process and replace reactor coolant at the flowrates required to maintain constant Reactor Coolant System (RCS) Coolant Volume. The major functions performed by the Makeup and Purification System are:

1. Letdown Control: Controlled removal of reactor coolant from the RCS and reduction of coolant temperature and pressure at a preset flowrate.

2. Purification: Removal of impurities from the reactor coolant using boric acid saturated ion exchange resins.

3. Coolant Processing and Chemical Addition: Recovery of concentrated boric acid and demineralized water from letdown reactor coolant; supply of demineralized (boric acid free) water and concentrated boric acid to adjust reactor coolant boric acid concentrations; and supply of lithium hydroxide to increase reactor coolent pH.

4. Reactor Coolant Pump (RC Pump) Seal Return: Collection, filtering and cooling of coolant flowing past the RC Pump shaft face seals.

5. RC Pump Seal Injection: Injection and filtering of processed letdown coolant to the RC pumps' shaft seals at a constant flowrate.

6. Reactor Coolant Makeup: Injection of process letdown coolant to the RCS at a flowrate controlled to maintain constant reactor coolant volume.

In addition to the normal functions performed by the Makeup and Purifications System, portions of the system are used to provide emergency injection of coolant following design basis plant accidents.

The major equipment and process flows within the Makeup and Purification System are illustrated in Figures 1 and 2. For the purposes to this study, the overall system has been divided into six subsystems, which are indicated in Figures 1 and 2 and described in the following section.

2.2 Subsystem Descriptions

The Makeup and Purification System was divided into six subsystems as shown in Figures 1 and 2. This section presents a brief functional description of each subsystem including any assumptions which were required to define the various operating modes of the system. Descriptions are based on material in the Oconee FSAR (Reference 1); specific FSAR reference drawings for the subsystems are as follows:

Subsystem 1.0 Letdown Coolers to Three-Way Valve
(Letdown Subsystem)
Figure 9-2A*, Figure 9.3-2 (Sheet 4);

Subsystem 2.0 RC Pump Seal Water Return
(Seal Return Subsystem)
Figure 9.3-2 (Sheets 1 and 4);

Subsystem 3.0 Letdown Storage Tank, Inlet Filters, and HPI Pumps
(HPI Pump Subsystem)
Figure 9.3-2 (Sheet 4);

Subsystem 4.0 RC Pump Seal Injection
(Seal Injection Subsystem)
Figure 9.3-2 (Sheets 1 and 4);

Subsystem 5.0 Reactor Coolant Makeup
(Makeup Subsystem)
Figure 9.3-2 (Sheets 1 and 4);

*Reference 2

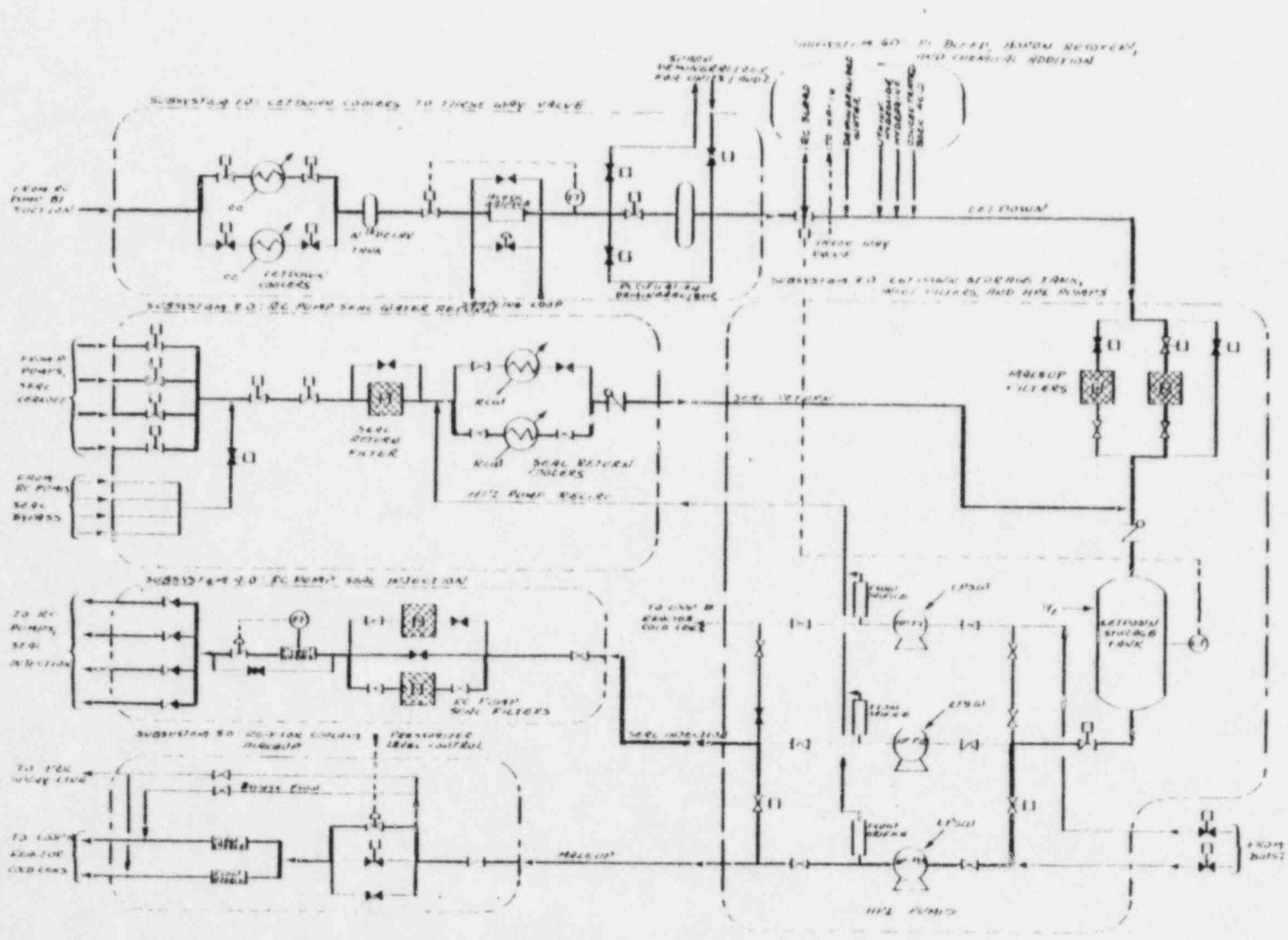

Figure 1. Makeup and Purification System Flow Sheet, Subsystems 1.0 - 5.0.

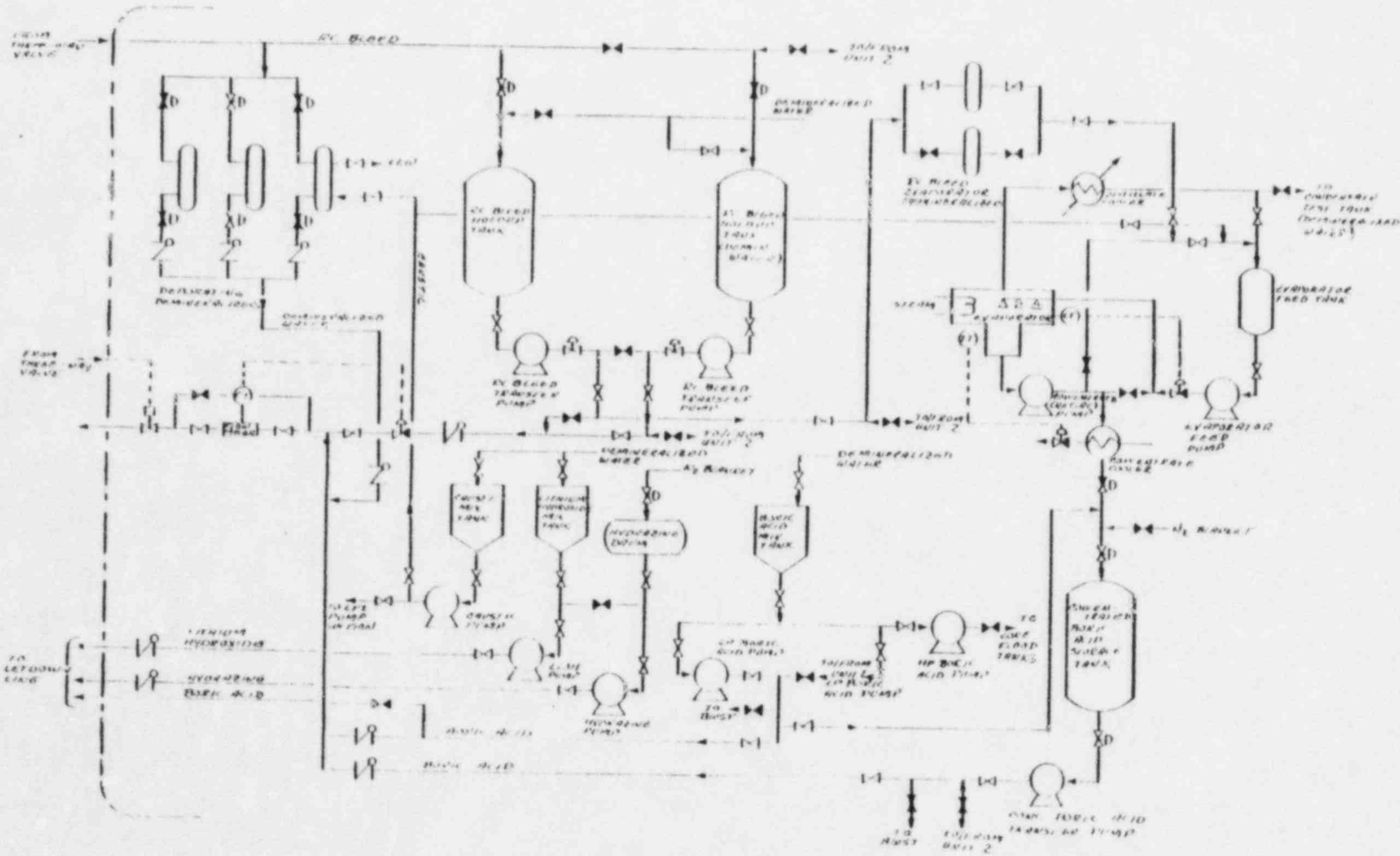

Figure 2. Makeup and Purification System Flow Sheet, Subsystem 6.0.

and seal water cooling in the circulation loop of seal water through the reactor coolant pumps. This subsystem also is used to remove heat added by the operating HPI pump.

A set of four return lines, one from the No. 1 face seal on each RC pump, normally collects the seal return flow into a common return header. Another set of four return lines, normally closed, collects the seal flow past the No. 2 face seal on each RC pump into the common return header when the leakage rate past the No. 1 face seal on any operating pump is less than one gpm (normal flow is approximately three gpm per pump).

The reactor coolant pump seal return header is an outflow line which penetrates the Reactor Building. The header has an electric motor-operated isolation valve inside the Reactor Building and a pneumatic valve outside which are automatically closed by an engineered safeguards signal. The seal return filter and coolers are outside the Reactor Building.

The seal return filter is installed in the seal return line upstream of the seal return coolers to remove particulate matter. A bypass is installed to permit servicing during operation.

The seal return coolers are sized to remove the heat added by the operating HPI pumps and the heat picked up in passage through the reactor coolant pump seals. Heat from these coolers is rejected to the Recirculated Cooling Water (RCW) System. Two coolers are provided in parallel and one is normally in operation. The flow from the seal return coolers discharges directly to the inlet header of the Letdown Storage Tank.

2.2.3 Letdown Storage Tank, Inlet Filters, and HPI Pumps

This subsystem consists of two makeup filters, the letdown storage tank (LST), three HPI pumps, pump discharge manifold, and other associated piping. The system collects the seal return and letdown flows from the RCS for the normal operation of the HPI pumps and discharges it to the RC pump seal and makeup subsystems.

The LST serves as a receiver for letdown, seal return, chemical addition, and system makeup. The tank also accommodates temporary changes in system coolant volume. All flows except seal return pass through one of the makeup filters before entering the LST. One filter is normally in operation and one is spare. The LST is continuously charged with hydrogen for RCS oxygen control.

During normal operation of the RCS, one high pressure injection pump continuously supplies high pressure water from the letdown storage tank to the seals of each of the reactor coolant pumps and to a makeup line connection to the Loop A reactor cold legs. Three high-pressure injection pumps are provided, each capable of supplying the required reactor coolant pump seal and makeup flow. One is normally in operation while another is in standby status to be used as needed. The third pump is used only for emergency injection.

2.2.4 RC Pump Seal Injection

This subsystem distributes seal injection water to the reactor coolant pumps. It consists of the seal injection header from the HPI pump discharge manifold, two RC pump seal filters, four individual injection lines (one to each RC pump), and associated piping and instrumentation.

Seal injection flow is filtered prior to entering the individual seal injection lines. One filter is normally in operation and one is spare. In addition, a bypass around both filters is available to permit maintenance during subsystem operation.

A flow control valve in the seal injection header to the pump seals automatically maintains the desired total injection flow to the seals. Manually pre-set throttle valves in each pump seal injection line provide a capability to balance the seal injection flow rates. A portion of the water supplied to the seals enters the RCS. The remainder returns to the letdown storage tank after passing through the seal return subsystem.

The four individual injection lines penetrate the Reactor Building. These lines each contain a stop-check valve inside and outside the Reactor Building for Reactor Building isolation.

2.2.5 Reactor Coolant Makeup

The reactor coolant makeup subsystem is designed to accommodate makeup requirements during normal operation, design reactor coolant system transients, and Reactor Coolant System cooldown. The subsystem consists of a makeup header off the HPI pump discharge manifold, a flow control loop, two main reactor inlets to the Loop A cold legs, and additional paths from the flow control loop feeding a small amount of flow to the reactor cold leg inlet nozzles and the pressurizer spray line.

Normal makeup flow is delivered to the two reactor cold legs of Loop A. During normal operation, makeup flow is diverted around the emergency HPI flow path through a flow control loop. A pneumatically operated control valve on the loop throttles the makeup flow to the two reactor cold legs. The flow path off the main flow control loop is assumed to provide a minimum flow bypass to minimize temperature changes in the reactor cold leg inlet nozzles and the pressurizer spray line.

2.2.6 RC Bleed, Boron Recovery, and Chemical Addition

This subsystem serves three functions:

1. Intermittent letdown of reactor coolant to a holdup tank and replacement with demineralized water or continuous operation of a deborating demineralizer;
2. Recovery of boron and purification of reactor coolant for reuse in the plant;
3. Chemical addition to add boric acid to reactor coolant for reactivity control, lithium hydroxide for pH control, hydrazine for oxygen control during shutdown, and caustic for resin regeneration in the demineralizers and chemistry control in the boron recovery operation.

Major components in this subsysytem are shown in Figure 2.

RC Bleed Holdup

RC Bleed Holdup is used for the collection and storage of reactor coolant. The coolant is received from the letdown line both as a result of reactor coolant expansion during startup and for boric acid concentration reduction during startup and normal operation. It is either conveyed to the coolant bleed holdup tank for storage or passed through a deborating demineralizer for boric acid removal and returned as unborated makeup to the makeup line. It was assumed that one deborating demineralizer is in operation, one is regenerated and available in stand-by, and a third is being regenerated at any time. A spray nozzle in the coolant bleed tanks on the inlet line allows some of the gases to be released. Recirculating the tank allows further stripping action to occur. Demineralized water can also be returned to the makeup line from the demineralized water holdup tank. Coolant from the bleed holdup tank is pumped to boron recovery for processing.

The coolant bleed holdup tank and the concentrated boric acid storage tank are vented to the gaseous waste vent header to provide for filling and emptying without overpressurization or causing a vacuum to exist. In addition, each tank is equipped with a relief valve and a vacuum breaker. Pressurized nitrogen can be supplied to each tank to allow purging.

Instruments and controls for operation of this system are located in the control room. Instruments and controls for the coolant bleed holdup tanks and pumps, demineralized water holdup tank and pump, and the concentrated boric acid storage tank and pump are duplicated on local auxiliary control boards.

Boron Recovery

Boron recovery is operated on a batch basis and is sized to process all of the reactor coolant bled from the RCS operating on an 8-hour per day basis. The system receives coolant from the bleed holdup tank through the coolant bleed evaporator demineralizers (one in operation; one available in stand-by) into the feed tank which is sized to hold sufficient feed for about five hours of evaporator operation. The coolant is then pumped into the evaporator by the evaporator feed pump which maintains a level in the evaporator while the recirculating pump recirculates the coolant until the temperature is stabilized. The distillate is returned to the feed tank until the distillate is of the desired quality for pumping to the condensate test tanks. The evaporator concentrate is sampled and normally pumped to the concentrated boric acid storage tanks at approximately 8700 ppm boron. The evaporator concentrate can be allowed to increase to 26000 ppm boron and pumped to the drumming station for ultimate disposal as solid waste.

Chemical Addition

The chemical addition portion of this system delivers the necessary chemicals to other systems as required. Boric acid is provided to the spent fuel pool, borated water storage tank, letdown storage tank, and core flooding tanks as makeup for leakage or to change the concentration of boric acid in the associated systems. Sodium hydroxide (caustic) is added to the waste evaporator feed tank during evaporator operation and to the deborating demineralizer during demineralizer resin regeneration.

A single boric acid mix tank is provided as a source of concentrated boric acid solution. The volume of the tank provides sufficient boric acid solution to increase the reactor coolant system boron concentration to that required for cold shutdown. Tank heaters and electrically heat traced transfer lines maintain the fluid temperature above that required to assure solubility of the boric acid. Three boric acid pumps are provided to transfer the concentrated boric acid solution from the boric acid tank to the borated water storage tank (BWST), makeup filters, spent fuel storage pool, or the core flooding tanks. One high pressure pump supplies boric acid to the core flooding tanks. The two low pressure pumps supply boric acid to other tanks, systems, and locations.

The caustic mix tank is used to prepare solution which neutralizes the feed to the waste evaporator. It also supplies sodium hydroxide to the deborating demineralizer for regeneration. The caustic pump transfers sodium hydroxide from the caustic mix tank to the intended destination.

Lithium hydroxide is mixed and added to the RCS from the lithium hydroxide tank. The lithium hydroxide pump transfers lithium hydroxide from the LiOH tank to the letdown line upstream of the makeup filters.

A 55-gallon drum supplies hydrazine to the Reactor Coolant System; the hydrazine is used to scavenge dissolved oxygen, primarily following a reactor shutdown. The hydrazine pump transfers to the letdown line upstream of the makeup filters.

2.3 Support Systems

(To be included in next draft).

3.0 FAILURE MODES AND EFFECTS ANALYSIS

3.1 Technical Approach

The analysis results documented in this report have been developed using failure modes and effects analysis (FMEA) techniques. A FMEA identifies failure modes for components of concern and traces their effects on other components, subsystems, and systems. Emphasis is placed on identifying problems associated with hardware failures. The advantage of the analysis technique is that while it is simple to apply, it provides for an orderly examination of potentially important failure modes throughout a system.

In a FMEA, the impact of potential faults is documented in tables which identify the component being considered, support systems associated with the component (for example, electric power for a motor-operated valve), potential component fault modes due to internal failures and unavailability of support systems, the impact of the fault on system operation, and potential remedial action if the fault occurs. Analysis of the completed tables permits identification of failures which have significant impact on system operation.

Because of the multiplicity of functions provided by the makeup and purification system, the initial FMEA was performed on a subsystem level. Makeup and purification subsystems are described in Section 2.0. Interfaces to each subsystem, including inlet and outlet links to other subsystems, support systems, and other reactor plant systems, were carefully defined during the analysis to permit integration of the subsystem analyses into a single analysis package for the entire system. Faults due to component failures were traced through the linked subsystems to identify the impact of such failures on the entire system. The impact of support system unavailabilities were traced in a similar way, except all subsystem faults due to the unavailability were concurrently traced for impact. Certain faults were grouped to facilitate analysis. As an example of this, a failed closed state was defined for normally open manual valves. This failure state included faults due to internal damage, due to plugging and due to inadvertant closure. Similarly, strainer plugging was considered in the same category as plugged lines.

The FMEAs for each subsystem are detailed in Appendices A through F. These appendices describe each component considered in the subsystem analyses, along with appropriate fault documentation, as described above. The subsystem FMEAs were formatted to permit computerized data basing at some future date if desired, for the inventory of components, the failure modes, the interfaces involved, the effects, and the remedial actions available. The impact of the subsystem faults at the subsystem boundaries is summarized in Section 3.3. The integration of the subsystem analysis results into a system-level failure analysis is documented in the following section.

3.2 System Level Results

A discussion and summary of system level results is TBD. However, the system level results are completed and detailed in Tables 1 through 8. The system level results include effects from the following eight categories of failures, with a corresponding table for each.

1. Pressure Boundary Failures
2. Flow Blockages
3. Flow Increases
4. Loss of Chemical Addition, Coolant Purification Capability
5. Control Instrumentation Malfunctions
6. Cooling Water Failures
7. Instrument Air Failures
8. AC Electric Power Failures

Analysis has considered support system failures (items 5 through 8 above) to the extent information was available.

3.3 Subsystem Level Results

Detailed FMEAs of the subsystems described in Section 2.2 were completed and are presented in Appendices A-F. The results of these analyses are summarized in this section. Included are tables for each subsystem which provide a list of the failure effects at the subsystem boundaries along with the failures which can lead to those effects.

TABLE 1. PRESSURE BOUNDARY FAILURES IN THE MAKEUP AND PURIFICATION SYSTEM

Failure Location	Effect	Remedial Actions
1. Letdown Subsystem		
1.1 In-Containment Piping	RC Leak or Small LOCA - decreasing pressurizer and LD tank levels, decreasing RCS pressure, and high contaminent radiation alarms alert the situation.	Emergency procedures for small LOCA's must be followed. Letdown flowpath is isolated and the HPI mode of operation initiated automatically at an RCS pressure of 1500 psi.
1.2 LD Cooler Tube Failure	RC leak or small LOCA - decreasing pressurizer and LD tank levels and high CC surge tank and radiation alarms alert operator to the situation. Until isolated, reactor coolant will pressurize the CC system resulting in the in-containment CC relief valves opening and discharging to the containment sump.	Emergency procedures for RCS leaks or small LOCA's must be followed depending on whether the leak rate exceeds the capacity of the Makeup System. Automatic isolation of the LD coolers from the RCS will not not occur. The operator must isolate the LD cooler(s) from the RCS based on high CC surge tank level and pressure. The situation may be confused by high containment sump levels and possible radiation alarms resulting from the CC relief valve discharge.

TABLE 1. PRESSURE BOUNDARY FAILURES IN THE MAKEUP AND PURIFICATION SYSTEM (Continued)

Failure Location	Effect	Remedial Actions
2. 3-Way Valve	Valve failure is considered as a flow blockage - See Table 2.	
3. HPI Pump Subsystem		
3.1 Piping Between 3-Way Valve and LD Tank	RC leak outside containment. Leak flowrate will be limited to a small increase above existing flowrate. Local radiation alarms, high sump levels and decreasing LD tank level alert operator to the situation. Manual isolation of letdown is required. In addition, breaks in locations downstream of check valve HP-7 could result in the release of H_2 which could result in fires or explosions.	Emergency procedures for a letdown line failure outside containment must be followed (if they exist). Operator must isolate the break and open an alternate flowpath from the BWST to the HPI pumps. Procedures covering subsequent shutdown of the plant without letdown must be followed.

TABLE 1. PRESSURE BOUNDARY FAILURES IN THE MAKEUP AND PURIFICATION SYSTEM (Continued)

Failure Location	Effect	Remedial Actions
3.2 Piping Between LD Tank and HPI Pumps	RC leak outside containment. Local radiation alarms, high sump levels, decreasing seal injection and makeup flowrates and possibly decreasing LD tank level alert operator to the situation. Larger leak rates (e.g., >20 gpm), may result in HPI pump cavitation and reduction in pump flowrate. This will result in the makeup control valve, HP-12, and seal injection control valve HP-31, opening to compensate, exacerbating the cavitation. This condition could lead to HPI pump damage unless the pump is manually tripped. If the HPI pump is tripped, RC pumps can continue to operate with CC water. In addition, leak paths in these locations may result in the release of H_2 which could result in fires or explosions.	Operator should trip the operating HPI pump if low or erratic flow persists, isolate the leak and provide an operable path for boric acid addition and RC pump seal injection. The letdown path to the Bleed Holdup tanks must be initiated to control pressurizer level.

TABLE 1. PRESSURE BOUNDARY FAILURES IN THE MAKEUP AND PURIFICATION SYSTEM (Continued)

Failure Location	Effect	Remedial Actions
4. RC Pump Seal Return Subsystem		
4.1 Piping Between RC Pumps and HPI Pump Subsystem	Small RC leak outside or inside containment. Local radiation alarms, high sump levels and a decreasing LD tank level alerts operator to the situation.	Isolate and repair the leak. If the leak must be isolated prior to shutdown, the flow past RC pumps #1 seals will be terminated.
4.2 Seal Return Cooler Tube Failure	Small RC leak to RCW System. Increasing RCW surge tank level, high RCW radiation alarms and decreasing LD tank level alert the operator to the situation.	Isolate the affected cooler and divert seal return flow through spare cooler.

TABLE 1. PRESSURE BOUNDARY FAILURES IN THE MAKEUP AND PURIFICATION SYSTEM (Continued)

Failure Location	Effect	Remedial Actions
5. Makeup Subsystem		
5.1 Piping Between HPI Pumps and RCS Pressure Boundary Check Valves	RC leak or high energy line failure outside or inside containment. Local radiation alarms, high sump levels, and decreasing LD Tank and Pressurizer levels alert operator to situation. For piping failures, Operating HPI pump(s) may "run-out". Unless tripped automatically by motor protection devices (if they exist) or by the operator, pump damage could occur. Effect of makeup fluid discharge unknown (see High Energy Line Break Analysis). In addition, breaks in these locations may result in the release of H_2 which could result in fires or explosions.	Emergency procedures for a high energy line break must be followed. Operator should trip the operating HPI pump, if required isolate the break and provide an operable path for boric acid addition and RC pump seal injection. Depending on the break location, RC Pump seal injection may not be possible.

TABLE 1. PRESSURE BOUNDARY FAILURES IN THE MAKEUP AND PURIFICATION SYSTEM (Continued)

Failure Location	Effect	Remedial Actions
6. Seal Injection Subsystem		
6.1 Piping Between Makeup Subsystem and RC Pumps	RC leak or high energy line failure outside or inside containment. Low seal injection flowrate alarms, local radiation alarms, high sump levels, and decreasing LD Tank and Pressurizer levels alert operator to situation. For piping failures, Operating HPI pump(s) may "run- out". Unless tripped automatically by motor protection devices (if they exist) or by the operator, pump damage could occur. Effect of makeup fluid discharge unknown (see High Energy Line Break Analysis). In addition, breaks in these locations may result in the release of H_2 which could result in fires or explosions.	Emergency procedures for a high energy line break must be followed. Operator should trip the operating HPI pump, if required, isolate the break and provide an operable path for boric acid addition and RC pump seal injection. Depending on the break location, RC Pump seal injection may not be possible.

TABLE 1. PRESSURE BOUNDARY FAILURES IN THE MAKEUP AND PURIFICATION SYSTEM (Continued)

Failure Location	Effect	Remedial Actions
7. Coolant Processing and Storage Subsystem		
7.1 Piping in the Coolant Processing and Storage Subsystem	Radiation alarms and high sump level alert the operator to the situation. Flooding may be a problem due to size of Bleed Holdup Tanks (~100,000 gal.). Failure of H_2 supply lines may result in fires or explosions. Normal letdown/makeup will be automatically initiated if a low LD Tank level results.	Operators must isolate break and take appropriate measures to control flooding or H_2 release. BWST can supply RCS boric acid requirements if required.

TABLE 2. FLOW BLOCKAGES IN THE MAKEUP AND PURIFICATION SYSTEM

Failure Location	Effect	Remedial Actions
1. Letdown Subsystem		
1.1 Letdown Path to Connection With 3-Way Valve - Letdown-Makeup Operation or Operation With Deborating Demineralizers	Reduced letdown from RCS results in makeup flow throttled due to increasing pressurizer level. Seal injection results in a continued net injection of 20 gpm and an alarmed low LD tank level.	Operator can establish an alternate letdown flowpath or clear the flow blockage. Minimum HPI pump flow recirculation must be maintained. Continued operation may require makeup to LD tank or throttling seal injection flow.
1.2 Letdown Path to Connection with 3-Way Valve - Letdown to Bleed Holdup Tank Operation	Increasing level in pressurizer results in throttling makeup flow. Demineralized water or boric acid flow to LD tank will continue resulting in an alarmed high LD tank level.	Operator can establish an alternate letdown flowpath or clear the flow blockage. Minimum HPI pump flow recirculation must be maintained. Continued operation requires throttling makeup to LD tank to avoid filling tank.

TABLE 2. FLOW BLOCKAGES IN THE MAKEUP AND PURIFICATION SYSTEM (Continued)

Failure Location	Effect	Remedial Actions
2. 3-Way Valve		
2.1 3-Way Valve Switches from Letdown to LD Tank to Coolant Processing and Storage Subsystem	Flow to LD tank stops while makeup to RCS continues at previous flowrates. Low LD tank level is alarmed and the level signal may automatically transfer valve to original position. Unless an alternate source of makeup water to LD tank is provided, the LD tank will be drained possibly resulting in damage to the operating HPI pumps.	Operator manually can transfer the 3-Way Valve to direct flow to the LD tank, open the bypass line from the letdown line to the makeup filters or provide makeup to the LD tank from the Coolant Storage Subsystem. If LD tank level cannot be maintained, the operator must throttle makeup flow to the RCS or trip the HPI pumps.
2.2 3-Way Valve Switches from Letdown to Coolant Processing and Storage Subsystem to LD Tank	LD tank level will increase and be alarmed on high level.	Return 3-Way Valve to original position or isolate makeup flow from Coolant Processing Subsystem to LD tank.
3. HPI Subsystem		
3.1 3-Way Valve to Connection With Seal Return Line-Letdown-Makeup Operation or Operation With Deborating Demineralizers	Reduced letdown from RCS results in makeup flow throttled due to increasing pressurizer level. Seal injection results in a continued net injection of 20 gpm and an alarmed low LD tank level.	Operator can establish an alternate letdown flowpath or clear the flow blockage. Minimum HPI pump flow recirculation must be maintained. Continued operation may require throttling seal injection flow.

TABLE 2. FLOW BLOCKAGES IN THE MAKEUP AND PURIFICATION SYSTEM (Continued)

Failure Location	Effect	Remedial Actions
3.2 3-Way Valve to Connection with Seal Return Line-Letdown to Bleed Holdup Tank Operation	Flow to LD tank stops while makeup to RCS continues at previous flowrates. Unless an alternate source of makeup water to LD tank is provided, the LD tank will be drained possibly resulting in damage to the operating HPI pumps.	Operator can establish an alternate letdown flowpath to the LD tank or clear the flow blockage. Continued operation may require throttling seal injection flowrate.
3.3 Seal Return Line to LD Tank	Decreasing LD tank level and isolated seal return flow alert operator to the situation. Failure to establish a flowpath from the BWST or trip the HPI pumps prior to draining the LD tank could result in HPI pump failure. If the operator trips the HPI pump(s), the RC pumps will be operating without seal injection. Injection from the BWST will result in increasing pressurizer level due to the net 20 gpm seal injection flowrate to the RCS unless a letdown flow-path to the Bleed Holdup tank is established.	Operator must open a path from the BWST prior to draining the LD tank or trip the operating HPI pump(s). To prevent filling the pressurizer, the flow blockage must be removed or a letdown flowpath to the Bleed Holdup tanks established.

TABLE 2. FLOW BLOCKAGES IN THE MAKEUP AND PURIFICATION SYSTEM (Continued)

Failure Location	Effect	Remedial Actions
3.4 LD Tank to HPI Pump Suction Piping	Low indicated makeup flowrate and low seal injection flowrate alarms alert operator to the situation. Unless the operator trips the operating HPI pump(s) or establishes a flowpath from the BWST rapidly, the operating HPI pump(s) will fail.	Operator must open path from the BWST or trip the operating HPI pumps. To prevent filling the pressurizer, the flow blockage must be removed or a letdown flowpath to the Bleed Holdup tanks established. If the operating HPI pump(s) fail, the operator must establish a flowpath through the remaining operable HPI pump(s) for RC pump seal injection and boration of the RCS.
3.5 HPI Suction Piping	Low indicated makeup flowrates and low seal injection flowrate alarms alert operator to the situation. Unless the operator trips the operating HPI pump(s) rapidly, the operating HPI pump(s) will fail.	Operator must trip the operating HPI pump(s). The operator may establish a flowpath from the BWST through the unblocked HPI pump(s) for RC pump seal injection and boration of the RCS. To prevent filling the pressurizer, the flow blockage must be removed or a letdown flowpath to the Bleed Holdup tank established.
3.6 Operating HPI Pump(s) Stop	Low indicated makeup flowrates, and low seal injection flowrates alert operator to the situation. Continued letdown flow and RC pump seal return flow result in an increasing LD tank level and a decreasing pressurizer level.	Operator may isolate letdown flow and start an alternate HPI pump after assessing the reason for the stoppage. Letdown flow may then be restored.

TABLE 2. FLOW BLOCKAGES IN THE MAKEUP AND PURIFICATION SYSTEM (Continued)

Failure Location	Effect	Remedial Actions
4. RC Pumps Seal Return Subsystem	Seal injection flow through the RC Pumps' #1 seals will cease. The seal injection flow will be directed through the RC Pumps' labyrinth seals to the RCS. Pump trip may be required if flow through one or both seals cannot be reestablished. In addition, minimum HPI pump flow must be maintained.	Operator must establish a flow-path from the #1 or #2 RC Pumps' seals to the LD tank. If the blockage stopped the HPI pump recirculation line, minimum HPI pump flow must be maintained by increasing letdown flow if required.
5. Makeup Subsystem	Operator alerted to the situation by decreasing pressurizer level and increasing LD tank level. Continued operation would slowly drain the pressurizer resulting in a reactor trip. With the pressurizer at an initially low level, the pressurizer may be drained during the subsequent transient.	Remove or bypass the flow blockage using one or more of the four HPI lines to the RCS to restore pressurizer level. If required, reduce letdown flow or boric acid/demineralized water flows to prevent filling the LD tank.

TABLE 2. FLOW BLOCKAGES IN THE MAKEUP AND PURIFICATION SYSTEM (Continued)

Failure Location	Effect	Remedial Actions
6. RC Pumps Seal Injection Subsystem	Seal injection flow to one or more RC pumps will cease. Operator alerted to the situation by seal injection low flow alarms. Reactor coolant will pass through the labyrinth seal (thermal barrier) where it will be cooled by the CC water supplied to the pump. The lower temperature reactor coolant flows through the RC Pumps' seals and back to the LD tank.	Restore seal injection. Observe RC pump procedures for operation without seal injection.
7. Coolant Processing and Storage Subsystem		
7.1 Letdown Path Through Deborating Demineralizers	Decreasing LD tank level will result in the automatic transfer of the 3-Way Valve to the LD tank.	Clear or bypass flowblockage and restore deborating demineralizer operation.
7.2 Letdown Path From 3-Way Valve to Bleed Holdup Tank	Increasing pressurizer level will result in throttled makeup flowrate to RCS. LD tank level will increase. Pressurizer level will continue to increase due to net RC Pumps' seal injection flowrate.	Operator manually can transfer 3-Way Valve to the LD tank.

TABLE 2. FLOW BLOCKAGES IN THE MAKEUP AND PURIFICATION SYSTEM (Continued)

Failure Location	Effect	Remedial Actions
7.3 Makeup Path to LD Tank	Decreasing LD tank level will result in the automatic transfer of the 3-Way Valve to the LD tank.	Clear or bypass flow blockage and restore letdown flowpath to Bleed Holdup tanks.

TABLE 3. FLOW INCREASES IN THE MAKEUP AND PURIFICATION SYSTEM

Failure Location	Effect	Remedial Actions
1. Letdown Subsystem		
1.1 Letdown Path to 3-Way Valve-Normal Letdown-Makeup Operation or Deborating Demineralizer Operation	Makeup valve to RCS opens in response to decreasing pressurizer level. LD tank level may increase. Single LD cooler operation could result in increased letdown fluid temperatures. If sufficiently high, letdown will be automatically isolated (see Table 2, Item 1.1).	Attempt to reduce flowrate or manually isolate.
1.2 Letdown Path to 3-Way Valve-Letdown to Bleed Holdup Tank	Makeup valve to RCS opens in response to decreasing pressurizer level. LD tank level decreases. 3-way valve will automatically transfer letdown to LD tank if LD tank level is sufficiently low. Single LD cooler operation could result in increased letdown fluid temperatures. If sufficiently high, letdown will be automatically isolated.	Attempt to reduce letdown flowrate. If required, transfer 3-way valve position to LD tank.

TABLE 3. FLOW INCREASES IN THE MAKEUP AND PURIFICATION SYSTEM (Continued)

Failure Location	Effect	Remedial Actions
2. 3-Way Valve		
2.1 3-Way Valve Switches from Letdown to LD Tank to Coolant Processing and Storage Subsystem	Flow to LD tank stops while makeup to RCS continues at previous flowrates. Low LD tank level is alarmed and the level signal may automatically transfer valve to original position. Unless an alternate source of makeup water to LD tank is provided, the LD tank will be drained possibly resulting in damage to the operating HPI pumps.	Operator manually can transfer the 3-Way Valve to direct flow to the LD tank, open the bypass line from the letdown line to the makeup filters or provide makeup to the LD tank from the Coolant Storage Subsystem. If LD tank level cannot be maintained, the operator must throttle makeup flow to the RCS or trip the HPI pumps.
2.2 3-Way Valve Switches from Letdown to Coolant Processing and Storage Subsystem to LD Tank	LD tank level will increase and be alarmed on high level.	Return 3-Way Valve to original position or isolate makeup flow from Coolant Processing Subsystem to LD tank.
3. HPI Pump Subsystem		
3.1 Flowpath to LD Tank from Coolant Processing and Storage Subsystem	Letdown tank level increases. Excessive addition of demineralized water will result in control rod insertion and automatic termination of demineralized water flow to LD tank.	Reduce or isolate flow from boric acid or bleed holdup tanks. Transfer letdown flow to LD tank if required.
3.2 Flowpath to HPI Pumps from BWST	LD tank level will increase.	Isolate BWST from HPI pump subsystem.

TABLE 3. FLOW INCREASES IN THE MAKEUP AND PURIFICATION SYSTEM (Continued)

	Failure Location	Effect	Remedial Actions
4.	Seal Return Subsystem	Makeup flow to RCS automatically increased in response to decreased pressurizer level.	Observe operating procedures for increased seal return flow which may be indicative of a damaged RC pump #1 seal.
5.	Makeup Subsystem	Operator alerted to the situation by increased pressurizer level and and decreased LD tank level.	Attempt to throttle makeup flowrate. Increase letdown flowrate if required to prevent filling pressurizer or draining LD tank.
6.	RC Pump Seal Injection Subsystem	Increasing pressurizer level will result in automatic throttling of makeup flow to RCS to compensate for increased seal injection.	Attempt to throttle RC pump seal injection flow.

TABLE 3. FLOW INCREASES IN THE MAKEUP AND PURIFICATION SYSTEM (Continued)

Failure Location	Effect	Remedial Actions
7. Coolant Processing and Storage Subsystem		
7.1 Flowpath to Bleed Holdup Tanks from Letdown Subsystem	Makeup valve to RCS opens in response to decreasing pressurizer level. LD tank level decreases. 3-way valve will automatically transfer letdown to LD tank if LD tank level is sufficiently low. Single LD cooler operation could result in increased letdown fluid temperatures. If sufficiently high, letdown will be automatically isolated.	Attempt to reduce letdown flowrate. If required, transfer 3-way valve position to LD tank.
7.2 Flowpath to HPI Subsystem from Coolant Processing and Storage Subsystem	Letdown tank level increases. Excessive addition of demineralized water will result in control rod insertion and automatic termination of demineralized water flow to LD tank.	Reduce or isolate flow from boric acid or bleed holdup tanks. Transfer letdown flow to LD tank if required.

TABLE 4. LOSS OF CHEMICAL ADDITION, COOLANT PURIFICATION CAPABILITY IN THE MAKEUP AND PURIFICATION SYSTEM

Failure	Effect	Remedial Actions
1. Boric Acid Makeup From Concentrated Boric Acid Tanks to LD Tank Fails	None during normal operation.	If required for plant shutdown, concentrated boric acid may be added to the LD tank from the boric acid mix tank or lower concentration boric acid may be injected from the BWST to the RCS.
2. Demineralized Water Makeup to LD Tank Fails	Failure to reduce the boric acid concentration of the reactor coolant will result in a slow decrease in core power due to decreasing core reactivity.	Restore demineralized water makeup to LD tank.
3. Lithium Hydroxide Addition to LD Tank Fails	Slow decrease in pH of reactor coolant. If pH exceeds specifications, plant shutdown will be required.	Monitor pH of reactor coolant. Restore lithium hydroxide addition to LD tank or shutdown plant if required.
4. Hydrazine Addition to LD Tank Fails	None during plant power operation. Hydrazine is required in the RCS only during plant shutdown for oxygen concentration reduction (Note: hydrazine is used during power operation for feedwater oxygen control. If feedwater oxygen concentration exceeds specifications, plant shutdown is required.).	Restore hydrazine addition capability.

TABLE 4. LOSS OF CHEMICAL ADDITION, COOLANT PURIFICATION CAPABILITY IN THE MAKEUP AND PURIFICATION SYSTEM (Continued)

Failure	Effect	Remedial Actions
5. Hydrogen Supply to LD Tank Isolated	Slow reduction in hydrogen concentration and increase in oxygen concentration in reactor coolant. If oxygen concentration exceeds specification, plant shutdown is required.	Monitor oxygen concentration in reactor coolant. Restore hydrogen addition to LD tank or shutdown plant if required.
6. Purification Demineralizers Bypassed or Depleted	Slow increase in reactor coolant impurities. If dissolved impurity concentration of reactor coolant exceeds specifications, plant shutdown may be required.	Monitor reactor coolant chemistry. Restore purification demineralizer operation or shutdown plant if required.
7. Letdown Filters Bypassed	Letdown filters and purification demineralizers unavailable for removal of particulates from reactor coolant. RC pump seal protected by seal injection filters. Effects of bypassing purification demineralizers discussed in Item 5. Other effects unknown.	Restore purification demineralizers and letdown filters to operation.

TABLE 4. LOSS OF CHEMICAL ADDITION, COOLANT PURIFICATION CAPABILITY IN THE MAKEUP AND PURIFICATION SYSTEM (Continued)

	Failure	Effect	Remedial Actions
8.	Seal Injection Filters Bypassed	Filter unavailable for removal of particulates prior to injection through RC pump seals. Unless bypassed, purification demineralizers and/or letdown filters can remove coolant particulates.	Restore seal injection filters to operation.

TABLE 5. CONTROL INSTRUMENTATION MALFUNCTIONS IN THE MAKEUP AND PURIFICATION SYSTEM

Failure	Effect	Remedial Actions
1. Spurious ES Signals (1 or 2 Output Channels)	Letdown and seal return lines isolated, 2 or 3 HPI pump injection mode initiated. RC pumps continue to operate with seal injection flow directed through the labyrinth seals (thermal barrier) unless the RC pumps are manually tripped by the operator.	After confirming no emergency condition exists, the operator may bypass the ES system, restore letdown and seal return flow, and return to pressurizer level controlled, single HPI pump makeup operation.
2. Spurious NNI Automatic Control Signals (Circuit Failures)		
2.1 High Letdown Fluid Temperature Circuit Isolates Letdown Valve HP-5	Letdown flow isolated. Makeup flow will be throttled automatically based on increasing pressurizer level. Pressurizer level will continue to rise slowly and the LD tank level drop due to the net 20 gpm seal injection input (See Table 2, Item 1.1, 1.2).	Operator alerted to the situation by high letdown temperature alarm. The operator can manually restore letdown flow and repair temperature circuit.

TABLE 5. CONTROL INSTRUMENTATION MALFUNCTIONS IN THE MAKEUP AND PURIFICATION SYSTEM (Continued)

Failure	Effect	Remedial Actions
2.2 Low LD Tank Level, "CRD Dilution Permit" or the "Batch Complete" Circuits Transfers 3-Way Valve From the Coolant Processing and Storage Subsystem to the LD Tank	MU&P system operation transfers from "Bleed and Feed" to normal letdown-makeup operation.*	The operator is alerted to the situation by a spurious low level alarm if the LD tank level transmitter failed low.
2.3 Pressurizer Level Control Circuit Opens Makeup Control Valve (HP-120)	Flow increase - makeup subsystem. See Table 3, Item 5.	See Table 3, Item 5.
2.4 Pressurizer Level Control Closes Makeup Control Valve (HP-120)	Flow blockage - makeup subsystem. See Table 2, Item 5.	See Table 2, Item 5.
2.5 RC Seal Injection Flow Control Circuit Closes Control Valve HP-31	Seal injection flow ceases and low flow is alarmed. RC pump continue to operate with reactor coolant cooled in the labyrinth seal, passing through the [illegible] shaft seal and returning through the seal return subsystem.	Operator slowly restores seal injection flow by manually opening HP-31 or its bypass valve HP-140.

*Assumes the signal from the 3-Way Valve Operator (HP-14) to the Coolant Processing and Storage Isolation Valve (HP-16) closes the isolation valve. If isolation valve remains open, see Table 3, Item 7.2.

TABLE 5. CONTROL INSTRUMENTATION MALFUNCTIONS IN THE MAKEUP AND PURIFICATION SYSTEM
(Continued)

Failure	Effect	Remedial Actions
2.6 RC Seal Injection Flow Control Circuit Opens Control Valve HP-31	Small increase in flowrate expected. The long term effects on the RC pumps and whether the increased flow is sufficient to trip the high seal P alarms is not known.	Operator manually can throttle HP-31.
3. Spurious NNI Automatic Control Signals (NNI Power Failures)		
3.1 Failure of Panelboard KI Power to ICS/NNI	The makeup control (HP-120) and letdown control valves' controls transfer to manual with their power supply automatically transferring to Panelboard KU. The valves will remain in position. The seal injection control valve (HP-31) automatic control will continue to function with its power supply automatically transferring to Panelboard KU. A spurious low LD tank signal will result in 3-way valve (HP-14) transferring letdown flow to the LD tank. Numerous other plant controls, alarms and indicators deenergized (See Section ___).	Emergency procedure for loss of KI bus, EP/O/A/1800/3, must be followed. These actions should include taking manual control valve (HP-120) and the turbine bypass valves and verifying other automatic actions.

TABLE 5. CONTROL INSTRUMENTATION MALFUNCTIONS IN THE MAKEUP AND PURIFICATION SYSTEM (Continued)

Failure	Effect	Remedial Actions
3.2 Failure of Hand Power to ICS/NNI (Branch HX)	E/P transducers for the letdown (HP-7), makeup (HP-120) and RC pump seal (HP-31) flow control valves freezing in position. Power to these transducers may be transferred to Panelboard KU (whether this transfer is automatic, as with loss of KI, or manual is unknown). The 3-Way Valve (HP-14) will be switched to transfer letdown flow to the LD tank. Numerous other plant controls, alarms are deenergized (See Section ___).	Operator must follow applicable procedures for loss of Hand Power. These actions should includue transferring (or verifying the transfer) the power for the makeup, seal injection and turbine bypass valves to KU, tripping the main feedwater pump and verifying the automatic initiation and control of emergency feedwater.
3.3 Failure of Auto Power to ICS/NNI (Branch H)	Automatic transfer of the makeup flow control to manual will occur. The valve (HP-120) will remain in position. Numerous other plant controls, alarms and indicators are deenergized (See Section ___).	Operator must follow applicable procedures for loss of autopower. These actions should include taking manual control of makeup flow, tripping the main feedwater pumps and verifying the automatic initiation and control of emergency feedwater and turbine bypass valves.

TABLE 5. CONTROL INSTRUMENTATION MALFUNCTIONS IN THE MAKEUP AND PURIFICATION SYSTEM (Continued)

Failure	Effect	Remedial Actions
3.4 Failure of Hand Power Branch H1X to ICS/NNI	Automatic control of makeup valve HP-120 operable. If manual control of valve at ICS Hand Station selected, valve will open or close to midposition. Numerous other (non-letdown/makeup) plant controls, alarms and indicators are deenergized (See Section ___).	Operator must follow applicable procedures for loss of H1X power. These actions should include transferring turbine bypass valve controls to KU and manually controlling them, tripping the main feedwater pumps and verifying the automatic initiation and control of emergency feedwater.
3.5 Failure of Hand Power Branch H2X to ICS/NNI	E/P transducers for the letdown (HP-7), Makeup (HP-120) and RC pump seal (HP-31) flow control valves are deenergized resulting in those valves freezing in position. Power to these transducers to Panelboard KU (whether this transfer is automatic as with loss of KI, or manual is unknown). The 3-Way Valve (HP-14) will be switched to transfer letdown flow to the LD tank. Other makeup/letdown alarms and indicators will also be deenergized.	Operator must follow applicable procedures for loss of H2X Power. These actions should include transferring (or verifying the transfer) the power for the makeup and seal injection to KU. Operator should be cautioned to verify operability of indicators he uses.

TABLE 5. CONTROL INSTRUMENTATION MALFUNCTIONS IN THE MAKEUP AND PURIFICATION SYSTEM (Continued)

Failure	Effect	Remedial Actions
3.6 Failure of Auto Power Branch H1 to ICS/NNI	Automatic transfer of the makeup flow control to manual will occur. The valve (HP-120) will remain in position. Numerous other plant controls, alarms and indicators are deenergized (See Section ___).	Operator must follow applicable procedures for loss of H1. These actions should include taking manual control of makeup flow, tripping the main feedwater pumps and verifying the automatic initiation and control of emergency feedwater and turbine bypass valves.
3.7 Failure of Auto Power Branch H2 to ICS/NNI	Numerous RC pump and LD tank alarms spuriously annunciate and indicators deenergized. Although no automatic controls are affected, if the operator trips the RC pumps, they cannot be restarted due to the spurious low seal injection flow interlock.	Operator should be cautioned to verify operability of alarms and indicators used for plant control/recovery.

TABLE 5. CONTROL INSTRUMENTATION MALFUNCTIONS IN THE MAKEUP AND PURIFICATION SYSTEM (Continued)

Failure	Effect	Remedial Actions
3.8 Power for Selected Pressurizer Level Transmitter Fails (Branch HEX, HEY or KU)	Indicated high pressurizer level will result in makeup control valve HP-120 closing. Pressurizer level will decrease and LD tank level will increase. In addition, if HEX or HEY failed power is selected for the SG startup level transmitter, low indicated SG startup level will result in overfilling the affected SG resulting in an automatic trip of the main feedwater pumps. If KU failed power is selected, the power computer will be lost.	Operator is alerted to the situation by high indicated and alarmed LD tank level. The operator should be cautioned to verify the operability of pressurizer level indications and alarms. Once the power failure is identified the operator may select one of the two operable pressurizer level transmitters for indication and control.

TABLE 6. COOLING WATER FAILURES IN THE MAKEUP AND PURIFICATION SYSTEM

Failure	Effect	Remedial Actions
1. Component Cooling (CC) System Failures		
1.1 Loss of CC Water to Operating LD Cooler	Increase in letdown fluid temperature resulting in automatic letdown isolation. See Table 2, Letdown Subsystem.	Restore CC flow to operating or standby LD cooler and place in operation. See also Table 2, Letdown Subsystem.
1.2 Loss of CC (Unit 1)	In addition to letdown flow isolation, cooling water will be lost to RC Pump labyrinth seals and CRDM cooling jackets. RC Pump can continue to operate without CC, however, loss of CRDM cooling may result in reactor trip.	Restore CC flow to LD cooler and other required components.
2. Low Pressure Service Water (LPSW) System Failures		
2.1 Loss of LPSW to Operating HPI Pump Motor Bearings	Motor bearing will overheat eventually requiring HPI pump trip. Long term operation would damage bearings.	Restore LPSW to operating pump or trip operating HPI pump and start backup HPI pump.

TABLE 6. COOLING WATER FAILURES IN THE MAKEUP AND PURIFICATION SYSTEM (Continued)

Failure	Effect	Remedial Actions
2.2 Loss of LPSW	In addition to loss of motor bearing cooling for the three HPI pumps, cooling water to Unit 1 and 2 CC coolers (see Item 1), the RC pump motor bearing coolers, emergency feedwater pump and turbine coolers, LPI coolers, RB cooling units, etc., will be lost.	Depending on the mode of failure, the backup LPSW pump may be started, the HPSW system may be used or the cause of failure (e.g., blocked LPSW suction strainers, loss of AC power) may be removed.
3. Recirculating Cooling Water (RCW) System Failures		
3.1 Loss of RCW to Operating Seal Return Cooler	Gradual increase in seal return temperature due to heat addition from RC pump seals and HPI pump. It is not known whether or how quickly the temperature could rise to the point where the HPI pump NPSH is inadequate.	Restore RCW to operating cooler or place standby cooler in operation. If seal return coolers' cooling water still unavailable, increased letdown and isolate HPI pump recirculation loop if required.

TABLE 6. COOLING WATER FAILURES IN THE MAKEUP AND PURIFICATION SYSTEM (Continued)

Failure	Effect	Remedial Actions
3.2 Loss of RCW	In addition to the above, cooling water to the main feedwater and condensate pumps (drivers) resulting in a loss of main feedwater, loss of spent fuel pool cooling, loss of cooling to air compressors plus loss of cooling to other miscellaneous functions. Reactor and turbine trip expected. Loss of air compressor cooling water result in loss of air compressors A, B, and C (existance of backup compressors unknown), and assumed isolation of letdown, seal return and makeup flows (see Table 6). Loss of main feedwater will result in automatic switch of emergency feedwater with pneumatic control valves automatically supplied from a backup N_2 tank.	Follow emergency procedures for loss of instrument air. Restore cooling water and air supply to pneumatic valves and restore letdown makeup operation. If air supply cannot be restored, manually restore makeup to RCS from BWST or makeup tank, provide makeup to LD tank from letdown or Bleed Holdup/Boric Acid tanks, if required, restore letdown to LD tank or Bleed Holdup tank, and restore seal return to the LD tank.

TABLE 7. INSTRUMENT AIR FAILURES IN THE MAKEUP AND PURIFICATION SYSTEM

Failure	Effect	Remedial Actions
Loss of Instrument Air	Pneumatic valves in the letdown line, seal return line, RCS makeup line and the makeup line from the coolant storage subsystem close; the seal injection control valve opens and pneumatic valves in other systems move to their failure position. Seal injection flow is passed through the RC pump labyrinth seals bypassing the #1 and #2 shaft seal and resulting in an increasing pressurizer level and decreasing LD tank level. Main feedwater will trip on high SG level (assuming reactor trip following loss of instrument air pressure) and emergency feedwater will be initiated and controlled using backup N_2 tanks for pneumatic control valves.	Operator must follow emergency procedure for loss of instrument air. Manually restore instrument air and/or manually restore letdown, seal return and makeup flows.

TABLE 8. EFFECT OF AC ELECTRIC POWER FAILURES IN THE MAKEUP AND PURIFICATION SYSTEM

Failure	Effect	Remedial Actions
1. 4160 VAC Bus 1TC Deenergized	o Operating HPI pump P1A stops, terminating seal injection and makeup to RCS. o LPSW pump A stops, reducing cooling water flow to Unit 1 and 2 serviced components by 50% including the component coolers. A gradual increase in letdown temperature is expected which may result in automatic isolation of letdown. o RCW pump D, if in operation, stops, reducing the cooling water flow to Unit 1, 2 and 3 serviced components by 33%. Overall effects of the RCW reduction are not known; the specific impact on the seal return temperature is expected to be minor.	Start standby HPI pump P1B, standby LPSW pump B and the standby RCW pump. If required open the letdown isolation valve which may close on high letdown temperature. Restore bus 1TC to service.

TABLE 8. EFFECT OF AC ELECTRIC POWER FAILURES IN THE MAKEUP AND PURIFICATION SYSTEM (Continued)

Failure	Effect	Remedial Actions
1. 4160 VAC Bus 1TC Deenergized (cont'd)	o One or both HPI discharge valves (HP-26, 27) and one or both BWST isolation valves to the HPI pumps (HP-24, 25) may be deenergized and not able to open if powered via bus TC. o The discharge valve from both letdown coolers A and B (HP-3, 4) may be deenergized and not able to close if powered via bus TC. o Air compressor motor B is deenergized and stops if energized via buses XF, X1 and TC. The air supply to serviced components is assumed to be provided by compressors B and C.	
2. 4160 VAC Bus 1TD Deenergized	o Standby HPI pump P1B and standby LPSW pump B (if connected to bus 1TD) deenergized and unavailable if required.	Restore bus 1TD to service.

TABLE 8. EFFECT OF AC ELECTRIC POWER FAILURES IN THE MAKEUP AND PURIFICATION SYSTEM
(Continued)

Failure	Effect	Remedial Actions
2. 4160 VAC Bus 1TD Deenergized (cont'd)	o One or both HPI discharge valves (HP-26, 27) and one or both BWST isolation valves to the HPI pumps (HP-24, 25) may be deenergized and not able to open if powered via bus TD.	
	o The discharge valve from both letdown coolers A and B (HP-3, 4) may be deenergized and not able to close if powered via bus TD.	
	o Air compressor motor A is deenergized and stops if energized via buses XD, X2 and TD. The air supply to serviced components is assumed to be provided by compressors A and C.	
3. 4160 VAC Bus 1TE Deenergized	o Standby HPI pump P1C deenergized and unavailable if required. If RCW pump A is in service, it will stop, reducing cooling water flow to Unit 1, 2 and 3 serviced components by 33%.	Start standby RCW pump if RCW pump A was in service. Restore bus 1TE to service.

TABLE 8. EFFECT OF AC ELECTRIC POWER FAILURES IN THE MAKEUP AND PURIFICATION SYSTEM (Continued)

Failure	Effect	Remedial Actions
3. 4160 VAC Bus 1TE Deenergized (cont'd)	o Compressor Motors A and/or B may be deenergized and stop if powered via backup buses X3 and TE. The ability of compressor C, assumed to be powered from a Unit 2 or 3 bus, to maintain air pressure is unknown (see Table 7, Failure of Instrument Air).	
4. 600 VAC, 208 VAC Buses XL Deenergized	The distillate pump, low pressure boric acid pump A, boric acid mix tank agitator and heater deenergized. Effect of this failure on plant power operation expected to be small.	Restore power to the XL buses. Concentrated boric acid requirements can be supplied via boric acid pump B.
5. 600 VAC, 208 VAC Buses XN Deenergized	The low pressure boric acid pump B and the lithium hydroxide pump and tank agitator deenergized. Effect of this failure on plant power operation expected to be small.	Restore power to the XN buses. Concentrated boric acid requirements can be supplied via boric acid pump A. Lithium hydroxide can be added using the hydrazine pump.

TABLE 8. EFFECT OF AC ELECTRIC POWER FAILURES IN THE MAKEUP AND PURIFICATION SYSTEM (Continued)

Failure	Effect	Remedial Actions
6. 600 VAC Buses XS1, XS2, X8 or X9 Deenergized	o One or both HPI discharge valves (HP-26, 27) and one or both BWST isolation valves to the HPI pumps (HP-24, 25) may be deenergized and not able to open if energized via XS1, XS2, X8 or X9. o The discharge valve from both letdown coolers A and B (HP-3, 4) may be deenergized and not able to close if energized via XS1, XS2, X8 or X9.	Restore power to deenergized bus.
7. 208 VAC Bus XS1	BWST isolation valve to the HPI pumps (HP-24) and the HPI pumps A and B HPI discharge valve (HP-26) deenergized and not able to open if required.	Restore Bus XS1 to service.
8. 208 VAC Bus XS2	BWST isolation valve to the HPI pumps (HP-25) and the HPI pump C HPI discharge valve (HP-27) deenergized and not able to open if required.	Restore Bus XS2 to service.

TABLE 8. EFFECT OF AC ELECTRIC POWER FAILURES IN THE MAKEUP AND PURIFICATION SYSTEM (Continued)

Failure	Effect	Remedial Actions
8. 208 VAC Bus XS2 (cont'd)	o The discharge valve from both letdown coolers A and B (HP-3, 4) deenergized and not able to close if required.	

Brief discussions of the major effects for each subsystem are also included in this section. However, effects such as incorrect process signals, reactor coolant leaks to the reactor building, reactor building isolation failure are generally not included in the discussions. Even though process signals that do not directly control could still potentially induce operator response leading to additional effects, given an incorrect signal, such responses were considered secondary and were generally not discussed further. Effects on isolation capability were also not discussed further since isolation was not considered normal operation and could generally be effected with available backup when required. Reactor coolant leaks are discussed with system-level results and are likewise not discussed further here.

3.3.1 Letdown Coolers to Three-Way Valve

The major effects at the subsystem interface resulting from various subsystem failures include: reduced, increased, and terminated letdown flow to three-way valve HP-14 (HP-V10); reactor coolant leaks; bypassing of letdown flow around the purification demineralizers; and failure to reduce the temperature of letdown flow from the subsystem. These effects can be precipitated by such failures as an internal component failure, a spurious control signal, or a loss of cooling water to the operating cooler. These effects and their precipitating faults are listed in Table 9. The most severe effect at the subsystem interface was found to be the termination of letdown flow to three-way valve HP-14 (HP-V10).

Reduced letdown flow can result from normally closed manual valves being opened or failing, creating leaks. Reduction in letdown flow can also result from the spurious opening of relief valves downstream of the block orifice. A radiation monitor loop and a boron meter loop bypass the block orifice. If a drain valve in either loop is left open after maintenance, a significant leak could occur when the use of the loops is initiated. A leak in one of these loops would reduce the letdown flow from the subsystem. Another possible failure is the opening of the normally closed control valve HP-9 (1HP-V8) due to internal fault or spurious control signal which would result in letdown flow diverted to Unit 2 rather than the Unit 1 LST.

TABLE 9. FMEA SUMMARY FOR SUBSYSTEM 1.0: LETDOWN COOLERS TO 3-WAY VALVE HP-14 (HP-V10)

Effects at Subsystem Interface		Precipitating Faults/Failure Modes
1. Reduced Letdown Flow to 3-Way Valve HP-14 (HP-V10)	a.	Internal component failures (normally closed manual valves fail open creating leaks or allowing some letdown flow to bypass HP-14 (HP-V10); relief valves spuriously open; if control valve HP-9 (1HP-V8) NC fails open, then letdown flow may leak to Unit 2 if HP-X2 is being used by Unit 2 and the pressure of Unit 1 letdown flow is greater than that of Unit 2 letdown flow; tube rupture in letdown cooler HP-C1A or HP-C1B)
	b.	Spurious control signal (if spurious signal corresponding to the open position is received by HP-9 (1HP-V8) NC, then letdown flow may leak to Unit 2 if HP-X2 is being used by Unit 2 and the pressure of Unit 1 letdown flow is greater than that of Unit 2 letdown flow)
2. Increased Letdown Flow to 3-Way Valve HP-14 (HP-V10)	a.	Internal component failures (manual or control valves which are NC fail open resulting in increased letdown flow)
	b.	Spurious control signal (if spurious signal corresponding to the open position is received by HP-7 (HP-V5), then increased letdown flow results; if spurious signal corresponding to the open position is received by HP-9 (1HP-V8) or HP-11 (1HP-V9), then increased letdown flow may result from an influx of Unit 2 letdown flow if HP-X2 is being used by Unit 2 and the pressure of Unit 2 letdown flow is greater than that of Unit 1 letdown flow)

TABLE 9. FMEA SUMMARY FOR SUBSYSTEM 1.0: LETDOWN COOLERS TO 3-WAY VALVE HP-14 (HP-V10)
(Continued)

Effects at Subsystem Interface	Precipitating Faults/Failure Modes
3. Letdown Flow to 3-Way Valve HP-14 (HP-V10) is Terminated	a. Internal component failures (manual or control valves which are NO fail closed obstructing letdown flow; resin beads in purification demineralizer HP-X1 melt resulting in flow blockage)
	b. Spurious control signal (if spurious signal ordering closure is received by any one: HP-1 (HP-V1A), HP-3 (HP-V2A), HP-5 (HP-V3), HP-6 (HP-V4), or HP-8 (HP-V7), then letdown flow stops)
	c. Loss of cooling water flow to the operating cooler (HP-C1A or HP-C1B) will result in increased letdown temperature and subsequent termination of letdown flow due to automatic closure of HP-5 (HP-V3)
4. Reactor Coolant Leaks	a. Internal component failures (manual or control valves which are NC fail open creating leaks; tube rupture in letdown cooler HP-C1A or HP-C1B)
	b. Spurious control signal (if spurious signal corresponding to the open position is received by HP-9 (1HP-V8), then letdown flow may leak to Unit 2 if HP-X2 is being used by Unit 2 and the pressure of Unit 1 letdown flow is greater than that of Unit 2 letdown flow
5. Chemistry of Letdown Flow to 3-Way Valve HP-14 (HP-V10) is Altered	a. Valve HP-13 (HP-V6) NC fails open due to internal fault or spurious control signal and allows the letdown flow to bypass purification demineralizer HP-X1 and proceed directly to 3-way valve HP-14 (HP-V10)
6. Increase in Temperature of Letdown Flow to 3-Way Valve HP-14 (HP-V10)	a. Loss of cooling water flow to the operating letdown cooler (HP-C1A or HP-C1B)

TABLE 9. FMEA SUMMARY FOR SUBSYSTEM 1.0: LETDOWN COOLERS TO 3-WAY VALVE HP-14 (HP-V10)
(Continued)

Effects at Subsystem Interface	Precipitating Faults/Failure Modes
7. Incorrect Process Signals to I&C System and Control Room - Letdown Flow - Cooler Discharge Temperature	a. Internal component failures in transmitters b. Loss of power supply to transmitter

Increased letdown flow can result from normally closed manual or control valves such as HP-42 or HP-7 (HP-V5) being opened or failing open. Increased letdown flow can also occur if a spurious control signal opens HP-7 (HP-V5), HP-9 (1HP-V8), or HP-11 (1HP-V9). If such a signal is received by HP-9 (1HP-V8) or HP-11 (1HP-V9), the increased letdown flow results from addition of Unit 2 letdown flow.

Termination of letdown flow can result from internal component failures and spurious control signals. Normally open manual or control valves can fail closed obstructing letdown flow, resin beads in purification demineralizer HP-X1 can agglomerate and plug resulting in flow blockage, or a main pipe or orifice can plug obstructing flow. Spurious control signal ordering closure to HP-1 (HP-V1A), HP-3 (HP-V2A), HP-5 (HP-V3), HP-6 (HP-V4), or HP-8 (HP-V7), can also terminate letdown flow.

Reactor coolant leaks can occur due to internal valve seal failures, pipe leaks, or a tube rupture in letdown cooler HP-C1A or HP-C1B.

Subsystem failures resulting in bypassing of the purification demineralizers may result in failure to remove RC impurities. If the normally closed valve HP-13 (HP-V6) fails open due to internal fault or spurious control signal. the letdown flow would bypass the purification demineralizer.

A loss of cooling water to the operating cooler would result in an increase in temperature of the letdown flow out of the subsystem. High cooler discharge temperature initiates isolation of the discharge upstream of the demineralizer, isolating letdown flow. If the temperature interlock failed to close the letdown isolation valve HP-5 (HP-V3) upon loss of cooling water to the operating cooler, the purification demineralizer HP-X1 could experience excessive heating causing resin beads to decompose or melt and subsequently block letdown flow.

3.3.2 RCP Seal Water Return

Single failures within the seal return subsystem can result in the following effects at the subsystem interfaces: blockage of flow from the RC pump seals; loss of, or reduced flow to the letdown storage tank (LST); and, temperature effects on discharge flow to the LST (high and low). Other effects of subsystem failures include reactor coolant leaks to the RCW or the auxiliary building; incorrect process indicators (flow, pressure, temperature signals); and, lack of system isolation when demanded. Table 10 lists the distinct effects that result from subsystem failures along with a summary of the precipitating faults, organized according to the fault source.

Different degrees of flow blockage from the RC pump seals can result from subsystem failures. Blockage from a single pump can result from valve failures or blockages on one of the return lines from the individual pumps. If a blockage on a seal leak-off line (the normal seal return path) is detected, the seal bypass lines can be opened. Since the bypass lines are shown to be used only in the event of an existing #1 seal-leak-off blockage (Reference 1), a failure only in a bypass line or header would not result in a change from the normal operating status. (It should be noted that operating the RC pumps with zero flow through the #2 face seals (seal bypass) is not common; increased seal wear may be occurring.)

Seal blockage from all four RC pump can result from any blockage in the common seal return header upstream of the LST. Potential failures in this category include: filter plugging; cooler tube blockage; and failed closed reactor building (RB) isolation valves and inline valves such as filter isolation valves, cooler isolation valves, and check valves. In addition to internal faults or inadvertent closure of a valve, loss of instrument air can result in the closure of the pneumatic RB isolation valve; a spurious signal from the I&C system can close the other RB isolation valve; and a spurious ES signal can close them both. If detected, blockages associated with the filter or coolers can be bypassed with local action.

TABLE 10. FMEA SUMMARY FOR SUBSYSTEM 2.0: RCP SEAL WATER RETURN

Effects at Subsystem Interface	Precipitating Faults/Failure Modes
1. Seal Leak-off Flow From a Single RC Pump Stopped	a. Spurious signal from I&C system closing a motor operated valve or the seal leakoff line
	b. Component fault within subsystem such as the motor operated valve or one of the manual isolation valves on a seal leakoff line failing closed (damage, plugging, etc.) or being closed inadvertantly
2. Seal Bypass Flow Path Blocked From a Single RC Pump	a. Component fault within subsystem (a check valve or manual valve on a seal bypass line failing closed or plugging)
3. Seal Return Bypass Flow Path Unavailable to All RC Pumps	a. Loss of control signal from I&C system to the motor operated valve on the bypass return header (HP-275)
	b. Loss of electric power to the valve described above, HP-275
	c. Component fault within subsystem (internal fault with valve HP-275)
4. Seal Return Flow From All RC Pumps Stopped	a. Spurious signal from I&C system or ES closing one of the two remote isolation valves on the seal return header (HP-20 (HP-V12) and HP-21 (HP-V13))
	b. Loss of instrument air fails remote isolation valve closed on seal return header (HP-21 (HP-V13))
	c. Component fault within subsystem (remote isolation valves, manual filter inlet and outlet valves, manual seal return cooler isolation valves or inline check valves failing closed, plugging, or inadvertantly closed; or filter plugging; or cooler heat exchanger tubes blocked)

TABLE 10. FMEA SUMMARY FOR SUBSYSTEM 2.0: RCP SEAL WATER RETURN
(Continued)

Effects at Subsystem Interface	Precipitating Faults/Failure Modes
5. Higher Temperature Discharge to Letdown Storage Tank	a. Component fault within subsystem (seal return cooler internal damage or vapor lock)
	b. Loss of Seal Injection Flow (Subsystem 4.0)
	c. Loss of RCW to seal return cooler
6. Lower Temperature Discharge to Letdown Storage Tank	a. Loss of flow from HPI pump recirculation line (Subsystem 3.0)
7. Reduced Seal Return Flow to Letdown Storage Tank	a. Loss of or reduced seal injection flow (Subsystem 4.0) or HPI pump recirculation (Subsystem 3.0)
	b. Component fault within subsystem (seal return cooler tube rupture, subsystem inline isolation or check valves plugged, or subsystem leaks)
8. Loss of Seal Return Flow to Letdown Storage Tank	a. Component fault within subsystem (inline isolation or check valves downstream of HPI pump recirculation line failed closed)
9. Reactor Coolant Leak to RCW System	a. Component fault within subsystem (tube rupture in seal return cooler)
10. Loss of Reactor Coolant	a. Component faults within subsystem such as leaks
11. Subsystem Not Isolated From Reactor Coolant System When Demanded	a. Loss of control signal from I&C to one of the 4 motor operated valves on one of the 4 seal leakoff lines
	b. Loss of electric power to one of the 4 motor operated valves on one of the 4 seal leakoff lines

TABLE 10. FMEA SUMMARY FOR SUBSYSTEM 2.0: RCP SEAL WATER RETURN
(Continued)

Effects at Subsystem Interface	Precipitating Faults/Failure Modes
11. Subsystem Not Isolated From Reactor Coolant System When Demanded (cont'd)	c. Internal damage to one of the 4 motor operated seal leakoff line valves (component fault within the subsystem)
12. Seal Return Flow Continues to Letdown Storage Tank When Isolation is Demanded	a. Failure of control signal from I&C system to close isolation valves on seal return header (HP-20 or HP-21)
	b. Loss of electric power supply to remote isolation valves on seal return header (HP-20 or HP-21)
	c. Loss of instrument air to remote isolation valve on seal return header (HP-21)
	d. Component fault within subsystem (remote isolation valves on seal return header failing)
13. Potential Loss of Vent on RCP Vent Seals	a. Motor operated isolation valve to Standpipe Fill (HP-276) fails open due to internal fault
	b. HP-276 opens on spurious signal from I&C system
14. Incorrect Process Signal to I&C System and Control Room - Seal Leak-off Line Pressures - Seal Bypass Line Pressures - Seal Leak-off Line Flows	a. Electric power supply to transmitters fails b. Component fault within subsystem such as instrument connection leaks or internal transmitter failures

Failures which result in reduced flow to the LST include loss of seal injection flow (flow input from the RC Pump Seal Injection subsystem); loss of HPI pump recirculation flow (input from the HPI Pump subsystem); and component faults within the subsystem, such as cooler tube rupture, leaks, or the inline flow blockages that also result in RC pump seal blockage. Failures which result in complete loss of flow to the LST are limited to closure failures (blockages, inadvertent closure, etc.) of inline isolation and check valves downstream of the HPI pump recirculation line inlet (just upstream of the seal return coolers).

Temperature variations in the seal return discharge to the LST can result from faults internal and external to the subsystem. High discharge temperature can result from internal cooler damage, vapor lock in the cooler, or loss of RCW. Loss of flow from the HPI pump recirculation line (Subsystem 3.0) to the system and through the cooler results in reduced flow and somewhat lower seal return discharge temperature to the LST.

3.3.3 Letdown Storage Tank, Inlet Filters, and HPI Pumps

Failures in this subsystem primarily affect output flow to RC makeup system and RC pump seal injection. Inlet flow can also be blocked from the seal return subsystem if the check valve to the LST plugs or fails closed. Component faults within the subsystem can also result in reduced H_2 concentration in the reactor coolant makeup. Table 11 summarizes resulting failure effects for this subsystem.

Affects on discharge flow from the subsystem to RC makeup and seal injection include immediate loss of flow, reduced flow, and eventual loss of available makeup. Failures that result in loss of available makeup in the LST can lead to loss of NPSH to the HPI pumps (if the LST empties while feeding the HPI pumps) and consequential pump damage or failure. These failures include blockages upstream of the LST (inline valves failed or inadvertently closed, makeup filter plugged as well as loss of instrument air or a spurious I&C signal closing the makeup filter inlet valve), and loss of inlet flow to the subsystem from letdown, seal return, or RC Bleed. If detected, most of the

TABLE 11. FMEA SUMMARY FOR SUBSYSTEM 3.0: LETDOWN STORAGE TANK (LST) INLET FILTERS, AND HPI PUMPS

Effects at Subsystem Interface	Precipitating Faults/Failure Modes
1. Reduction and Eventual Loss of Available Makeup in the Letdown Storage Tank	a. Component fault within subsystem including various valves upstream of the Letdown Storage Tank (LST) (and the filter) plugging, failing closed, or being inadvertantly closed
	b. Loss of instrument air to the pneumatic isolation valve HP-18 (HP-V29B) upstream of the LST and filter
	c. Spurious signal from the I&C system closing HP-18
	d. Loss of inlet flow from Subsystem 1.0 (RC Letdown)
2. Incorrect Process Signal(s) to I&C System and Control Room - Filter Pressure Drop - LST Level - LST Pressure	a. Transmitter failure or instrument connection leak (component fault within subsystem)
	b. Loss of electric power supply to transmitter
3. Reduction in H_2 Concentration in Reactor Coolant	a. H_2 supply valve blocked or LST vent failed closed (component fault within subsystem)
	b. Incorrect operator response (LST tank overfilling) to faulted LST tank level indication
4. Loss of Flow to RC Makeup and RC Pump Seals	a. Component fault within the subsystem such as valve failures that cause line blockage to or from the operating HPI pump; or failure of the operating pump, either from internal faults or damage from blockage induced deadheading of the pump or loss of pump NPSH
	b. Spurious signal from the I&C system causing the motor operated valves on the operating pump suction or discharge to close, or I&C control signal failure to the operating pump

TABLE 11. FMEA SUMMARY FOR SUBSYSTEM 3.0: LETDOWN STORAGE TANK (LST) INLET FILTERS, AND HPI PUMPS
(Continued)

Effects at Subsystem Interface	Precipitating Faults/Failure Modes
4. Loss of Flow to RC Makeup and RC Pump Seals (cont'd)	c. Loss of electric power supply to the operating HPI pump
	d. Incorrect operator response to faulted LST tank level indication, resulting in decreasing LST level and eventual HPI pump damage
5. Reduced Flow to Either the RC Pump Seals or RC Makeup	a. HPI pump discharge check valve failure allowing backflow and flow diversion through a nonoperating HPI pump, or system leaks (component fault within subsystem)
6. Loss of Flow to Either the RC Pump Seals or RC Makeup	a. Inadvertant closure or valve failure of the motor operated isolation valve on the HPI pump discharge manifold (HP-119 (HP-V35A)) (component fault within subsystem)
	b. Spurious signal from the I&C system causing HP-119 to close
7. Flow Blocked From Seal Return (Subsystem 2.0)	a. Inlet check valve to LST failure due to plugging or damage (internal component failure)
	b. Incorrect operator response (LST tank overfilling) to faulted LST tank level indication

blockages can be bypassed from the control room. However, the blockages that restrict flow into the LST cannot be bypassed during steady state operation.

Failures which result in immediate loss of RC makeup and seal injection include: valve failures on the suction or discharge of the operating HPI pump; and pump failures (both due to internal damage, loss of low pressure service water, and loss of power supply). The precipitating valve failures can occur due to internal faults or due to a spurious I&C signal to certain motor-operated valves on the pump manifold. Flow can be lost to only the RC makeup header or only to seal injection as a result of similar valve failures on the HPI pump discharge manifold (internal faults, inadvertent closure, spurious I&C signals). In most cases the system can be realigned with alternate valving and/or an alternate HPI pump to restore flow. However, there is potential for loss of NPSH and damage in bringing the alternate pump onstream if sequencing and alignment are not correct.

Some reduction in subsystem discharge flow can result from a failed check valve (loss of backflow prevention) on the discharge of a nonoperating HPI pump. This failure mode would allow recirculation back through the nonoperating pump and the operating pump suction, resulting in reduction of actual discharge flow.

Deviations in RCS chemistry quality can occur as a result of two internal subsystem faults as well as loss of inlet flows from the Chemical Addition System. Internally the H_2 supply valve to the LST tank can fail closed, cutting off the H_2 supply; and the vent valve on the LST can fail closed, allowing potential accumulation of non-H_2 noncondensible gases in the LST and reduction of H_2 mass transfer to the reactor coolant.

Incorrect level indication in the LST due to transmitter failure, connection leaks, or loss of power to the transmitter, could lead an operator to take faulty remedial action. This could result in overfilling the LST, which could reduce or stop H_2 addition, or allowing the LST level to drop, which could result in loss of NPSH to the HPI pumps and ultimate loss of subsystem discharge flow to makeup and seal injection as discussed above.

3.3.4 RC Pump Seal Injection

The major effect of single failures within the seal injection subsystem is loss of or reduced seal flow to the RC pumps. Other effects include increased seal injection flow to a single pump and incorrect process signals (pressure and flow) transmitted to the I&C system and the control room. Table 12 summarizes resulting failure effects for this subsystem organized according to the source of the failure.

Subsystem failures can result in loss of seal injection flow to all four RC pumps, loss of flow to only a single pump, increased flow to a single pump, and reduced flow to all four pumps. Loss of seal flow to all four pumps can result from blockages in the inlet header (inline valves failed or inadvertantly closed, filters plugged, or orifice plugged) or loss of inlet flow to the system from the HPI pumps. Inline blockage from failure of the header flow control valve failing closed can result from an I&C signal failure, in addition to an internal fault. If detected, blockages associated with the filter path or the control valve can be bypassed, but no bypass exists in the event of failure of the inlet block valve. Reduced flow to all four pumps can result from partial failures of inline components, system leaks, and I&C-fault-induced failures of the header flow control valve.

Component faults in one of the four individual injection lines can result in loss of seal injection to a single RC pump. Each line has a throttle valve, and a flow measuring nozzle, and check valves that could potentially fail closed or plug. If one of the throttle valves fails open, increased flow to a single RC pump can result.

3.3.5 Reactor Coolant Makeup

Single failures in the RC makeup subsystem can impact normal makeup flow to the cold legs, cooling flow to the cold leg inlet nozzles and pressurizer spray lines, and inlet flow rate from the letdown storage tank in Subsystem 3.0 Table 13 summarizes the failure effects for this subsystem organized

TABLE 12. FMEA SUMMARY FOR SUBSYSTEM 4.0: RC PUMP SEAL INJECTION

Effects at Subsystem Interface	Precipitating Faults/Failure Modes
1. Seal Injection Flow to RC Pumps Stopped	a. Component faults within subsystem (manual valves, or control valve on inlet header failing closed, plugging, or inadvertantly closed, filter or orifice plugging)
	b. Loss of instrument air potentially failing header flow control valve closed
	c. Loss of control signal from 1FT-75 potentially failing header control valve closed
	d. Loss of electric power supply potentially failing header control valve closed
	e. Loss of flow from HPI pumps (Subsystem 3.0)
2. Seal Injection Flow to a Single RC Pump Stopped	a. Component faults within subsystem (manual throttle valves, check valves, and isolation valves in individual RC injection lines failing closed, plugging, or inadvertantly closed)
3. Seal Injection Flow to a Single RC Pump Higher Than Setpoint	a. Component faults within subsystem (manual throttle valve(s) on individual RC injection lines fail open or are inadvertantly opened)
4. Reduced Seal Injection Flow to RC Pumps	a. Component faults within subsystem as in 1.a. above but limited to partial closures and plugging. Also system leaks downstream of the control valve
	b. Loss of electric power supply to seal injection flow controller
	c. I&C signal failure to header flow control valve

TABLE 12. FMEA SUMMARY FOR SUBSYSTEM 4.0: RC PUMP SEAL INJECTION
(Continued)

Effects at Subsystem Interface	Precipitating Faults/Failure Modes
5. Incorrect Process Signal to I&C System and Control Room - Filter Drop Pressure - Injection Header Flow - Injection Line Flows	a. Component faults within subsystem such as instrument connection leaks and internal transmitter failures b. Loss of electric power supply to transmitter

TABLE 13. FMEA SUMMARY FOR SUBSYSTEM 5.0: REACTOR COOLANT (RC) MAKEUP

Effects at Subsystem Interface	Precipitating Faults/Failure Modes
1. Loss of Makeup Flow to Reactor	a. Component fault within subsystem (subsystem inlet header block valve failed closed)
	b. Loss of flow input from HPI pumps (Subsystem 3.0)
2. Loss of Bypass Flow to One or Two Reactor Cold Leg Inlet Nozzles	a. Component fault within subsystem (inline manual valve or throttle valve on one of the two minimum flow loops fails closed from plugging or damage)
	b. Loss of flow input from HPI pumps (Subsystem 3.0)
3. Loss of Bypass Flow to Pressurizer Spray Line	a. Component fault within subsystem (manual valves upstream of Pressurizer Spray Line tee fail closed from plugging or damage)
	b. Loss of flow input from HPI pumps (Subsystem 3.0)
4. Reduced Makeup Flow to Reactor	a. Component fault within subsystem (flow control valve (HP-120) or manual isolation valves on main flow control loop fail closed)
	b. Instrument air system failure causes the flow control valve on the main flow control loop (HP-120) to fail closed
	c. Control signal fault from the I&C system causes HP-120 to close down
	d. Reduced flow input from HPI pumps (Subsystem 3.0)
5. Temporary Decreased Flow to Pressurizer Spray Line	a. Component fault within subsystem (control valve (HP-120) in normal flow path, or ES valve (HP-26) fail open, diverting flow from spray line)

TABLE 13. FMEA SUMMARY FOR SUBSYSTEM 5.0: REACTOR COOLANT (RC) MAKEUP
(Continued)

Effects at Subsystem Interface	Precipitating Faults/Failure Modes
5. Temporary Decreased Flow to Pressurizer Spray Line (cont'd)	b. Instrument air system failure causes the normal path flow control valve (HP-120) to fail open
	c. Control signal fault from I&C causes HP-120 of ES valve (HP-26) to open up
6. Excess Makeup Flow to RCS, Drop in Letdown Storage Tank Level, Potential Loss of HPI Pump NPSH, Increased Pressurizer Level	a. Component fault within subsystem (motor operated valve (HP-26) on HPI emergency flow path fails open or is inadvertantly opened; or the flow control valve (HP-120) on the makeup flow path fails open)
	b. Instrument air system failure causes the flow control valve (HP-120) on the makeup flow path to fail open
	c. I&C system fault causes HP-120 to open spuriously
	d. Spurious signal from the I&C system or ES causes the motor operated valve (HP-26) on the HPI emergency flow path to open
7. Excess Flow to One of Two Reactor Cold Leg Inlet Nozzles, and Potential Drop in Letdown Storage Tank Level	a. Component fault within subsystem (manual throttle valve on one of two bypass flow loops fails open)
8. Excess Flow to Pressurizer Spray Line	a. Component fault within subsystem (manual throttle valve on minimum flow loop upstream of pressurizer spray line fails open)
9. Flow Imbalance Between the Two Reactor Cold Legs (Most Flow to One and Little to the Other)	a. Component fault within subsystem (orifice or check valve on one of two reactor inlets plugged or failed closed)

TABLE 13. FMEA SUMMARY FOR SUBSYSTEM 5.0: REACTOR COOLANT (RC) MAKEUP
(Continued)

Effects at Subsystem Interface	Precipitating Faults/Failure Modes
10. Incorrect Process Signal(s) to I&C System and Control Room - Makeup Header Flow - Bypass Line Flows	a. Component fault within subsystem (transmitter failure or instrument connection leak) b. Loss of electric power supply to transmitter

according to the source of the failure.

Failure effects on the normal makeup flow to the cold leg include: loss of flow, reduction in flow, increased flow, and flow imbalance between the two cold leg inlets. Loss of input flow from the HPI pumps (Subsystem 3.C) and failure of the block valve on the inlet header (plugging, damage, inadvertant closure, etc.) will result in total loss of makeup flow. In addition, single downstream blockages in the main flow path can stop normal makeup flow, but some flow will continue to the RCS via the minimum flow bypass loop to the cold leg inlet nozzles and the pressurizer spray line. These blockages could potentially result from failures associated with the flow control valve, block valves, and inline check valve. Failures in the instrument air system or I&C system, in addition to internal damage, could fault the flow control valve. However, both a remote operated and local bypass around the flow control valve are available to resume flow.

Increased flow through the normal makeup path can result from either the flow control valve or the normally closed motor operated ES valve failing open. In addition to internal faults, the control valve can fail open due to an instrument air system fault and a control signal fault, and the ES valve can open on a spurious ES or I&C signal.

Failures which result in flow imbalance between the two reactor cold legs are limited to component faults within the subsystem. These include blockages associated with the check valve or flow orifice on one of the cold leg inlets.

Failure effects on the bypass flow paths to the cold leg inlet nozzles and the pressurizer spray line include loss of flow and excess flow to one of the inlet nozzles. Loss of flow to both nozzles and the spray line can result from failure of the inlet block valve to the minimum flow bypass loop and the inlet block valve to the subsystem. Loss of flow to one nozzle can result from failure of either the throttle valve or the block valve on either cooling flow line. Loss of flow to the pressurizer spray line which branches off one of the cooling flow lines can likewise result from line blockages upstream of the spray line inlet. Excess flow to one nozzle and possibly the spray line can result from the throttle valve on one of the lines failing open. Likewise, a temporary reduction in flow in these lines can result from open-valve-failures in the normal makeup flow path, diverting flow away from the minimum flow bypass loop. Instrument air system and I&C system faults, in addition to internal faults, could produce this effect through inadvertant opening of the flow control valve or the ES valve.

Excess flow rate through the subsystem via failed open valves could also potentially result in drop in the letdown storage tank level and possible loss of NPSH to the HPI pumps (Subsystem 3.0) and increased level in the pressurizer.

3.3.6 RC Bleed, Boron Recovery, and Chemical Addition

The major effect of failures in this subsystem is loss of demineralized water return to the reactor coolant system upstream of the makeup filters. Other effects include loss of RC bleed holdup and transfer capability, loss of chemical addition capabilities including boric acid addition, loss of boron recovery capability, and loss of deboration capability. These effects are summarized in Table 14 and discussed below.

Failures which result in loss of demineralized water return to the reactor coolant system include electric power supply failure to the transfer pump, transfer pump failure, and failures in any one of several manual isolation or control valves. Failures in control valves HP-15 and HP-16, either from control signal failures or internal valve failures, can also result in loss of return flow. Since this system is operated on demand only, failure to supply the holdup tank with demineralized water or allowing the tank to remain empty can result in no demineralized water available when required. However, the valve configuration would allow makeup from the bleed holdup tank (although it would not have been through the boron recovery cycle) or makeup from the Unit 2 demineralized water or bleed holdup tanks.

TABLE 14. FMEA SUMMARY FOR SUBSYSTEM 6.0:
RC BLEED, BORON RECOVERY, AND CHEMICAL ADDITION

Effects at Subsystem Interface	Precipitating Faults/Failure Modes
6.1 Chemical Addition:	
1. No N_2H_4 Available to Makeup Filters	a. N_2 blanket system fails isolation
	b. Manual control, isolation valves fail closed
	c. Check valves fail to prevent backflow
	d. Hydrazine drum empties and not replaced. Leaks from the tank will eventually lead to the same effect
2. Alternate Flow Path Through Lithium Hydroxide Pump Required	a. Electric power supply to hydrazine pump fails
	b. Hydrazine pump fails
	c. Manual isolation valves fail closed
3. No LiOH Available to Makeup Filters	a. Demineralized water supply to mix tank fails
	b. Lithium hydroxide tank empties and not refilled. Leaks from the tank will eventually lead to same effect
	c. Manual isolation valves fail closed
4. Decreased LiOH Available to Makeup Filters	a. Sampling, waste lines downstream of tank fail open
5. Incorrect LiOH Concentration Available to Makeup Filters	a. Manual isolation valve DW-121 fails open and dilutes LiOH in tank; fails closed and results in concentrated LiOH in tank.
6. Alternate Flow Path Through Hydrazine Pump Required	a. Electric power supply to lithium hydroxide pump fails
	b. Lithium hydroxide pump fails
	c. Manual isolation valves fail closed

TABLE 14. FMEA SUMMARY FOR SUBSYSTEM 6.0:
RC BLEED, BORON RECOVERY, AND CHEMICAL ADDITION
(Continued)

Effects at Subsystem Interface	Precipitating Faults/Failure Modes
7. No Caustic Available to LPI Pumps, RC Bleed Evaporator Feed Tank, Deborating Demineralizers	a. Demineralized water supply to mix tank fails
	b. Manual isolation valves fail closed
	c. Causic mix tank empties and not refilled. Leaks from the tank will eventually lead to same effect
	d. Electric power supply to caustic pump fails
	e. Caustic pump fails
8. Decreased Caustic Available to LPI Pumps, RC Bleed Evaporator Feed Tank, Deborating Demineralizers	a. Sampling, waste lines downstream of tank fail open
9. Incorrect Caustic Concentration Available to LPI Pumps, RC Bleed Evaporator Feed Tank, Deborating Demineralizers	a. Manual isolation valve DW-120 fails open and dilutes caustic in tank; fails closed and results in concentrated caustic in tank
6.2 Boric Acid Addition:	
1. No Boric Acid Available to Makeup Filters, BWST Filters, BWST	a. Flows from boron recovery and boric acid mix tank fail and concentrated boric acid storage tank empties and not refilled. Leaks from tank will eventually lead to same effect.
	b. Manual isolation valves and manual control valve CS-62 fail closed
	c. Electric power supply to concentrated boric acid transfer pump fails
	d. Concentrated boric acid transfer pump fails

TABLE 14. FMEA SUMMARY FOR SUBSYSTEM 6.0: RC BLEED, BORON RECOVERY, AND CHEMICAL ADDITION (Continued)

Effects at Subsystem Interface	Precipitating Faults/Failure Modes
1. No Boric Acid Available to Makeup Filters, BWST Filters, BWST (cont'd)	e. Electric power supply to trace heating or trace heating fails leading to plugged lines
2. No Boric Acid Flow Available to Core Flood Tank	a. Electric power supply to HP boric acid pump fails
	b. HP boric acid pump fails
	c. Manual isolation valves fail closed
3. Decreased Boric Acid Flow Available to Makeup Filters, BWST	a. Drain, sample lines downstream of storage tank fail open
4. Boron Recovery or Adequate Concentrated Boric Acid Storage Tank Inventory Required as Boric Acid Source (Internal Subsystem Effect Only)	a. Demineralized water supply to boric acid mix tank fails
	b. Manual isolation valves fail closed
	c. Manual isolation valve DW-118 fails open and dilutes boric acid in mix tank; fails closed and results in concentrated boric acid in mix tank
	d. Electric power supply to mix tank heater or mix tank heater fails leading to plugged lines
	e. Mix tank empties and not refilled. Leaks from tank will eventually lead to same effect
5. Incorrect Process Parameters to I&C System and Control Room - Boric Acid Mix Tank Level, Temperature - LP Boric Acid Pump Discharge Pressure - Concentrated Boric Acid Storage Tank Level	a. Electric power supplies to transmitters fail
	b. Transmitter signal connection leaks
	c. Transmitters fail

TABLE 14. FMEA SUMMARY FOR SUBSYSTEM 6.0: RC BLEED, BORON RECOVERY, AND CHEMICAL ADDITION (Continued)

Effects at Subsystem Interface	Precipitating Faults/Failure Modes
6.3 RC Bleed Holdup Tanks and Transfer Pumps:	
1. No Demineralized Water to Makeup Filters	a. Manual isolation and control valves fail closed
	b. Demineralized water supply to demineralized water holdup tank fails
	c. N_2 blanket to demineralized water holdup tank fails resulting in tank unavailability
	d. Demineralized water holdup tank empties and not refilled. Leaks from tank will eventually lead to same effect
	e. Electric power supply to bleed transfer pump fails
	f. RC bleed transfer pump fails
	g. Check valves fail to prevent backflow
	h. Control valves HP-15 or HP-16 fail closed (control signal, instrument air supply, electric power supply, valve failure)
	i. Control valves HP-15 or HP-16 fail open allowing backflow from letdown line
	j. Electric power supply to trace heating or trace heating fails leading to plugged lines
1. No Demineralized Water to Makeup Filters (cont'd)	k. Flow orifices plug
2. Decreased Demineralized Water to Makeup Filters	a. Waste, drain, or sample lines downsteam of holdup tank fail open
3. Increased Demineralized Water to Makeup Filters	a. Control valves HP-15 and HP-16 fail open (control signal fails to close valve or spurious signal to open valve)

TABLE 14. FMEA SUMMARY FOR SUBSYSTEM 6.0: RC BLEED, BORON RECOVERY, AND CHEMICAL ADDITION
(Continued)

Effects at Subsystem Interface	Precipitating Faults/Failure Modes
4. Alternate Flow Path Through Unit 2 Bleed Holdup Tank Required	a. RC bleed flow from letdown fails
	b. Manual isolation and control valves fail closed
	c. N_2 blanket to bleed holdup tank fails resulting in tank unavailability
	d. RC bleed holdup tank empties and not refilled. Leaks from tank will eventually lead to same effect
	e. Electric power supply to trace heating or trace heating fails leading to plugged lines
	f. Waste, drain, sample lines downstream of holdup tank fail open
	g. Electric power supply to bleed transfer pump fails
	h. RC bleed transfer pump fails
	i. Flow orifice plugs
	j. Check valves fail to prevent backflow
5. Incorrect Process Parameters to I&C System and Control Room	a. Electric power supply to transmitters fail
- RC Bleed Holdup Tank Level	b. Transmitter connection leaks
- RC Bleed Flow	c. Transmitter fails
- Demineralized Water Holdup Tank Level	
- Demineralized Water Flow	

TABLE 14. FMEA SUMMARY FOR SUBSYSTEM 6.0: RC BLEED, BORON RECOVERY, AND CHEMICAL ADDITION
(Continued)

Effects at Subsystem Interface	Precipitating Faults/Failure Modes
6.4 Boron Recovery:	
1. Alternate Flow Path Through Second Evaporator Demineralizer Required (Internal Subsystem Effect Only)	a. Manual isolation valves fail closed
	b. Demineralizer resin fill fails
	c. Demineralizer tank or tank vents leak
2. RC Bleed Evaporator Feed Tank Required to be Full at Beginning of Boron Recovery Cycle (Internal Subsystem Effect Only)	a. Electric power supply to trace heating or trace heating fails leading to plugged lines
	b. RC bleed flow from holdup tank fails
	c. Evaporator distillate, distillate cooler flows fail
	d. Manual isolation valves fail
3. No Temperature Control of Distillate Returned to Evaporator Feed Tank, Condensate Test Tank (Demineralized Water)	a. Cooling water supply to distillate cooler fails
	b. Loss or degraded heat transfer capability in distil
4. No or Decreased Distillate Flow to Condensate Test Tanks (Demineralized Water)	a. Cooler tubes blocked or tube rupture leading to decreased flow or coolant release to distillate
	b. Distillate cooler leaks
	c. Evaporator distillate flow fails; see effects 5 and 6
5. Boron Recovery Stops; Concentrated Boric Acid Storage Tanks Required to be Full (Internal Subsystem Effect Only)	a. Evaporator concentrate flow returned to feed tank or evaporator
	b. Evaporator feed tank empties and not refilled. Leaks from tank, including vent and relief valves failed open, will eventually lead to same effect
	c. Manual isolation valves fail closed

TABLE 14. FMEA SUMMARY FOR SUBSYSTEM 6.0: RC BLEED, BORON RECOVERY, AND CHEMICAL ADDITION
(Continued)

Effects at Subsystem Interface	Precipitating Faults/Failure Modes
5. Boron Recovery Stops; Concentrated Boric Acid Storage Tanks Required to be Full (Internal Subsystem Effect Only)	d. Electric power supply to evaporator feed pump or concentrate pump fails
	e. Evaporator feed pump or concentrate pump fails
	f. Control valves CT-24 or CT-40 fail to operate (instrument air, control signal, valve failure)
	g. Waste, drain, sample lines downstream of feed tank or evaporator fail open
	h. Steam supply to evaporator fails
	i. Loss of heat transfer capability in evaporator
	j. Evaporator empties and not refilled. Leaks from evaporator will eventually lead to same effect
	k. Electric power supply to trace heating, or evaporator heating fails leading to plugged lines
6. Boron Recovery Rate Decreases; Concentrated Boric Acid Storage Tank Required to be Full (Internal Subsystem Effect Only)	a. Electric power supply to trace heating, trace heating, or evaporator heating fails leading to plugged lines
	b. Evaporator tubes blocked or tube rupture leading to decreased flow or steam release to vapor space
	c. Concentrate cooler leaks
7. No Temperature Control of Concentrate Returned to Boric Acid Storage Tanks (Internal Subsystem Effect Only)	a. Cooling water supply to concentrate cooler fails
	b. Loss or degraded heat transfer capability in concentrate cooler
	c. Temperature transmitter control signal to cooling water control valve fails

TABLE 14. FMEA SUMMARY FOR SUBSYSTEM 6.0: RC BLEED, BORON RECOVERY, AND CHEMICAL ADDITION (Continued)

Effects at Subsystem Interface	Precipitating Faults/Failure Modes
6.5 Deborating Demineralizer:	
1. No RC Return to Makeup Filters	a. RC bleed flow from 3-way valve fails
	b. Manual isolation valves fail closed
	c. Control valve HP-16 fails closed (instrument air, control signal, valve failure)
	d. Check valve fails to prevent backflow
2. Deboration Stops; Alternate Flow Path Through Second Demineralizer Required	a. Resin in demineralizer saturates or was not regenerated as required due to failure to provide caustic.
3. No RC Return to Makeup Filters; Alternate Flow Path Through Second Demineralizer Required	a. Manual isolation, control valves fail closed
	b. Tank empties. Leaks from tank; including vent and relief valves failed open, will eventually lead to same effect.
	c. Electric power supply to trace heating, trace heating fails leading to plugged lines
4. Decreased Return Flow to Makeup Filters; Alternate Flow Path Through Second Demineralizer Required	a. Waste, drain, sample lines fail open
	b. Demineralizer tank leaks

Loss of bleed holdup and transfer capability can result form valve failures, plugs in lines due to loss of trace heating, and unavailability of the holdup tank. However, valve configuration would allow bleed flow to the demineralized water holdup tank or the Unit 2 bleed or demineralized water holdup tanks. Electric power supply failure or transfer pump failure can result in loss of flow to boron recovery which also leads unavailability of the holdup tank for subsequent bleed and makeup cycles.

Addition of hydrazine and lithium hydroxide to the reactor coolant is also a per-demand-operation. Failure to supply either chemical can result from manual isolation, control, or check valve failures; or allowing either tank to remain empty. Valve configuration would allow pumping either chemical to its destination through the other chemical pump; however, if both chemicals are required simultaneously, failure of either pump results in unavailability of that chemical.

Failure to provide caustic to the LPI pumps, RC bleed evaporator, and deborating demineralizers can result from isolation valve failures, electric power supply and pump failures, or allowing the mix tank to remain empty. No remedial action within the subsystem is available to compensate for loss of caustic either within the subsystem or at the interfaces.

Loss of concentrated boric acid to the makeup filters and the BWST can result from allowing the concentrated boric acid storage tank to empty, various manual isolation or control valve failures, electric power supply or transfer pump failures, or plugs in lines due to trace heating failures. Two sources of concentrated boric acid are available: a boric acid mix tank and the concentrate from boron recovery. In the event of failure of one source, the other would be available to supply boric acid requirements. The valve configuration would also allow boric acid addition from the Unit 2 concentrated boric acid storage tank.

Failures in the boron recovery operation result in no concentrate flow to the concentrated boric acid storage tank. Component failures include various pumps and manual valves, either of two control valves, the evaporator, feed storage tank, and trace heating. Support system failures such as steam supply and electric power can also result in boron recovery failure. Recirculation paths can be established so that concentrated boric acid is returned either to the evaporator or the evaporator feed tank rather than the storage tank.

Failure of the deboration capability in the on-line deborating demineralizer results from various manual isolation and control valve failures, failure of caustic flow for regenerating the resin, and plugs in lines due to trace heating failures. These failures result in the requirement that a second demineralizer is available. Flow can also be diverted to the bleed holdup tank with makeup provided from the demineralized water holdup tank.

4.0 SUMMARY AND CONCLUSIONS

(To be included in the next draft.)

5.0 REFERENCES

1. 1982 Revision Oconee Nuclear Station, Final Safety Analysis Reports, Revision 18.

2. Oconee Nuclear Station, Final Safety Analysis Reports, Revision 18.

3. Plant Electrical Distribution System Drawings 0701, 0702, 0703, 0704, and 0705.

4. ICS Instruction Manual

APPENDIX A

FAILURE MODES AND EFFECTS ANALYSIS

SUBSYSTEM 1.0: LETDOWN COOLERS TO THREE-WAY VALVE

Reference Drawings: FSAR Figure 9.3-2
FSAR Figure 9-2A

1.0 SUBSYSTEM: LETDOWN COOLERS TO 3-WAY VALVE HP-14 (HP-V10)

	Component	Potential Failure Mode: Mode	Potential Failure Mode: Interface Involved	Immediate Effects: Within Subsystem	Immediate Effects: At Subsystem Interface	Remedial Action Within Subsystem
1.1	Letdown Coolers:					
1.1.1	Miscellaneous Normally Closed, Manual Valves Such as HP-329 (Including Double Isolation Valves Such as HP-32 and HP-359)	1. Opened or fails open due to internal fault	Vent or Drain	Reduced letdown flow rate; RC leak	Some letdown flow is diverted to sumps; hence, reduced letdown flow to 3-way valve HP-14 (HP-V10) and RC leak	Though detection is difficult, close or repair when found
1.1.2	Valve HP-1 (NO) (HP-V1A)	1. Fails closed due to internal fault	--	Letdown flow to Ltdn Cooler HP-C1A obstructed	Letdown flow to 3-way valve HP-14 (HP-V10) is terminated	Open HP-V1B and use Ltdn Cooler HP-C1B
		2. Spuriously closed	Control Signal	Letdown flow to Ltdn Cooler HP-C1A obstructed	Letdown flow to 3-way valve HP-14 (HP-V10) is terminated	Open HP-V1A
		3. Fails to close when required due to internal fault	--	Unobstructed letdown flow to Ltdn Cooler HP-C1A. Ltdn Cooler HP-C1A cannot be isolated if valve HP-1 (HP-V1A) is open	If HP-C1A has experienced a loss of cooling water, then letdown fluid temperature will increase; letdown flow to 3-way valve HP-14 (HP-V10) will continue until series isolation valve HP-3 (HP-V2A) or HP-5 (HP-V3) is closed to protect HP-X1. If HP-C1A has experienced a tube rupture, then an RC leak to CCW system will occur	Close series isolation valve None
		4. Fails to close when required due to unavailability of electric power	Electric Power	Unobstructed letdown flow to Ltdn Cooler HP-C1A. Ltdn Cooler HP-C1A cannot be isolated if valve HP-1 (HP-V1A) is open	If HP-C1A has experienced a loss of cooling water, then letdown fluid temperature will increase; letdown flow to 3-way valve HP-14 (HP-V10) will continue until series isolation valve HP-3 (HP-V2A) (powered from separate bus or manually closed) or HP-5 (HP-V3) is closed to protect HP-X1. If HP-C1A has experienced a tube rupture, then an RC leak to CCW system will occur	Close series isolation valve Restore electric power

Reference Drawings: FSAR Figure 9.3-2
FSAR Figure 9-2A

1.0 SUBSYSTEM: LETDOWN COOLERS TO 3-WAY VALVE HP-14 (HP-V10) (Continued)

	Component	Potential Failure Mode: Mode	Potential Failure Mode: Interface Involved	Immediate Effects: Within Subsystem	Immediate Effects: At Subsystem Interface	Remedial Action Within Subsystem
1.1.3	Valve HP-2 (NC) (HP-V1B)	1. Fails open due to internal fault	--	Unobstructed letdown flow to Ltdn Cooler HP-C1B	Unless component cooling water provided to Ltdn Cooler HP-C1B, letdown temperature will increase possibly resulting in letdown isolation, i.e., termination of letdown flow to 3-way valve HP-14 (HP-V10)	Close HP-4 (HP-V2B)
		2. Spuriously opened	Control Signal	Unobstructed letdown flow to Ltdn Cooler HP-C1B	Unless component cooling water provided to Ltdn Cooler HP-C1B, letdown temperature will increase possibly resulting in letdown isolation, i.e., termination of letdown flow to 3-way valve HP-14 (HP-V10)	Close HP-2 (HP-V1B), close HP-4 (HP-V2B)
		3. Fails to open when required due to internal fault	--	Use of Ltdn Cooler HP-C1B prevented	May result in increased letdown temperature or continued letdown isolation	None (isolate and repair)
		4. Fails to open when required due to unavailability of electric power	Electric Power	Use of Ltdn Cooler HP-C1B prevented	May result in increased letdown temperature or continued letdown isolation	Restore electric power
1.1.4	Operating Letdown Cooler HP-C1A (or HP-C1B)	1. Loss of cooling water flow	Component Cooling Water System	Increased letdown temperature. High temperature sensed on TT-3 resulting in automatic closure of isolation valve HP-5 (HP-V3) and indicated in control room	Increased letdown fluid temperature possibly resulting in automatic letdown flow isolation, i.e., termination of letdown flow to 3-way valve HP-14 (HP-V10)	Isolate HP-C1A and utilize HP-C1B if cooling water available to HP-C1B. Restore letdown flow if it has been isolated
		2. Reduction in heat transfer capability due to fouling	--	Increased letdown temperature. High temperature sensed on TT-3 and indicated in control room	Increased letdown fluid temperature	Isolate HP-C1A, utilize HP-C1B

Reference Drawings: FSAR Figure 9.3-2
FSAR Figure 9-2A

1.0 SUBSYSTEM: LETDOWN COOLERS TO 3-WAY VALVE HP-14 (HP-V10) (Continued)

	Component	Potential Failure Mode: Mode	Potential Failure Mode: Interface Involved	Immediate Effects: Within Subsystem	Immediate Effects: At Subsystem Interface	Remedial Action Within Subsystem
1.1.4	Operating Letdown Cooler HP-C1A (or HP-C1B) (cont'd)	3. Tube rupture	Component Cooling Water System	Reduced letdown flow rate due to flow diversion	Reduced letdown flow to 3-way valve HP-14 (HP-V10). Loss of reactor coolant to CCW system. Decreasing Ltdn tank level, RCS pressure. Safety injection signal will not isolate letdown cooler. Increased CCW surge tank level, discharge of reactor coolant through CCW relief valves to RB	Close HP-1 (HP-V1A) and HP-3 (HP-V2A), and open path through HP-C1B
1.1.5	Standby Letdown Cooler HP-C1B (or HP-C1A)	1. Tube rupture	Component Cooling Water System	Reduced letdown flow rate due to flow diversion	Reduced letdown flow to 3-way valve HP-14 (HP-V10). Loss of reactor coolant to CCW system. Decreasing Ltdn tank level, RCS pressure. Safety injection signal will isolate letdown cooler. Increased CCW surge tank level, discharge of reactor coolant through CCW relief valves to RB	Close or verify closure of HP-4 (HP-V2B); letdown flow through HP-C1A is possible once leak is isolated
1.1.6	Valve HP-3 (NO) (HP-V2A)	1. Fails closed due to internal fault	--	Letdown flow through HP-C1A is obstructed	Letdown flow to 3-way valve HP-14 (HP-V10) is terminated	Close HP-1 (HP-V1A), open HP-2 (HP-V1B) to divert letdown flow through HP-C1B
		2. Spuriously closed	Control Signal	Letdown flow through HP-C1A is obstructed	Letdown flow to 3-way valve HP-14 (HP-V10) is terminated	Open HP-3 (HP-V2A)
		3. Fails to close when required due to internal fault	--	Prevents isolation of HP-C1A	If HP-C1A has experienced a tube rupture, HP-1 (HP-V1A) has been closed, and HP-C1B is to be used, then an RC leak to the CCW system will occur.	None
					If HP-C1A has experienced a loss of cooling water and HP-1 (HP-V1A) can not be closed, then letdown fluid temperature will increase and HP-5 (HP-V3) will close, terminating letdown flow to HP-14 (HP-V10)	Automatic closure of HP-5 (HP-V3); HP-C1A cannot be isolated until HP-3 (HP-V2A) is repaired

Reference Drawings: FSAR Figure 9.3-2
FSAR Figure 9-2A

1.0 SUBSYSTEM: LETDOWN COOLERS TO 3-WAY VALVE HP-14 (HP-V10) (Continued)

	Component	Potential Failure Mode: Mode	Potential Failure Mode: Interface Involved	Immediate Effects: Within Subsystem	Immediate Effects: At Subsystem Interface	Remedial Action Within Subsystem
1.1.6	Valve HP-3 (NO) (HP-V2A) (cont'd)	4. Fails to close when required due to unavailability of power on bus 1EXS21	Electric Power	Prevents isolation of HP-C1A	If HP-C1A has experienced a tube rupture, HP-1 (HP-V1A) has been closed, and HP-C1B is to be used, then an RC leak to the CCW system will occur. If HP-C1A has experienced a loss of cooling water and HP-1 (HP-V1A) cannot be closed, then letdown fluid temperature will will increase and HP-5 (HP-V3) will close terminating letdown flow to HP-14 (HP-V10)	None Automatic closure of HP-5 (HP-V3); HP-C1A cannot be isolated until power is restored on bus 1EXS21
		5. Fails to close when required due to failure of ES signal	Engineered Safeguards Protective System (ESPS)	Prevents isolation of HP-C1A	If HP-C1A has experienced a tube rupture, HP-1 (HP-V1A) has been closed, and HP-C1B is to be used, then an RC leak to the CCW system will occur. If HP-C1A has experienced a loss of cooling water and HP-1 (HP-V1A) cannot be closed, then letdown fluid temperature will increase and HP-5 (HP-V3) will close terminating letdown flow to HP-14 (HP-V10)	None Automatic closure of HP-5 (HP-V3); HP-C1A cannot be isolated until ES signal is restored
1.1.7	Valve HP-4 (NO) (HP-V2B)	1. Fails closed due to internal fault	--	None	None	Close HP-2 (HP-V1B) to divert letdown flow through HP-C1A
		2. Spuriously closed	Control Signal	None	None	Open HP-4 (HP-V2B)
		3. Fails to close when required due to internal fault	--	Prevents isolation of HP-C1B	If HP-C1B has experienced a tube rupture, then an RC leak to the CCW system will occur	None; HP-C1B cannot be isolated until HP-4 (HP-V2B) is repaired
		4. Fails to close when required due to unavailability of power on bus 1EXS21	Electric Power	Prevents isolation of HP-C1B	If HP-C1B has experienced a tube rupture, then an RC leak to the CCW system will occur	None; HP-C1B cannot be isolated until power is restored on bus 1EXS21

Reference Drawings: FSAR Figure 9.3-2
FSAR Figure 9-2A

1.0 SUBSYSTEM: LETDOWN COOLERS TO 3-WAY VALVE HP-14 (HP-V10) (Continued)

	Component	Potential Failure Mode: Mode	Potential Failure Mode: Interface Involved	Immediate Effects: Within Subsystem	Immediate Effects: At Subsystem Interface	Remedial Action Within Subsystem
1.1.7	Valve HP-4 (NO) (HP-V2B) (cont'd)	5. Fails to close when required due to failure of ES signal	Engineered Safeguards Protective System (ESPS)	Prevents isolation of HP-C1B	If HP-C1B has experienced a tube rupture, then an RC leak to the CCW system will occur	None; HP-C1B cannot be isolated until ES signal is restored
1.2	Block Orifice:					
1.2.1	Miscellaneous Normally Closed Manual Valves Such as HP-36 or HP-332	1. Opened or fails open due to internal fault	Vent or Drain	Reduced letdown flow rate	Reduced letdown flow to 3-way valve HP-14 (HP-V10)	Though detection is difficult, close or repair when found
1.2.2	Valve HP-5 (NO) (HP-V3)	1. Fails closed due to internal fault	--	Letdown flow terminated	Letdown flow to 3-way valve HP-14 (HP-V10) is terminated	Close HP-3 (HP-V2A), HP-4 (HP-V2B), and HP-6 (HP-V4) and repair
		2. Spuriously closed	Control Signal	Letdown flow terminated	Letdown flow to 3-way valve HP-14 (HP-V10) is terminated	Open HP-5 (HP-V3)
		3. Fails to close when required due to internal fault	--	High temperature letdown flow to purification demineralizer is unobstructed. Increased letdown fluid temperature may result in melting the resin beads in HP-X1 and thus blocking flow	High temperature letdown flow possibly causing flow blockage if resin beads in HP-X1 melt	Close HP-6 (HP-V4). If purification resins damaged, use standby demineralizer
		4. Spuriously closed due to unavailability of instrument air (assumed)	Instrument Air	Letdown flow terminated	Letdown flow to 3-way valve HP-14 (HP-V10) is terminated	Restore instrument air, open HP-5 (HP-V3)
		5. Fails to close when required due to unavailability of letdown temperature interlock	Plant Instrumentation	High temperature letdown flow to purification demineralizer is unobstructed. Increased letdown fluid temperature may result in melting the resin beads in HP-X1 and thus blocking flow	High temperature letdown flow possibly causing flow blockage if resin beads in HP-X1 melt	Close HP-6 (HP-V4) and restore temperature interlock. If purification resins damaged, use standby demineralizer

Reference Drawings: FSAR Figure 9.3-2
FSAR Figure 9-2A

1.0 SUBSYSTEM: LETDOWN COOLERS TO 3-WAY VALVE HP-14 (HP-V10) (Continued)

	Component	Potential Failure Mode: Mode	Potential Failure Mode: Interface Involved	Immediate Effects: Within Subsystem	Immediate Effects: At Subsystem Interface	Remedial Action Within Subsystem
1.2.2	Valve HP-5 (NO) (HP-V3) (cont'd)	6. Fails to close when required due to unavailability of ES signal	Engineered Safeguards Protective System (ESPS)	Failure of one of two redundant containment isolation valves. High temperature letdown flow to purification demineralizer is unobstructed. Increased letdown fluid temperature may result in melting the resin beads in HP-X1 and thus blocking flow	None, if HP-6 (HP-V4) successfully closes. Otherwise, high temperature letdown flow possibly causing flow blockage if resin beads in HP-X1 melt	Close HP-6 (HP-V4) and restore ES signal. If purification resins damaged, use standby demineralizer
1.2.3	Valve HP-6 (NO) (HP-V4)	1. Fails closed due to internal fault	--	Letdown flow to purification demineralizer is obstructed unless HP-42 or HP-7 (HP-V5) is open	Letdown flow to 3-way valve HP-14 (HP-V10) is terminated unless HP-42 or HP-7 (HP-V5) is open	Utilize HP-7 (HP-V5) for letdown throttling
		2. Spuriously closed	Control Signal	Letdown flow to purification demineralizer is obstructed unless HP-42 or HP-7 (HP-V5) is open	Letdown flow to 3-way valve HP-14 (HP-V10) is terminated unless HP-42 or HP-7 (HP-V5) is open	Open HP-6 (HP-V4) or HP-7 (HP-V5)
		3. Fails to close when required due to internal fault	--	Letdown flow to block orifice is unobstructed	If HP-5 (HP-V3) has failed to close and the letdown flow has not been cooled, then temperature of letdown flow to HP-14 (HP-V10) will continue to increase and resin beads in HP-X1 may melt causing flow blockage	Close HP-8 (HP-V7) to protect purification demineralizer HP-X1
		4. Fails to close when required due to unavailability of instrument air (assumed)	Instrument Air	Letdown flow to block orifice is unobstructed	If HP-5 (HP-V3) has failed to close and the letdown flow has not been cooled, then temperature of letdown flow to HP-14 (HP-V10) will continue to increase and resin beads in HP-X1 may melt causing flow blockage	Close HP-8 (HP-V7) to protect purification demineralizer HP-X1; restore instrument air
1.2.4	Block Orifice	1. Fails plugged	--	Letdown flow to purification demineralizer is obstructed if HP-42 and HP-7 (HP-V5) are closed	Letdown flow to 3-way valve HP-14 (HP-V10) is terminated if HP-42 and HP-7 (HP-V5) are closed	Utilize HP-7 (HP-V5) for letdown flow throttling
1.2.5	Flow Transmitter FT-29	1. Internal fault results in incorrect signal	Plant Instrumentation	None	Incorrect information sent to plant operators	Isolate and repair
		2. Fails due to loss of power	Electric Power	None	Incorrect information sent to plant operators	Restore electric power

Reference Drawings: FSAR Figure 9.3-2
FSAR Figure 9-2A

1.0 SUBSYSTEM: LETDOWN COOLERS TO 3-WAY VALVE HP-14 (HP-V10) (Continued)

	Component	Potential Failure Mode: Mode	Potential Failure Mode: Interface Involved	Immediate Effects: Within Subsystem	Immediate Effects: At Subsystem Interface	Remedial Action Within Subsystem
1.2.6	Valve HP-39 (NO)	1. Fails closed due to internal fault	--	Letdown flow to purification demineralizer is obstructed if HP-42 and HP-7 (HP-V5) are closed	Letdown flow to 3-way valve HP-14 (HP-V10) is terminated if HP-42 and HP-7 (HP-V5) are closed	Open HP-7 (HP-V5)
1.2.7	Valve HP-42 (NC)	1. Fails open due to internal fault	--	Unobstructed letdown flow through orifice bypass to purification demineralizer	Increased letdown flow to 3-way valve HP-14 (HP-V10)	Isolate block orifice to reduce letdown flow
1.2.8	Valve HP-40 (NO)	1. Fails closed due to internal fault	--	Letdown flow to HP-7 (HP-V5) is obstructed	None, if HP-7 (HP-V5) (NC) is closed. Otherwise, reduced letdown flow to 3-way valve HP-14 (HP-V10)	Open HP-42, if required
1.2.9	Valve HP-7 (NC) (HP-V5)	1. Fails open due to internal fault	--	Block orifice bypassed, increased letdown flow	Increased letdown flow to 3-way valve HP-14 (HP-V10), and potentially increased letdown temperatures	Close HP-40 and/ or HP-41 and repair
		2. Spuriously opened	Control Signal	Block orifice bypassed, increased letdown flow	Increased letdown flow to 3-way valve HP-14 (HP-V10)	Close HP-7 (HP-V5)
		3. Fails to open when required due to internal fault	--	Additional letdown flow not provided	Additional letdown flow not provided	Open HP-42 if required, close HP-40 and HP-41 and repair
		4. Fails to open when required due to unavailability of instrument air (assumed)	Instrument Air	Additional letdown flow not provided	Additional letdown flow not provided	Utilize HP-42, if required; restore instrument air
1.2.10	Valve HP-41 (NO)	1. Fails closed due to internal fault	--	Obstructs letdown flow to purification demineralizer if HP-7 (HP-V5) is open	Reduced letdown flow to 3-way valve HP-14 (HP-V10) if HP-7 (HP-V5) is open	Utilize HP-42 if required
1.2.11	Radiation Monitor Loop	1. Normally closed manual drain valve opened, fails open, or not closed after maintenance, or relief valve spuriously opens	High Activity Waste Tank, Miscellaneous Waste Tank	Diversion of letdown flow when radiation monitoring loop used	Reduced letdown flow to 3-way valve HP-14 (HP-V10); flow diverted to Miscellaneous Waste Tank or High Activity Waste Tank	Isolate Loop; close valve or repair when found; sampling available at other points in subsystem
		2. Loop becomes plugged	--	Reduced letdown flow; radiation monitoring prevented	Reduced letdown flow to 3-way valve HP-14 (HP-V10)	Unplug when found; sampling available at other points in subsystem

Reference Drawings: FSAR Figure 9.3-2
FSAR Figure 9-2A

1.0 SUBSYSTEM: LETDOWN COOLERS TO 3-WAY VALVE HP-14 (HP-V10) (Continued)

	Component	Potential Failure Mode: Mode	Potential Failure Mode: Interface Involved	Immediate Effects: Within Subsystem	Immediate Effects: At Subsystem Interface	Remedial Action Within Subsystem
1.2.12	Boron Meter Loop	1. Normally closed manual drain valve opened, fails open, or not closed after maintenance, or relief valve spuriously opens	High Activity DR Tank, Miscellaneous Waste Tank	Diversion of letdown flow when boron meter loop used	Reduced letdown flow to 3-way valve HP-14 (HP-V10); flow diverted to High Activity DR Tank or Miscellaneous Waste Tank	Isolate Loop; close valve or repair when found; sampling available at other points in subsystem
		2. Loop becomes plugged	--	Reduced letdown flow; boron content measurement prevented	Reduced letdown flow to 3-way valve HP-14 (HP-V10)	Unplug when found; sampling available at other points in subsystem
1.3	Purification Demineralizer:					
1.3.1	Flow Nozzle	1. Fail plugged	--	Letdown flow to purification demineralizer is obstructed	Letdown flow to 3-way valve HP-14 (HP-V10) is reduced or terminated	
1.3.2	Flow Transmitters FT-6, FT-6P, and FT-6A	1. Internal fault results in incorrect signal	Plant Instrumentation	None	None	Utilize FT-29 to determine letdown flow (requires HP-7 (HP-V5) and HP-42 be shut), repair transmitters; restore electric power
		2. Control power failure results in incorrect signal	Electric Power	None	None	
1.3.3	Pressure Gauge PG-73	1. Internal fault results in incorrect measurement	Plant Instrumentation	None	None	Repair when detected

Reference Drawings: FSAR Figure 9.3-2
FSAR Figure 9-2A

1.0 SUBSYSTEM: LETDOWN COOLERS TO 3-WAY VALVE HP-14 (HP-V10) (Continued)

	Component	Potential Failure Mode: Mode	Potential Failure Mode: Interface Involved	Immediate Effects: Within Subsystem	Immediate Effects: At Subsystem Interface	Remedial Action Within Subsystem
1.3.7	Valve HP-196 (NC)	1. Fails open due to internal fault	Outlet of Letdown Filter HP-F1A	Reduced letdown flow to purification demineralizer	Reduced letdown flow to 3-way valve HP-14 (HP-V10). (Letdown flow bypasses HP-X1 and HP-14 (HP-V10))	Close HP-57
1.3.8	Valve HP-197 (NC)	1. Fails open due to internal fault	Inlet of Letdown Filter HP-F1A	Reduced letdown flow to purification demineralizer	Reduced letdown flow to 3-way valve HP-14 (HP-V10). (Letdown flow bypasses HP-X1 and HP-14 (HP-V10))	Close HP-57
1.3.9	Valve HP-13 (NC) (HP-V6)	1. Fails open due to internal fault	--	Letdown flow bypasses the purification demineralizer; letdown flow chemistry altered	Letdown flow chemistry altered	None
		2. Spuriously opened	Control Signal	Letdown flow bypasses the purification demineralizer; letdown flow chemistry altered	Letdown flow chemistry altered	Close HP-13 (HP-V6)
		3. Fails to open when required due to internal fault	--	Purification demineralizer HP-X1 bypass unavailable if required	Letdown flow to 3-way valve HP-14 (HP-V10) is terminated if HP-X1 is plugged	Open HP-9 (1HP-V8) and HP-11 (1HP-V9) and use HP-X2 if available
		4. Potential failure to open due to unavailability of instrument air (assumed)	Instrument Air	Purification demineralizer HP-X1 bypass unavailable if required	Letdown flow to 3-way valve HP-14 (HP-V10) is terminated if HP-X1 is plugged	Restore instrument air; open HP-9 (1HP-V8) and HP-11 (1HP-V9) and use HP-X2 if available
1.3.10	Valve HP-8 (NO) (HP-V7)	1. Fails closed due to internal fault	--	Letdown flow through purification demineralizer HP-X1 is obstructed	Letdown flow to 3-way valve HP-14 (HP-V10) is terminated	Open HP-9 (1HP-V8) and HP-11 (1HP-V9) and utilize purification demineralizer HP-X2 if not being used by Unit 2
		2. Spuriously closed	Control Signal	Letdown flow through purification demineralizer HP-X1 is obstructed	Letdown flow to 3-way valve HP-14 (HP-V10) is terminated	Open HP-9 (1HP-V8) and HP-11 (1HP-V9) and utilize purification demineralizer HP-X2 if not being used by Unit 2

Reference Drawings: FSAR Figure 9.3-2
FSAR Figure 9-2A

1.0 SUBSYSTEM: LETDOWN COOLERS TO 3-WAY VALVE HP-14 (HP-V10) (Continued)

	Component	Potential Failure Mode: Mode	Potential Failure Mode: Interface Involved	Immediate Effects: Within Subsystem	Immediate Effects: At Subsystem Interface	Remedial Action Within Subsystem
1.3.10	Valve HP-8 (NO) (HP-V7) (cont'd)	3. Fails to close when required due to internal fault	--	Purification demineralizer HP-X1 isolation is unavailable	Continued letdown flow to 3-way valve HP-14 (HP-V10)	Close HP-47
		4. Fails to close when required due to unavailability of instrument air (assumed)	Instrument Air	Purification demineralizer HP-X1 isolation is unavailable	Continued letdown flow to 3-way valve HP-14 (HP-V10)	Close HP-47; restore instrument air
1.3.11	Purification Demineralizer HP-X1	1. Fail plugged	--	Letdown flow is blocked in purification demineralizer HP-X1	Letdown flow to 3-way valve HP-14 (HP-V10) is terminated	Isolate HP-X1 using HP-8 (HP-V7) and use HP-X2 if available or bypass by opening HP-13 (HP-V6) (reduced chemistry control)
1.3.12	Stop Check Valve HP-47	1. Fails plugged	--	Letdown flow through purification demineralizer HP-X1 is obstructed	Letdown flow to valve HP-14 (HP-V10) is terminated	Isolate HP-X1 using HP-8 (HP-V7) and use HP-X2 if available or bypass by opening HP-13 (HP-V6) (reduced chemistry control)
1.3.13	Valve HP-9 (NC) (1HP-V8)	1. Fails open due to internal fault	--	If purification demineralizer HP-X2 is being used by Unit 2, then the letdown flows of the two units may be mixed depending on the pressure difference between the two letdown flows	Increased or reduced letdown flow to 3-way valve HP-14 (HP-V10)	Remedial action dependent on Unit 2 operating requirements
		2. Spuriously opened	Control Signal	If purification demineralizer HP-X2 is being used by unit 2, then the letdown flows of the two units may be mixed depending on the pressure difference between the two letdown flows	Increased or reduced letdown flow to 3-way valve HP-14 (HP-V10)	Close HP-9 (1HP-V8)

Reference Drawings: FSAR Figure 9.3-2
FSAR Figure 9-2A

1.0 SUBSYSTEM: LETDOWN COOLERS TO 3-WAY VALVE HP-14 (HP-V10) (Continued)

	Component	Potential Failure Mode: Mode	Potential Failure Mode: Interface Involved	Immediate Effects: Within Subsystem	Immediate Effects: At Subsystem Interface	Remedial Action Within Subsystem
1.3.13	Valve HP-9 (NC) (1HP-V8) (cont'd)	3. Fails to open when required due to internal fault	--	Prevents use of spare purification demineralizer HP-X2 by unit 1	Potential reduction in chemistry control	Continue to use HP-X1 if available or open HP-13 (HP-V6) and bypass HP-X1
		4. Potential failure to open due to unavailability of instrument air (assumed)	Instrument Air	Prevents use of spare purification demineralizer HP-X2 by unit 1	Potential reduction in chemistry control	Continue to use HP-X1 if available or open HP-13 (HP-V6) and bypass HP-X1; restore instrument air
1.3.14	Valve HP-11 (NC) (1HP-V9)	1. Fails open due to internal fault	--	If purification demineralizer HP-X2 is being used by unit 2, then the letdown flow of unit 2 will leak into the letdown flow of unit 1 if unit 2 letdown pressure is greater than unit 1 letdown pressure	Increased letdown flow to 3-way valve HP-14 (HP-V10)	Close HP-10 (2HP-V8) and HP-12 (2HP-V9) depending on Unit 2 operating requirements
		2. Spuriously opened	Control Signal	If purification demineralizer HP-X2 is being used by unit 2, then the letdown flow of unit 2 will leak into the letdown flow of unit 1 if unit 2 letdown pressure is greater than unit 1 letdown pressure	Increased letdown flow to 3-way valve HP-14 (HP-V10)	Close HP-11 (1HP-V9)
		3. Fails to open when required due to internal fault	--	Prevents use of spare purification demineralizer HP-X2 by unit 1	Potential reduction in chemistry control	Continue to use HP-X1 if available or open HP-13 (HP-V6) and bypass HP-X1
		4. Potential failure to open due to unavailability of instrument air (assumed)	Instrument Air	Prevents use of spare purification demineralizer HP-X2 by unit 1	Potential reduction in chemistry control	Continue to use HP-X1 if available or open HP-13 (HP-V6) and bypass HP-X1; restore instrument air

APPENDIX B

FAILURE MODES AND EFFECTS ANALYSIS
SUBSYSTEM 2.0: RC PUMP SEAL WATER RETURN

Reference Drawings: FSAR Figure 9.3-2 (Sheets 1 and 4)

2.0 SUBSYSTEM: RCP SEAL WATER RETURN

	Component	Potential Failure Mode: Mode	Potential Failure Mode: Interface Involved	Immediate Effects: Within Subsystem	Immediate Effects: At Subsystem Interface	Remedial Action Within Subsystem
2.1	Seal Leak-off Line(s) (4 Total, 1/RCP):					
2.1.1	Pressure Transmitter(s) 1PT-19, 1PT-20, 1PT-21, 1PT-22	1. Instrument connection leak	--	Small loss of reactor coolant	Incorrect pressure signal to I&C system and control room	If accessible, repair component
		2. Transmitter failure due to internal faults	--	No effect	Incorrect pressure signal to I&C system and control room	If accessible, repair component
		3. Incorrect output due to loss of power	I&C System, Electric Power Supply	No effect	Incorrect pressure signal to I&C system and control room	Restore power supply
2.1.2	Motor Operated Isolation Valve(s) HP-228 (1HP-V43A), HP-232 (1HP-V43B), HP-226 (1HP-V43C), HP-230 (1HP-V43D)	1. Closes on spurious signal	I&C System	Flow stopped in single leak-off line	Seal leak-off flow from a single RC pump blocked, control room alarm	Attempt to open failed valve or open seal bypass valve (HP-275)
		2. Inadvertently closed	--	Flow stopped in single leak-off line	Seal leak-off flow from a single RC pump blocked, control room alarm	Reopen valve
		3. Fails closed due to internal fault	--	Flow stopped in single leak-off line	Seal leak-off flow from a single RC pump blocked, control room alarm	Open seal bypass valve (HP-275)
		4. Valve fails to close when required due to control signal failure	I&C System	Flow not isolated	Subsystem not isolated from RCS	Close local valves on affected line
		5. Valve fails to close on demand	Electric Power Supply	Flow not isolated	Subsystem not isolated from RCS	Restore power, close local valves on affected line
		6. Valve fails to close on demand due to internal fault	--	Flow not isolated	Subsystem not isolated from RCS	Close local valves on affected line
2.1.3	Manual Isolation Valves (2/line) HP-205, HP-207, HP-212, HP-214, * HP-219, HP-221, HP-259, HP-261	1. Valve failed closed (plugging, damaged, etc.)	--	Flow stopped in single leak-off line	Seal leak-off flow from a single RC pump blocked, control room alarm	Open bypass valve around failed valve (local action)
2.1.4	Flow Transmitter(s) 1FT-19, 1FT-20, 1FT-21, 1FT-22, 1FT-113, 1FT-114, 1FT-115, 1FT-116	1. Instrument connection leak	--	Small loss of reactor coolant	Incorrect flow signal to I&C system and control room	If accessible, isolate leaking transmitter(s), flow bypass available (local action just outside of secondary shielding)

Reference Drawings: FSAR Figure 9.3-2 (Sheets 1 and 4)

2.0 SUBSYSTEM: RCP SEAL WATER RETURN (Continued)

	Component	Potential Failure Mode: Mode	Potential Failure Mode: Interface Involved	Immediate Effects: Within Subsystem	Immediate Effects: At Subsystem Interface	Remedial Action Within Subsystem
2.1.4	Flow Transmitter(s) 1FT-19, 1FT-20, 1FT-21, 1FT-22, 1FT-113, 1FT-114, 1FT-115, 1FT-116 (cont'd)	2. Incorrect output due to loss of power	Electric Power Supply, I&C System	No effect	Incorrect flow signal to I&C system and control room	Restore power supply
		3. Transmitter failure due to internal fault	--	No effect	Incorrect flow signal to I&C system and control room	If accessible, utilize bypass, isolate component and repair (local action just outside of secondary shielding)
2.2	Seal Bypass Line(s) (Normally Closed, Open When #1 Seal-Leakoff Rate is Too Low) (4 Total, 1/RCP):					
2.2.1	Pressure Transmitter(s) 1PT-19, 1PT-20, 1PT-21, 1PT-22	1. Instrument connection leak	--	Small loss of reactor coolant	Incorrect pressure signal transmitted to I&C and control room	If accessible, repair component
		2. Incorrect output due to loss of power	Electric Power Supply, I&C System	No effect	Incorrect pressure signal transmitted to I&C and control room	Restore power supply
		3. Transmitter failure due to internal fault	--	No effect	Incorrect pressure signal transmitted to I&C and control room	If accessible, repair component
2.2.2	Check Valve(s) HP-263, HP-266, HP-269, HP-272	1. Valve failed closed (plugged, damaged, etc.)	--	Flow in a single bypass line stopped	Seal bypass flow path blocked from a single RC pump	If accessible, repair component
		2. Valve fails to prevent backflow	--	No effect during steady state	No effect during steady state	Repair component at shutdown
2.2.3	Manual Isolation Valves (2/line) HP-264, HP-265, HP-267, HP-268, HP-270, HP-271, HP-273, HP-274	1. Valve fails closed (plugged, damaged, etc.)	--	Flow in a single bypass line stopped	Seal bypass flow path blocked from a single RC pump	If accessible, repair component
2.2.4	Flow Transmitter(s) 1FT-109, 1FT-110, 1FT-111, 1FT-112	1. Instrument connection leak	--	Small loss of reactor coolant	Incorrect flow signal transmitted to I&C and control room	If accessible, repair component
		2. Transmitter failure due to internal fault	--	No effect	Incorrect flow signal transmitted to I&C and control room	If accessible, repair component
		3. Incorrect output due to loss of power	Electric Power Supply, I&C System	No effect	Incorrect flow signal transmitted to I&C and control room	Restore power supply

2. SUBSYSTEM: RCP SEAL WATER RETURN (Continued)

	Component	Potential Failure Mode: Mode	Potential Failure Mode: Interface Involved	Immediate Effects: Within Subsystem	Immediate Effects: At Subsystem Interface	Remedial Action Within Subsystem
2.3	Seal Bypass Return Header:					
2.3.1	Motor Operated Isolation Valve HP-275 (HP-V48)	1. Valve fails to open when required due to control signal failure or closes on spurious signal	I&C System	Seal return bypass flow blocked	Seal return bypass flow path unavailable to all RC pumps	None
		2. Valve fails to open on demand or closes on spurious signal	Electric Power Supply	Seal return bypass flow blocked	Seal return bypass flow path unavailable to all RC pumps	Restore power
		3. Valve fails to open on demand due to internal fault	--	Seal return bypass flow blocked	Seal return bypass flow path unavailable to all RC pumps	Repair component if accessible
		4. Valve fails open or fails to close when required	I&C System, Electric Power Supply, Internal	No effect	No effect	Repair component if accessible
2.3.2	Motor Operated Isolation Valve to Stand Pipe Fill and Makeup HP-276 (HP-V49)	1. Valve fails open due to internal fault	--	Stand pipe fill lines open to seal return flow	Potential loss of vent on RCP vent seal	None
		2. Valve opens on spurious signal	I&C System	Stand pipe fill lines open to seal return flow	Potential loss of vent on RCP vent seal	None
2.4	Seal Water Cooler Inlet Header:					
2.4.1	Motor Operated Isolation Valve HP-20 (HP-V12)	1. Valve fails closed due to internal fault	--	Seal return flow stopped	Seal return flow from all RC pumps stopped	Repair component
		2. Valve closes on spurious signal	I&C System, ES	Seal return flow stopped	Seal return flow from all RC pumps stopped	None
		3. Valve inadvertantly closed	--	Seal return flow stopped	Seal return flow form all RC pumps stopped	Reopen valve
		4. Valve fails to close on demand	Electric Power Supply	Reactor building isolation degraded	Seal return flow continues to letdown storage tank	Restore power
		5. Valve fails to close when required	ES	Reactor building isolation degraded	No effect provided, redundant valve closes	None
		6. Valve fails to close when required	I&C System	Reactor building isolation degraded, seal return flow not isolated from coolers	Seal return flow continues to letdown storage tank	Utilize valve HP-21
		7. Valve fails to close on demand due to internal fault	--	Reactor building isolation degraded, seal return flow not isolated from coolers	Seal return flow continues to letdown storage tank	Utilize valve HP-21
2.4.2	Pneumatic Operated Isolation Valve HP-21 (HP-V13)	1. Valve fails closed (assuming valve is air-to-open)	Instrument Air	Seal return flow stopped	Seal return flow from all RC pumps stopped	Attempt to open valve locally
		2. Valve closes on spurious signal	I&C System	Seal return flow stopped	Seal return flow from all RC pumps stopped	Attempt to open valve locally
		3. Valve closes on spurious signal	ES	Seal return flow stopped	Seal return flow from all RC pumps stopped	Attempt to open valve locally

2.4 SUBSYSTEM: RCP SEAL WATER RETURN (Continued)

	Component	Potential Failure Mode: Mode	Potential Failure Mode: Interface Involved	Immediate Effects: Within Subsystem	Immediate Effects: At Subsystem Interface	Remedial Action Within Subsystem
2.4.2	Pneumatic Operated Isolation Valve HP-21 (HP-V13) (cont'd)	4. Valve fails closed due to internal fault	--	Seal return flow stopped	Seal return flow from all RC pumps stopped	Repair component
		5. Valve fails to close on demand due to internal fault	--	Reactor building isolation degraded, seal return flow not isolated from seal return coolers	Seal return flow continues to letdown storage tank	Utilize valve HP-20
		6. Valve fails to close when required	ES	Reactor building isolation degraded	No effect provided redundant valve closes	None
		7. Valve fails to close when required	I&C System	Reactor building isolation degraded, seal return flow not isolated from coolers	Seal return flow continues to letdown storage tank	Utilize valve HP-20
2.4.3	Seal Return Filter Throttle Valve HP-277 (HP-V50)	1. Valve failed closed (plugged, damaged, etc.)	--	Seal return flow reduced or stopped	Seal return flow from all RC pumps reduced or stopped	Repair component
2.4.4	Seal Return Filter Isolation Valve(s) HP-278, HP-279	1. Valve failed closed (plugged, damaged, etc.)	--	Seal return flow reduced or stopped	Seal return flow from all RC pumps reduced or stopped	Open bypass valve (HP-280) around filter (local action)
2.4.5	Seal Return Filter	1. Filter plugged	--	Seal return flow reduced or stopped	Seal return flow from all RC pumps reduced or stopped high P transmitted on 1PT-114	Open bypass valve (HP-280) around filter (local action)
2.5	Seal Return Cooler(s):					
2.5.1	Manual Isolation Valve(s) HP-72, HP-74, HP-75, HP-77	1. Valve fails closed (plugging, damaged, stuck closed, etc.)	--	Seal return flow reduced or stopped	Seal water flow from all RC pumps reduced or stopped	Valve in spare cooler (local action)
2.5.2	Operating RC Seal Return Cooler HP-C1B (or Spare HP-C1A)	1. Heat exchanger tubes blocked	--	Seal return flow reduced or stopped	Seal water flow from all RC pumps reduced or stopped	Valve in spare cooler (local action) and repair blocked cooler
		2. Tube failure	RCW System	Loss of reactor coolant to RCW system	Reactor coolant leakage to RCW system, reduced seal water return to letdown storage tank	Valve in spare cooler (local action) or isolate seal return header from control room if required and take appropriate precautions for stopping seal return

2.0 SUBSYSTEM: RCP SEAL WATER RETURN (Continued)

	Component	Potential Failure Mode: Mode	Potential Failure Mode: Interface Involved	Immediate Effects: Within Subsystem	Immediate Effects: At Subsystem Interface	Remedial Action Within Subsystem
2.5.2	Operating RC Seal Return Cooler HP-C1B (or Spare HP-C1A) (cont'd)	3. Loss of RCW	RCW System	Loss of seal return cooling (high cooler discharge temperature)	High temperature discharge to letdown storage tank, high temperature reading on TT-45 or TT-46	Valve in spare cooler if RCW is available to it (local action)
		4. Loss of heat transfer capability due to internal damage	--	Loss of seal return cooling (high cooler discharge temperature)	High temperature discharge to letdown storage tank, high temperature reading on TT-45 or TT-46	Isolate affected cooler and valve in spare (local action)
		5. Vapor lock in cooler	--	Reduction in seal return cooling capacity (high cooler discharge temperature)	High temperature discharge to letdown storage tank, high temperature reading on TT-45 or TT-46	Isolate affected cooler and valve in spare (local action)
2.5.3	Cooler Discharge Header Check Valve HP-189	1. Valve fails closed (plugging, damaged, etc.)	--	Seal return flow reduced or stopped	Seal return flow to letdown storage tank reduced or stopped, seal return flow from all RC pumps reduced or stopped	Repair component
		2. Valve fails to prevent backflow	Seal Water Coolers, Letdown Storage Tank, Makeup Filter(s) Discharge	No effect during steady state since pressures at outlet interfaces are lower than cooler discharge line pressure	No effect during steady state since pressures at outlet interfaces are lower than cooler discharge line pressure	No immediate action necessary, repair component
2.6	System Inlet Flows:					
2.6.1	Seal Injection Flow	1. Loss of flow	Seal injection (Subsystem 4.0), RC Pumps	Seal return flow from RCS hotter than normal seal return	Slightly hotter discharge flow to letdown storage tank	None
2.6.2	HPI Pump Recirculation	1. Loss of flow	HPI Pumps (Subsystem 3.0)	Reduced flow through seal return coolers	Reduced flow and somewhat cooler discharge than normal to letdown storage tank	None
2.7	System Piping:					
2.7.1	Vents, Drains, Piping, Instrument Connections, etc.	1. System leaks	--	Loss of reactor coolant	Loss of reactor coolant, slightly reduced flow to letdown storage tank	Isolate leaks and repair as needed

APPENDIX C

FAILURE MODES AND EFFECTS ANALYSIS

SUBSYSTEM 3.0: LETDOWN STORAGE TANK, INLET FILTERS, AND HPI PUMPS

Reference Drawings: FSAR Figure 9.3-2 (Sheet 1)

3.0 SUBSYSTEM: LETDOWN STORAGE TANK (LST), INLET FILTERS, AND HPI PUMPS

Component		Potential Failure Mode: Mode	Potential Failure Mode: Interface Involved	Immediate Effects: Within Subsystem	Immediate Effects: At Subsystem Interface	Remedial Action Within Subsystem
3.1 Letdown (Makeup) Filters (2):						
3.1.1	Pneumatic Operated Inlet Valve(s) HP-17 (HP-V29A), HP-18 (HP-V29B)	1. Valve fails closed (assumed valve is air-to-open)	Instrument Air	Loss of flow to LST from letdown, chemical addition, and system makeup	Reduction and eventual loss of available makeup in LST	Utilize spare filter, open valve locally, bypass to LST, or switch to BWST if LST level is unacceptably low
		2. Valve fails closed due to internal fault	--	Loss of flow to LST from letdown, chemical addition, and system makeup	Reduction and eventual loss of available makeup in LST	Utilize spare filter, bypass to LST, or switch to BWST if LST level is unacceptably low
		3. Valve closes on spurious signal	I&C System	Loss of flow to LST from letdown, chemical addition, and system makeup	Reduction and eventual loss of available makeup in LST	Utilize spare filter, open valve locally, bypass to LST or switch to BWST if LST level is unacceptably low
		4. Valve inadvertently closed	--	Loss of flow to LST from letdown, chemical addition, and system makeup	Reduction and eventual loss of available makeup in LST	Reopen valve
		5. Valve fails to close when required	I&C, Electric Power Supply, Internal	Cannot isolate filter for maintenance	No effect	Repair component
3.1.2	Makeup Filter P Transmitter 1PT-15	1. Transmitter failure due to internal fault	--	Potential for undetected filter plugging	Incorrect pressure drop signal to I&C and control room	Monitor pressure drop with local gage
		2. Incorrect output due to loss of power	Electric Power Supply, I&C	Potential for undetected filter plugging	Incorrect pressure drop signal to I&C and control room	Monitor pressure drop with local gage
		3. Instrument connection leak	--	Small loss of reactor coolant and small reduction in flow to LST	Incorrect pressure drop signal to I&C and control room	Repair leak
3.1.3	Filter(s) HP-F1A, HP-F1B	1. Filter plugged	--	Letdown, chemical addition, and system makeup flow reduced or stopped	Reduced inventory in LST and high pressure drop signal to I&C from 1PT-15	Utilize spare filter or bypass filters via HP-19

3.0 SUBSYSTEM: LETDOWN STORAGE TANK (LST), INLET FILTERS, AND HPI PUMPS (Continued)

Component		Potential Failure Mode		Immediate Effects		Remedial Action Within Subsystem
		Mode	Interface Involved	Within Subsystem	At Subsystem Interface	
3.1.4	Manual Filter Discharge Block Valve(s) HP-57, HP-58	5. Valve failed closed (plugging, damaged, etc.)	--	Loss of flow to LST from letdown, chemical addition, and system makeup	Reduction and eventual loss of available makeup in LST	Utilize spare filter path or bypass filters via HP-19
3.2	Letdown Storage Tank:					
3.2.1	Inlet Check Valve HP-78	1. Valve failed closed	Subsystem 2.0	Loss of all flow to LST, potential loss of NPSH to HPI pumps if LST level is too low	Reduction and eventual loss of available makeup in LST, flow blocked from seal return (Subsystem 2.0)	Monitor LST level, switch to BWST if LST level is unacceptably low
		2. Valve fails to prevent backflow	Subsystem 2.0 (Seal Return)	None during steady state	None since check valve HP-18 in Subsystem 2.0 is a backup	Repair component
3.2.2	Tank Vent Globe Valve HP-80	1. Valve failed closed (plugged, damaged, etc.)	Chemical Addition (Subsystem 5.0)	Loss of normal LST vent path, buildup of noncondensible gases in LST, potential reduction in H_2 mass transfer rate into reactor coolant	Potential reduction of H_2 concentration in reactor coolant and reduction in O_2 scavenging capability	Monitor LST pressure and level and repair component
3.2.3	Manual H_2/N_2 Supply/Isolation Valve H-111	1. Valve failed closed (plugged, damaged, etc.)	H_2 Bulk Storage, N_2 Blanketing System	Loss of H_2 addition to LST	Reduction in H_2 concentration in reactor coolant and reduction in O_2 scavenging capability	Repair component
3.2.4	Level Transmitters 1LT-33P1, 1LT-33P2	1. Transmitter failure due to internal fault	--	If selected transmitter indicates low flow from 3-way valve automatically transfers letdown flow to LST and operator may increase LST level with bleed holdup. Potential for LST tank overfilling, H_2 addition blockage, and lower H_2 concentration in RCS. If transmitter indicates high, operator may decrease letdown flow and potentially reduce NPSH on HPI pumps	Loss of or incorrect LST level indication, incorrect signal to 3-way valve interlock circuit and potential for reduced H_2 concentration in RCS. Operator response may also result in decreased letdown flow	Monitor with redundant transmitter

3.0 SUBSYSTEM: LETDOWN STORAGE TANK (LST), INLET FILTERS, AND HPI PUMPS (Continued)

	Component	Potential Failure Mode: Mode	Potential Failure Mode: Interface Involved	Immediate Effects: Within Subsystem	Immediate Effects: At Subsystem Interface	Remedial Action Within Subsystem
3.2.4	Level Transmitters 1LT-33P1, 1LT-33P2 (cont'd)	2. Incorrect output due to loss of power to transmitter	Electric Power Supply, I&C System	If selected transmitter indicates low flow from 3-way valve automatically transfers letdown flow to LST and operator may increase LST level with bleed holdup. Potential for LST tank overfilling, H_2 addition blockage, and lower H_2 concentration in RCS. If transmitter indicates high, operator may decrease letdown flow and potentially reduce NPSH on HPI pumps	Loss of or incorrect LST level indication, incorrect signal to 3-way valve interlock circuit and potential for reduced H_2 concentration in RCS. Operator response may also result in decreased letdown flow	Restore power supply or monitor with redundant transmitter if on a different power source
		3. Instrument connection leak	--	Small loss of LST inventory. Both transmitters affected. If selected transmitter indicates low flow from 3-way valve automatically transfers letdown flow to LST and operator may increase LST level with bleed holdup. Potential for LST tank overfilling, H_2 addition blockage, and lower H_2 concentration in RCS. If transmitter indicates high, operator may decrease letdown flow and potentially reduce NPSH on HPI pumps	Loss of or incorrect LST level indication, incorrect signal to 3-way valve interlock circuit and potential for reduced H_2 concentration in RCS. Operator response may also result in decreased letdown flow	Repair component
3.2.5	Pressure Transmitter 1PT-10	1. Incorrect output due to loss of power	Electric Power Supply, I&C System	No effect	Loss of or incorrect LST pressure indication	Restore power supply
		2. Transmitter failure	--	No effect	Loss of or incorrect LST pressure indication	Repair component
		3. Instrument connection leak	--	Small loss of LST inventory	Loss of or incorrect LST pressure indication	Repair component
3.3	HPI Pump Suction Headers:					
3.3.1	Motor Operated Isolation Valve HP-23 (HP-V21)	1. Valve fails closed	--	Flow to HPI pumps stopped, loss of NPSH to HPI pump resulting possible in pump damage	Immediate loss of flow to RC makeup and RC pump seals	Align supply from BWST via motor operated valves and align alternate HPI pump if required

Reference Drawings: FSAR Figure 9.3-2 (Sheet 1)

3.0 SUBSYSTEM. LETDOWN STORAGE TANK (LST), INLET FILTERS, AND HPI PUMPS (Continued)

	Component	Potential Failure Mode: Mode	Potential Failure Mode: Interface Involved	Immediate Effects: Within Subsystem	Immediate Effects: At Subsystem Interface	Remedial Action Within Subsystem
3.3.1	Motor Operated Isolation Valve HP-23 (HP-V21) (cont'd)	2. Valve closes on spurious signal	I&C System	Flow to HPI pumps stopped, loss of NPSH to HPI pump resulting possible in pump damage	Immediate loss of flow to RC makeup and RC pump seals	Manually open valve or align supply from BWST via motor operated valves and align alternate HPI pump if required
		3. Valve inadvertently closed	--	Flow to HPI pumps stopped, loss of NPSH to HPI pump resulting possible in pump damage	Immediate loss of flow to RC makeup and RC pump seals	Reopen valve, align alternate HPI pump if required
		4. Valve fails to close when required	I&C System, Electric Power Supply, Internal Fault	LST discharge not isolated	No effect	Utilize local valves for isolation
3.3.2	Check Valve HP-97	1. Valve fails closed	--	Flow to HPI pump stopped, loss of NPSH to HPI pump resulting in possible pump damage	Immediate loss of flow to RC makeup and RC pump seals	Align supply from BWST via motor operated valves and align alternate HPI pump if required
		2. Valve fails to prevent backflow	--	No effect during steady state operation	No effect during steady state operation	Monitor pressure and level in LST. Isolate LST if BWST flow is aligned
3.3.3	Motor Operated Isolation Valve HP-98 (HP-V28A)	1. Valve fails closed	--	Flow to HPI pump 1A stopped, if in use pump 1A may be damaged	If HP-P1A in use, loss of flow to RC makeup and seal injection. If HP-P1B in use, no effect	Trip HPI pump 1A and use pump 1B
		2. Valve inadvertantly closed	--	Flow to HPI pump 1A stopped, if in use pump 1A may be damaged	If HP-P1A in use, loss of flow to RC makeup and seal injection. If HP-P1B in use, no effect	Trip HPI pump 1A and use pump 1B
		3. Valve closes on spurious signal	I&C System	Flow to HPI pump 1A stopped, if in use pump 1A may be damaged	If HP-P1A in use, loss of flow to RC makeup and seal injection. If HP-P1B in use, no effect	Trip HPI pump 1A and use pump 1B
		4. Valve fails to close on demand	--	Cannot remotely isolate pump HP-P1A for maintenance	No effect	Isolate pump HP-P1A with manual valves. If desired, utilize one of 2 remaining HPI pumps

Reference Drawings: FSAR Figure 9.3-2 (Sheet 1)

3.0 SUBSYSTEM: LETDOWN STORAGE TANK (LST), INLET FILTERS, AND HPI PUMPS (Continued)

	Component		Potential Failure Mode: Mode	Potential Failure Mode: Interface Involved	Immediate Effects: Within Subsystem	Immediate Effects: At Subsystem Interface	Remedial Action Within Subsystem
3.3.3	Motor Operated Isolation Valve HP-98 (HP-V28A) (cont'd)	5.	Valve fails to close when required	I&C System	Cannot remotely isolate pump HP-P1A for maintenance	No effect	Isolate pump HP-P1A with manual valves. If desired, utilize one of 2 remaining HPI pumps
		6.	Valve fails to close when required	Electric Power Supply	Cannot remotely isolate pump HP-P1A for maintenance	No effect	Isolate pump HP-P1A with manual valves. If desired, utilize one of 2 remaining HPI pumps
3.3.4	Manual Isolation Valves HP-99 (HP-V28B), HP-100 (HP-V28C), HP-111 (HP-V26C)	1.	Valve fails closed (plugging, damaged, etc.)	--	Suction to standby pump HP-P1C blocked. If pump is started, pump may be damaged	If pump HP-P1C in use, loss of flow to RC makeup and seal injection. If other pump in use, no effect	Utilize alternate HPI pump
3.3.5	Manual Isolation Valve HP-107 (HP-V26B)	1.	Valve fails closed (plugging, damaged, etc.)	--	Suction to standby pump HP-P1B blocked. If pump is started, pump may be damaged	If pump HP-P1B in use, loss of flow to RC makeup and seal injection. If other pump in use, no effect	Utilize alternate HPI pump
3.3.6	Manual Isolation Valve HP-103 (HP-V26A)	1.	Valve fails closed (plugging, damaged, etc.)	--	Flow to operating pump HP-P1A blocked. Unless pump is tripped, pump damage could occur	If pump HP-P1A in use, loss of flow to RC makeup and seal injection. If other pump in use, no effect	Trip HPI pump 1A and utilize pump 1B
3.4	HPI Pumps and Discharge Manifold:						
3.4.1	Operating HPI Pump HP-P1A	1.	Mechanical failure to operate	--	No discharge flow from failed pump	No flow to RC makeup or RC pump seals	Utilize alternate HPI pump
		2.	Pump fails due to loss of power	Electric Power Supply	No discharge flow from failed pump	No flow to RC makeup or RC pump seals	Restore power or utilize an alternate HPI pump on another power source
3.4.2	Spare HPI Pumps HP-P1B, HP-P1C	1.	Pump fails to start due to signal failure	I&C System	No discharge flow from pump demanded	If pump is demanded because of failure with operating pump, no flow to RC makeup or RC pump seals. If pumps are just being switched, no effect	Utilize alternate HPI pump, repair circuit

Reference Drawings: FSAR Figure 9.3-2 (Sheet 1)

3.0 SUBSYSTEM: LETDOWN STORAGE TANK (LST), INLET FILTERS, AND HPI PUMPS (Continued)

	Component	Potential Failure Mode: Mode	Potential Failure Mode: Interface Involved	Immediate Effects: Within Subsystem	Immediate Effects: At Subsystem Interface	Remedial Action Within Subsystem
3.4.2	Spare HPI Pumps HP-P1B, HP-P1C (cont'd)	2. Pump fails to start due to internal fault	--	No discharge flow from pump demanded	If pump is demanded because of failure with operating pump, no flow to RC makeup or RC pump seals. If pumps are just being switched, no effect	Utilize alternate HPI pump, repair pump
3.4.3	Discharge Check Valve(s) HP-105, HP-108	1. Valve in operating pump discharge fails closed (plugging, damaged, etc.)	--	No discharge flow through failed valve	No flow from operating HPI pump to RC makeup or RC pump seals	Utilize alternate HPI pump
		2. Valve in standby pump discharge fails to prevent backflow	--	Backflow through a nonoperating spare pump to suction of operating pump (potential HPI pump damage)	Reduced flow to seal injection and/or makeup	Isolate failed check valve (local action). Monitor critical flows
3.4.4	Recirculation Line(s) Associated With Pumps: HP-P1A, HP-P1B, HP-P1C	1. Line blockage due to plugged block valve or orifice	Seal Return Cooler Inlet (Subsystem 2.0)	Potential damage to HPI pump via pump deadheading if pump discharge to makeup and seal injection is not enough for pump operation	Potential loss of RC makeup and seal injection	Utilize alternate HPI pump (other action available from outside the subsystem)
3.4.5	Discharge Block Valve(s) HP-106 (HP-V34A), HP-110 (HP-V34B), HP-114 (HP-V34C)	1. Valve in operating pump discharge fails closed (plugged, damaged, etc.)	RCP Seals, Reactor Inlet Line Loops A, B and Crossovers A and B	No discharge flow through failed valve	No discharge flow from operating HPI pump to RC pumps seals or RC makeup	Utilize alternate HPI pump
3.4.6	Motor Operated Isolation Valve HP-115 (HP-V35A)	1. Valve closes on spurious signal	I&C System	If pump HP-P1A operating, flow to seal injection is stopped. If pump HP-P1B is operating, flow to normal RC makeup is stopped	If pump HP-P1A operating, flow to seal injection is stopped. If pump HP-P1B is operating, flow to normal RC makeup is stopped	If operating pump is HP-P1A, start pump HP-P1B. If operating pump is HP-P1B, start HP-P1A or (for unthrottled makeup) open valve HP-118 to reactor inlet LOOP B

Reference Drawings: FSAR Figure 9.3-2 (Sheet 1)

3.0 SUBSYSTEM: LETDOWN STORAGE TANK (LST), INLET FILTERS, AND HPI PUMPS (Continued)

	Component	Potential Failure Mode: Mode	Potential Failure Mode: Interface Involved	Immediate Effects: Within Subsystem	Immediate Effects: At Subsystem Interface	Remedial Action Within Subsystem
3.4.6	Motor Operated Isolation Valve HP-115 (HP-V35A) (cont'd)	2. Valve fails closed due to internal fault	--	If pump HP-P1A operating, flow to seal injection is stopped. If pump HP-P1B is operating, flow to normal RC makeup is stopped	If pump HP-P1A operating, flow to seal injection is stopped. If pump HP-P1B is operating, flow to normal RC makeup is stopped	If operating pump is HP-P1A, start pump HP-P1B. If operating pump is HP-P1B, start HP-P1A or (for unthrottled makeup) open valve HP-118 to reactor inlet LOOP B
		3. Valve inadvertently closed	--	If pump HP-P1A operating, flow to seal injection is stopped. If pump HP-P1B is operating, flow to normal RC makeup is stopped	If pump HP-P1A operating, flow to seal injection is stopped. If pump HP-P1B is operating, flow to normal RC makeup is stopped	Reopen valve
		4. Valve fails to close when required	I&C System, Electric Power Supply, or Internal Fault	Intended isolation not effected	No effect on steady state operation	Utilize local isolation valves
3.4.7	Isolation Valve HP-118 (HP-V35B)	1. Valve fails open (damaged, etc.)	--	Loss of separation between HPI injection paths A and B	No effect during normal operation since injection path B is normally closed	Utilize HP-117 for isolation
3.4.8	Isolation Valve HP-117 (HP-V35C)	1. Valve fails closed (plugging, damaged, etc.)	--	Loss of ability to use HP-P1B as spare for safety injection to cold leg B	Loss of ability to use HP-P1B as spare for safety injection to cold leg B	Repair component
3.5	System Inlet Flows:					
3.5.1	Reactor Coolant Letdown Inlet Flow	1. Loss of flow	Subsystem 1.0	Reduction and eventual loss of available makeup in LST, loss of letdown flow to subsystem	Loss of letdown flow to subsystem	Monitor LST level and utilize supply from BWST, bleed holdup tank, or boric acid tank
3.5.2	RC Bleed Makeup Feed Inlet Flow	1. Loss of flow	Subsystem 6.0	If in letdown/bleed and feed operating mode, reduction in LST level	Loss of batch inputs to LST from RC bleed makeup	Restore letdown flow to LST
3.5.3	RCP Seal Return Inlet Flow	1. Loss of flow	Subsystem 2.0	Partial loss of flow to LST, loss of HPI pump recirculation	Potential long-term loss of LST level and requirement to switch to BWST suction	Monitor LST level, utilize RC bleed makeup or BWST if required

Reference Drawings: FSAR Figure 9.3-2 (Sheet 1)

3.0 SUBSYSTEM: LETDOWN STORAGE TANK (LST), INLET FILTERS, AND HPI PUMPS (Continued)

Component	Potential Failure Mode		Immediate Effects		Remedial Action Within Subsystem
	Mode	Interface Involved	Within Subsystem	At Subsystem Interface	
3.6 System Piping:					
3.6.1 Vents, Drains, Piping, Instrument Connections, etc.	1. System leaks	--	Loss of reactor coolant, potential for loss of NPSH to HPI pumps	Loss of reactor coolant, potential for slight reduction in makeup flow or seal injection	Isolate leak, utilize supply from BWST if required

APPENDIX D

FAILURE MODES AND EFFECTS ANALYSIS

SUBSYSTEM 4.0: RC PUMP SEAL INJECTION

Reference Drawings: FSAR Figure 9.3-2 (Sheets 1 and 4)

4.0 SUBSYSTEM: RC PUMPS SEAL INJECTION

	Component	Potential Failure Mode: Mode	Potential Failure Mode: Interface Involved	Immediate Effects: Within Subsystem	Immediate Effects: At Subsystem Interface	Remedial Action Within Subsystem
4.1	RC Pumps Seal Injection Header:					
4.1.1	Seal Injection Header Manual Isolation Valve HP-126 (HP-V27B)	1. Valve fails closed (plugged, damaged, etc.)	--	Seal injection flow stopped	Seal injection flow to RC pumps stopped	Repair component
4.1.2	Seal Injection Header Pressure Transmitter 1PT-18	1. Incorrect output due to loss of power	I&C System, Electric Power Supply	No effect	Incorrect pressure signal	Repair component
		2. Instrument connection leak	--	Small loss of reactor coolant	Incorrect pressure signal	Repair component
		3. Transmitter failure due to internal fault	--	No effect	Incorrect pressure signal	Repair component
4.2	RC Pump Seal Filters:					
4.2.1	Operating Filter Manual Isolation Valves HP-29, HP-132, HP-133, HP-134	1. Valve fails closed (plugged, damaged, etc.)	--	Flow through filter stopped	Seal injection flow to RC pumps stopped	Valve in spare filter path, or bypass both main and standby filters (local action)
4.2.2	Operating Seal Filter HP-F-1B (HP-F-1A Standby)	1. Filter plugged	--	Flow through filter stopped	Seal injection flow to RC pumps stopped	Valve in spare filter path, or bypass both main and standby filters (local action)
4.2.3	Manual Isolation Valves for Standby Filter or Bypass HP-28, HP-135	1. Valve fails to open on demand	--	No effect during normal operation. Loss of spare or bypass capacity	No effect during normal operation when spare or bypass is not demanded	If one of these backups has failed, utilize the remaining one if required
4.2.4	Standby Filter Manual Isolation Valves HP-129, HP-130, HP-131	1. Valve fails closed (plugged, damaged, etc.)	--	Flow through standby filter prevented	No effect	Valve in filter bypass if required (local action)
4.3	Seal Injection Flow Control:					
4.3.1	Flow Orifice	1. Orifice plugged	--	Seal injection flow reduced or stopped and control signal to throttle valve incorrect	Seal injection flow to RC pumps stopped	Repair component

Reference Drawings: FSAR Figure 9.3-2 (Sheets 1 and 4)

4.0 SUBSYSTEM: RC PUMPS SEAL INJECTION (Continued)

	Component	Potential Failure Mode: Mode	Potential Failure Mode: Interface Involved	Immediate Effects: Within Subsystem	Immediate Effects: At Subsystem Interface	Remedial Action Within Subsystem
4.3.2	Flow Controller/ Transmitter 1FT-75	1. Transmitter failure	Electric Power Supply, I&C System, Internal Fault	Incorrect signal to flow control valve, potentially resulting in too much or too little flow.	Negligable effect for high flow since flow is throttled downstream. On low flow, reduced seal injection flow to RC pumps. Incorrect signal to I&C system	Monitor and control flow from individual seal injection lines if required
4.3.3	Flow Control Valve HP-31 (HP-V42)	1. Valve fails open (valve assumed air-to-close)	Instrument Air	Full HPI pump discharge flow to individual seal injection lines	Negligable effect on seal injection supply	Manually control seal flow with HP-140 or with individual seal injection line throttle valves (local action)
		2. Valve fails open	Control Signal from 1FT-75, Electric Power Supply	Full HPI pump discharge flow to individual seal injection lines	Negligable effect on seal injection supply	Manually control seal flow with HP-140 or with individual seal injection line throttle valves (local action)
		3. Valve fails open due to internal damage	--	Full HPI pump discharge flow to individual seal injection lines	Negligable effect on seal injection supply	Manually control seal flow with HP-140 or with individual seal injection line throttle valves (local action)
		4. Valve fails closed	Control Signal from 1FT-75, Electric Power Supply	Seal injection flow reduced or stopped	Seal injection flow to RC pumps stopped	Valve in bypass and manually control seal flow from header (HP-140) or from individual seal injection lines (local action)
		5. Valve fails closed due to internal damage or plugging, etc.	--	Seal injection flow reduced or stopped	Seal injection flow to RC pumps stopped	Valve in bypass and manually control seal flow from header (HP-140) or from individual seal injection lines (local action)

Reference Drawings: FSAR Figure 9.3-2 (Sheets 1 and 4)

4.0 SUBSYSTEM: RC PUMPS SEAL INJECTION (Continued)

	Component	Potential Failure Mode: Mode	Potential Failure Mode: Interface Involved	Immediate Effects: Within Subsystem	Immediate Effects: At Subsystem Interface	Remedial Action Within Subsystem
4.3.4	Manual Isolation Valve(s) HP-138, HP-139	1. Valve fails closed (plugged, damaged, etc.)	--	Seal injection flow stopped	Seal injection flow to RC pumps stopped	Valve in bypass and manually control seal flow from header (HP-140) or from individual seal injection lines (local action)
4.4	Individual RC Pump Seal Injection Lines (4 Total, 1/RC Pump):					
4.4.1	Flow Transmitter(s) 1FT-101, 1FT-102, 1FT-103, 1FT-104	1. Incorrect output due to loss of power	I&C System, Electric Power Supply	No effect	Incorrect flow signal to control room	Restore power
		2. Instrument connection leak	--	Small loss of reactor coolant	Incorrect flow signal to control room	Repair component if accessible
		3. Transmitter failure due to internal fault	--	No effect	Incorrect flow signal to control room	Repair component if accessible
4.4.2	Manual Throttle Valve(s) HP-64, HP-65, HP-66, HP-67	1. Valve fails closed (plugged, damaged, etc.)	--	Seal injection flow in affected line stopped	Seal injection flow to one RC pump stopped	Repair component if accessible
		2. Valve fails open	--	Flow in affected line unthrottled	Seal injection flow to a single RC pump higher than setpoint	Repair component, utilize stop check valves in line on short term basis for flow throttling if required (local action)
4.4.3	Check Valves (2/line) HP-144, HP-145, HP-146, HP-147, HP-283, HP-284, HP-286, HP-393	1. Valve fails closed	--	Flow in affected seal injection line stopped	Seal injection flow to a single RC pump stopped	Repair component if accessible
		2. Valve fails to prevent backflow	--	No effect since there are 2 check valves per line (one inside and one outside RB)	No effect since there are 2 check valves per line	Repair component at shutdown
4.4.4	Manual Isolation Valves On Line to RC Pump HP-394, HP-285	1. Valve fails closed	--	Flow in affected Seal Injection line stopped	Seal injection flow to a single RC pump stopped	Repair component if accessible
4.5	System Inlet Flows:					
4.5.1	Seal Injection Flow From HPI Pumps	1. Loss of flow	Subsystem 3.0	No flow	Loss of Seal Injection to RC pumps	None

Reference Drawings: FSAR Figure 9.3-2 (Sheets 1 and 4)

4.0 SUBSYSTEM: RC PUMPS SEAL INJECTION (Continued)

Component	Potential Failure Mode: Mode	Potential Failure Mode: Interface Involved	Immediate Effects: Within Subsystem	Immediate Effects: At Subsystem Interface	Remedial Action Within Subsystem
4.6 System Piping:					
4.6.1 Vents, Drains, Piping, Instrument Connections, etc.	1. System leaks	--	Loss of reactor coolant	Loss of reactor coolant, potential for slight reduction in seal injection rate if leak is downstream of flow control valve (HP-31)	Isolate leaks and repair as needed

APPENDIX E

FAILURE MODES AND EFFECTS ANALYSIS

SUBSYSTEM 5.0: REACTOR COOLANT MAKEUP

Reference Drawings: FSAR Figure 9.3-2 (Sheets 1 and 4)

5.0 SUBSYSTEM: REACTOR COOLANT (RC) MAKEUP

Component		Potential Failure Mode: Mode	Potential Failure Mode: Interface Involved	Immediate Effects: Within Subsystem	Immediate Effects: At Subsystem Interface	Remedial Action Within Subsystem
5.1 Reactor Inlet Line Loop A Header:						
5.1.1	Manual Isolation Valve HP-118 (HP-V27A)	1. Valve fails closed (plugging, damaged, etc.)	--	Makeup flow stopped	Loss of normal makeup flow	Repair component, if required provide makeup flow via Loop B injection path (open local HP-18 and throttle with remote HP-27)
5.1.2	Flow Transmitter 1FT-7, 7A and 7B	1. Transmitter failure due to internal fault	--	No effect	Incorrect flow signal on one transmitter	Repair component
		2. Incorrect output due to signal failure	I&C System, Electric Power Supply	No effect	Incorrect flow signal from all 3 transmitters	Restore power supply
		3. Instrument connection leak	--	Small loss of reactor coolant	Incorrect flow signals from all 3 transmitters	Repair component
5.1.3	Motor Operated Valve HP-26 (HP-V24A)	1. Valve opens on spurious signal	I&C System	Makeup flow is not throttled	Increased makeup flow, increased pressurizer level, drop in LST level, potential loss of HPI pump NPSH	Manually close valve (local action)
		2. Valve opens on spurious signal	ES	Makeup flow is not throttled	Increased makeup flow, increased pressurizer level, drop in LST level, potential loss of HPI pump NPSH	Manually close valve (local action)
		3. Valve inadvertantly opened	--	Makeup flow is not throttled	Increased makeup flow, increased pressurizer level, drop in LST level, potential loss of HPI pump NPSH	Close valve
		4. Valve fails open due to internal fault	--	Makeup flow is not throttled	Increased makeup flow, increased pressurizer level, drop in LST level, potential loss of HPI pump NPSH	Isolate with HP-118 (local action) (will stop makeup flow)
		(Modes involving failure to open are part of emergency HPI and not included here)				
5.2 Minimum Flow Bypass Loops:						
5.2.1	Manual Isolation Valve HP-234	1. Valve fails closed (plugging, damaged, etc.)	--	No flow through minimum flow loop	No cooling flow to pressurizer spray line or cold leg inlet nozzles, no effect on makeup capacity	Repair component

5.0 SUBSYSTEM: REACTOR COOLANT (RC) MAKEUP (Continued)

	Component	Potential Failure Mode: Mode	Potential Failure Mode: Interface Involved	Immediate Effects: Within Subsystem	Immediate Effects: At Subsystem Interface	Remedial Action Within Subsystem
5.2.2	Flow Transmitters 1FT-117, 1FT-118	1. Instrument connection leak	--	Small loss of coolant	Incorrect flow signal to control room	Repair component
		2. Incorrect output due to loss of power	Electric Power Supply, I&C System	No effect	Incorrect flow signal to control room	Restore power supply
		3. Transmitter failure due to internal fault	--	No effect	Incorrect flow signal to control room	Repair component
5.2.3	Manual Throttle Valve HP-241	1. Valve fails closed (plugging, damaged, etc.)	--	Minimum flow path blocked to one of two reactor cold leg inlet nozzles	No cooling flow to one cold leg inlet nozzle	Repair component
		2. Valve fails open	--	Minimum flow path unthrottled to one of two reactor cold leg inlet nozzles, automatic reduction in flow through normal makeup valve	Excess flow (full HPI pump discharge to minimum flow loop) to one reactor cold leg inlet nozzle, potential drop in LST level	If required valve HP-234 available to block flow into loop (local action), repair component
5.2.4	Manual Throttle Valve HP-235	1. Valve fails closed (plugging, damaged, etc.)	--	Minimum flow path blocked to pressurizer spray line and one of two reactor cold leg inlet nozzles	No effect on reactor makeup, but no cooling flow to pressurizer spray line or to one cold leg inlet nozzle	Repair component
		2. Valve fails open	--	Minimum flow path unthrottled to pressurizer spray line and one of two reactor cold legs, automatic reduction in flow through normal makeup valve	Excess flow to pressurizer spray line and to one reactor cold leg inlet nozzle, potential drop in LST level	Close valve HP-234, or valves HP-340 and HP-356 in reactor building (local action)
5.2.5	Manual Isolation Valve HP-340	1. Valve fails closed (plugging, damage, etc.)	--	Minimum flow path blocked to pressurizer spray line	No bypass flow to pressurizer spray line	Repair component
5.2.6	Manual Isolation Valve HP-356	1. Valve fails closed (plugging, damage, etc.)	--	Minimum flow path blocked to one of two reactor cold legs	No bypass cooling flow to one of two reactor cold leg inlet nozzles (no effect on normal makeup)	Repair component
5.3	Normal Makeup Flow Control Loop:					
5.3.1	Flow Transmitter 1FT-10, 10A, 10B	1. Instrument connection leak	--	Small loss of coolant	Incorrect flow signal from all transmitters	Monitor flow with FT-7, repair component
		2. Incorrect output due due to loss of power	Electric Power Supply, I&C System	No effect	Incorrect flow signal from all transmitters	Monitor flow with FT-7, restore powere supply
		3. Transmitter failure	--	None	Incorrect flow signal from failed transmitter	Monitor flow with FT-7, repair component

Reference Drawings: FSAR Figure 9.3-2 (Sheets 1 and 4)

5.0 SUBSYSTEM: REACTOR COOLANT (RC) MAKEUP (Continued)

	Component	Potential Failure Mode: Mode	Potential Failure Mode: Interface Involved	Immediate Effects: Within Subsystem	Immediate Effects: At Subsystem Interface	Remedial Action Within Subsystem
5.3.2	Flow Control Valve HP-120 (HP-V23)	1. Valve fails closed (assuming valve is air-to-open)	Instrument Air	Normal flow to reactor inlets stopped, flow through minimum flow loop continues	Bypass flow continues. Overall significant reduction in makeup flow	If required, manually control with bypass valve HP-26
		2. Valve fails closed due to internal fault	--	Normal flow to reactor inlets stopped, flow through minimum flow loop continues	Bypass flow continues. Overall significant reduction in makeup flow	If required, manually control with bypass valve HP-26
		3. Valve closes down due to incorrect control signal	I&C System	Normal flow to reactor inlets reduced, flow through minimum flow loop continues	Bypass flow continues. Overall significant reduction in makeup flow	If required, manually control with bypass valve HP-26
		4. Valve fails open due to internal fault	--	HPI flow not throttled. Excess makeup flow to RCS	Excess makeup flow to RCS, temporary decreased bypass flow to pressurizer spray line, potential drop in LST holdup, potential loss of NPSH to HPI pump	Isolate valve HP-120 and manually control flow with bypass valve HP-26
		5. Valve opens up due to incorrect control signal	I&C System	HPI flow not throttled. Excess makeup flow to RCS	Excess makeup flow to RCS, temporary decreased bypass flow to pressurizer spray line, potential drop in LST holdup, potential loss of NPSH to HPI pump	Isolate valve HP-120 and manually control flow with bypass valve HP-26
5.3.3	Manual Isolation Valves HP-119, HP-121	1. Valve fails closed (plugging, damage, etc.)	--	Normal makeup flow to RCS stopped, bypass flow through minimum flow loop continues	Bypass flow continues. Overall significant reduction in makeup flow	Isolate valve HP-120 and manually control flow with bypass valve HP-26
5.3.4	Check Valve HP-194	1. Valve fails closed (plugging, damage, etc.)	--	Normal makeup flow to RCS stopped, bypass flow through minimum flow loop continues	Bypass flow continues Overall significant reduction in makeup flow	If required, provide makeup flow via Loop B injection path (open local HP-118 and throttle with remote HP-27)
		2. Valve fails to prevent backflow	--	No effect during steady state operation	No effect during steady state operation	Repair component at shutdown
5.3.5	Inlet Line Orifices	1. Orifice plugged	--	Normal flow to one of two cold legs stopped or reduced, increased flow to the other cold leg	Flow imbalance between the two reactor cold legs	Repair component

Reference Drawings: FSAR Figure 9.3-2 (Sheets 1 and 4)

5.0 SUBSYSTEM: REACTOR COOLANT (RC) MAKEUP (Continued)

Component	Potential Failure Mode: Mode	Potential Failure Mode: Interface Involved	Immediate Effects: Within Subsystem	Immediate Effects: At Subsystem Interface	Remedial Action Within Subsystem
5.3.6 Inlet Line Check Valves HP-126, HP-127	1. Valve failed closed (plugging, damage, etc.)	--	Normal flow to one of two reactor cold legs stopped or reduced, increased flow to the other cold leg	Flow imbalance between the two reactor cold legs	Repair component
5.4 Subsystem Input:					
5.4.1 Flow From HPI Pumps	1. Loss of flow	Subsystem 3.0	Loss of makeup flow and flow to pressurizer spray line	Loss of makeup flow and bypass flow to pressurizer spray line	None
	2. Reduced flow	Subsystem 3.0	Reduced makeup flow and reduced flow to pressurizer spray line	Reduced makeup flow and bypass reduced flow to pressurizer spray line	None
5.5 System Piping:					
5.5.1 Vents, Drains, Piping, Instrument Connections, etc.	1. System leaks	--	Loss of reactor coolant	Loss of reactor coolant, potential for reduction in reactor coolant makeup rate	Isolate leaks and repair as needed

APPENDIX F

FAILURE MODES AND EFFECTS ANALYSIS

SUBSYSTEM 6.0: RC BLEED, BORON RECOVERY AND CHEMICAL ADDITION

Reference Drawings: FSAR Figure 9.3-1 (Sheet 1)
FSAR Figure 9.3-2 (Sheet 3)
FSAR Figure 9.3-5 (Sheets 1,3,&4)

6.0 SUBSYSTEM: RC BLEED, BORON RECOVERY, AND CHEMICAL ADDITION

	Component	Potential Failure Mode: Mode	Potential Failure Mode: Interface Involved	Immediate Effects: Within Subsystem	Immediate Effects: At Subsystem Interface	Remedial Action Within Subsystem
6.1	Chemical Addition:					
6.1.1	Manual Control Valve (N-83)	1. N_2 blanket system fails	N_2 Blanket	Possible N_2H_4 backflow; no N_2 blanket in N_2H_4 drum	No N_2H_4 available to makeup filters	Close control valve N-83
		2. Valve fails closed	--	No N_2 blanket in N_2H_4 drum; possible explosive mixture	Probably none	
6.1.2	Check Valve (N-84)	1. Fails to prevent backflow	--	N_2H_4 backflow; possible explosive mixture	No N_2H_4 available to makeup filters	Close control valve N-83
6.1.3	Hydrazine Drum	1. Drum leaks	--	Possible explosive mixture; eventual loss of suction pressure to pump	Eventual loss of N_2H_4 available to makeup filters	Isolate drum and replace
		2. Drum emptied	--	No N_2H_4	No N_2H_4 available to makeup filters	Isolate drum and replace
6.1.4	Manual Isolation Valves (CA-88, CA-45)	1. Valves fail closed	--	No N_2H_4	No N_2H_4 available to makeup filters	None
6.1.5	Manual Isolation Valves (CA-52, CA-54)	1. Valves fail closed	--	No N_2H_4	None if alternate flow path available	Open CA-46; crossover to pump CA-P3
6.1.6	Hydrazine Pump (CA-P4)	1. Electric power supply fails	Electric Power	Pump stops; no N_2H_4	None if alternate flow path available	Open CA-46; crossover to pump CA-P3
		2. Pump fails	--	No N_2H_4	None if alternate flow path available	Open CA-46; crossover to pump CA-P3
6.1.7	Check Valve (CA-56)	1. Fails to prevent backflow	--	Possible backflow to drum if pump is not running	No N_2H_4 available to makeup filters	Close CA-54
6.1.8	Manual Isolation Valve (DW-121)	1. Demineralized water supply fails	Demineralized Water	No demineralized water to tank	No LiOH available to makeup filters	None
		2. Valve fails closed	--	No demineralized water to tank	No LiOH or incorrect LiOH concentration available to makeup filters	Concentration checked via sampling
		3. Valve fails open	--	Dilutes LiOH in tank	Incorrect LiOH concentration available to makeup filters	Concentration checked via sampling
6.1.9	LiOH Mix Tank (CA-T3)	1. Tank leaks	-	Eventual loss of suction pressure to pump	Eventual loss of LiOH available to makeup filters	None
		2. Tank empties	-	No LiOH	No LiOH available to makeup filters	None
6.1.10	Sampling, Waste Lines	1. Lines fail open	--	Decreased LiOH	Decreased LiOH available to makeup filters	None

Reference Drawings: FSAR Figure 9.3-1 (Sheet 1)
FSAR Figure 9.3-2 (Sheet 3)
FSAR Figure 9.3-5 (Sheets 1,3,&4)

6.0 SUBSYSTEM: RC BLEED, BORON RECOVERY, AND CHEMICAL ADDITION

	Component	Potential Failure Mode: Mode	Potential Failure Mode: Interface Involved	Immediate Effects: Within Subsystem	Immediate Effects: At Subsystem Interface	Remedial Action Within Subsystem
6.1.11	Manual Isolation Valve (CA-44)	1. Valve fails closed	--	No LiOH	No LiOH available to makeup filters	None
6.1.12	Manual Isolation Valve (CA-47, CA-49)	1. Valves fail closed	--	No LiOH	None if alternate flow path available	Open CA-46; crossover to pump CA-P4
6.1.13	LiOH Pump (CA-P3)	1. Electric power supply fails	Electric Power	Pump stops; no LiOH	None if alternate flow path available	Open CA-46; crossover to pump CA-P4
		2. Pump fails	--	No LiOH	None if alternate flow path available	Open CA-46; crossover to pump CA-P4
6.1.14	Check Valve (CA-51)	1. Fails to prevent backflow	--	Possible backflow to tank if pump is not running	No LiOH available to makeup filters	Close CA-49
6.1.15	Manual Isolation Valve (DW-120)	1. Demineralized water supply fails	Demineralized Water	No demineralized water to tank; no caustic or incorrect caustic concentration available to boron recovery	No caustic or incorrect caustic concentration available to LPI pumps	Concentration checked via sampling
		2. Valve fails closed	--	No demineralized water to tank; no caustic or incorrect caustic concentration available to boron recovery	No caustic or incorrect caustic concentration available to LPI pumps	Concentration checked via sampling
		3. Valve fails open	--	Dilutes caustic in tank; incorrect caustic concentration available to boron recovery	Incorrect caustic concentration available to LPI pumps	Concentration checked via sampling
6.1.16	Caustic Mix Tank (CA-T1)	1. Tank leaks	--	Eventual loss of suction pressure to pump	Eventual loss of caustic available to LPI pumps	None
		2. Tank empties	--	No caustic available to boron recovery	No caustic available to LPI pumps	None
6.1.17	Manual Isolation Valves (CA-34, CA-35, CA-37)	1. Valves fail closed	--	No caustic available to boron recovery	No caustic available to LPI pumps	None
6.1.18	Caustic Pump (CA-P1)	1. Electric power supply fails	Electric Power	Pump stops; no caustic available to boron recovery	No caustic available to LPI pumps	None
		2. Pump fails	--	No caustic available to boron recovery	No caustic available to LPI pumps	None
6.1.19	Sampling, Waste Lines	1. Lines fail open	--	Decreased caustic available to boron recovery	Decreased caustic available to LPI pumps	None

Reference Drawings: FSAR Figure 9.3-1 (Sheet 1)
FSAR Figure 9.3-2 (Sheet 3)
FSAR Figure 9.3-5 (Sheets 1,3,&4)

6.0 SUBSYSTEM: RC BLEED, BORON RECOVERY, AND CHEMICAL ADDITION

	Component	Potential Failure Mode: Mode	Potential Failure Mode: Interface Involved	Immediate Effects: Within Subsystem	Immediate Effects: At Subsystem Interface	Remedial Action Within Subsystem
6.2	Boric Acid Addition:					
6.2.1	Manual Isolation Valve (DW-118)	1. Demineralized water supply fails	Demineralized Water	No demineralized water to tank; no boric acid or incorrect boric acid concentration available to concentrated boric acid storage tanks	None if concentrated boric acid available from boron recovery or adequate concentrated boric acid storage tank inventory is available	Concentration checked via sampling
		2. Valve fails closed	--	No demineralized water to tank; no boric acid or incorrect boric acid concentration available to concentrated boric acid storage tanks	None if concentrated boric acid available from boron recovery or adequate concentrated boric acid storage tank inventory is available	Concentration checked via sampling
		3. Valve fails open	--	Dilutes boric acid; incorrect boric acid concentration to concentrated boric acid storage tanks	None if concentrated boric acid available from boron recovery or adequate concentrated boric acid storage tank inventory is available	Concentration checked via sampling
6.2.2	Boric Acid Mix Tank (CA-T2)	1. Electric power supply fails	Electric Power	Heater fails; boric acid may crystallize; small potential for plugging and loss of flow to storage tanks	None if concentrated boric acid available from boron recovery or adequate concentrated boric acid storage tank inventory is available	Replace heater; unplug lines
		2. Heater fails	--	Boric acid may crystallize; small potential for plugging and loss of flow to storage tanks	None if concentrated boric acid available from boron recovery or adequate concentrated boric acid storage tank inventory is available	Replace heater; unplug lines
		3. Tank leaks	--	Eventual loss of suction pressure to pumps	None if concentrated boric acid available from boron recovery or adequate concentrated boric acid storage tank inventory is available	None
		4. Tank empties	--	No boric acid flow to concentrated boric acid storage tanks	None if concentrated boric acid available from boron recovery or adequate concentrated boric acid storage tank inventory is available	None
6.2.3	Level Transmitter	1. Electric power supply fails	Electric Power	No local level indication	No level indication to I&C system	None
		2. Connection leaks	Process Signal	Incorrect signal to transmitter	No level indication to I&C system	None
		3. Transmitter fails	--	No local level indication	No level indication to I&C system	None

Reference Drawings: FSAR Figure 9.3-1 (Sheet 1)
FSAR Figure 9.3-2 (Sheet 3)
FSAR Figure 9.3-5 (Sheets 1,3,&4)

6.0 SUBSYSTEM: RC BLEED, BORON RECOVERY, AND CHEMICAL ADDITION

	Component	Potential Failure Mode: Mode	Potential Failure Mode: Interface Involved	Immediate Effects: Within Subsystem	Immediate Effects: At Subsystem Interface	Remedial Action Within Subsystem
6.2.4	Temperature Transmitter	1. Electric power supply fails	Electric Power	No local temperature indication	None	None
		2. Connection leaks	Process Signal	Incorrect signal to transmitter	None	None
		3. Transmitter fails	--	No local temperature indication	None	None
6.2.5	Manual Isolation Valve (CA-4)	1. Valve fails closed	--	No boric acid to storage tanks	None if concentrated boric acid available from boron recovery or adequate concentrated boric acid storage tank inventory is available	None
6.2.6	Miscellaneous Piping	1. Electric power supply to trace heating fails	Electric Power	Boric acid may crystallize; small potential for plugging and loss of flow to concentrated boric acid storage tanks	None if concentrated boric acid available from boron recovery or adequate concentrated boric acid storage tank inventory is available	Restore trace heating; unplug lines
		2. Trace heating fails	--	Boric acid may crystallize; small potential for plugging and loss of flow to concentrated boric acid storage tanks	None if concentrated boric acid available from boron recovery or adequate concentrated boric acid storage tank inventory is available	Restore trace heating; unplug lines
6.2.7	Manual Isolation Valve (CA-5)	1. Valve fails closed	--	No boric acid to concentrated boric storage tanks; alternate flow path available	None	Alternate flow path through CA-P2B available
6.2.8	LP Boric Acid Pump (CA-P2A)	1. Electric power supply fails	Electric Power	Pump stops; no boric acid to concentrated storage tanks; alternate flow path available	None	Alternate flow path through CA-P2B available
		2. Pump fails	--	No boric acid to concentrated boric acid storage tanks; alternate flow path available	None	Alternate flow path through CA-P2B available
6.2.9	Manual Isolation Valve (CA-7)	1. Valve fails closed	--	No boric acid to concentrated boric acid storage tanks; alternate flow path available	None	Alternate flow path through CA-P2B available
6.2.10	Check Valve (CA-15)	1. Fails to prevent backflow	--	Possible backflow to mix tank if pump is not running; alternate flow path available	None	Close isolation valve CA-7; alternate flow path through CA-P2B available

Reference Drawings: FSAR Figure 9.3-1 (Sheet 1)
FSAR Figure 9.3-2 (Sheet 3)
FSAR Figure 9.3-5 (Sheets 1,3,4&)

6.0 SUBSYSTEM: RC BLEED, BORON RECOVERY, AND CHEMICAL ADDITION

	Component	Potential Failure Mode: Mode	Potential Failure Mode: Interface Involved	Immediate Effects: Within Subsystem	Immediate Effects: At Subsystem Interface	Remedial Action Within Subsystem
6.2.11	Manual Isolation Valves (1CA-16, 1CA-13, 1CA-1C, etc.)	1. Valves fail closed	--	No boric acid to concentrated boric acid storage tanks	None if concentrated boric acid available from boron recovery or adequate concentrated boric acid storage tank inventory is available	None
6.2.12	Pressure Transmitter	1. Electric power supply fails	Electric Power	No local pressure indication	No pressure indication to I&C system	None
		2. Connection leaks	Process Signal	Incorrect signal to transmitter	No pressure indication to I&C system	None
		3. Transmitter fails	--	No local pressure indication	No pressure indication to I&C system	None
6.2.13	Check Valve (CA-85)	1. Fails to prevent backflow	--	Possible backflow if pump is not running	None if concentrated boric acid available from concentrated boric acid transfer pumps	Close 1CA-16, 1CA-18
6.2.14	Manual Isolation Valve (CA-25)	1. Valve fails closed	--	No boric acid	No boric acid available to core flood tanks	None
6.2.15	HP Boric Acid Pump (CA-P5)	1. Electric power supply fails	Electric Power	Pump stops; no boric acid	No boric acid available to core flood tank	None
		2. Pump fails	--	No boric acid	No boric acid available to core flood tank	None
6.2.16	Manual Isolation Valves (1CA-26, 1CA-28)	1. Valves fail to open, fail closed	--	No boric acid	No boric acid available to core flood tank	None
6.2.17	Manual Control Valve (CS-62)	1. Valve fails closed	--	No boric acid to concentrated boric acid storage tanks	No boric acid available to makeup filters, BWST	Alternate flow path available
6.2.18	Concentrated Boric Acid Storage Tank (1WD-T22)	1. N_2 blanket system fails	N_2 Blanket	Possible boric acid backflow	None	Close control valve CS-62
		2. Electric power supply to trace heating fails	Electric Power	Boric acid crystallizes; potential plugging and loss of flow	No boric acid available to makeup filters, BWST	Alternate flow path available
		3. Trace heating fails	--	Boric acid crystallizes; potential plugging and loss of flow	No boric acid available to makeup filters, BWST	Alternate flow path available
		4. Inlet boric acid flow fails	Boric Acid From Mix Tank/RC Bleed Evaporator Concentrate Cooler	No boric acid	None unless concentrated boric acid storage tanks are empty	Alternate flow path available

Reference Drawings: FSAR Figure 9.3-1 (Sheet 1)
FSAR Figure 9.3-2 (Sheet 3)
FSAR Figure 9.3-5 (Sheets 1,3,&4)

6.0 SUBSYSTEM: RC BLEED, BORON RECOVERY, AND CHEMICAL ADDITION

	Component	Potential Failure Mode: Mode	Potential Failure Mode: Interface Involved	Immediate Effects: Within Subsystem	Immediate Effects: At Subsystem Interface	Remedial Action Within Subsystem
6.2.18	Concentrated Boric Acid Storage Tank (1WD-T22) (cont'd)	5. Tank leaks	--	Possible flooding; eventual loss of suction pressure to pump	Eventual loss of boric acid available to makeup filters, BWST	Alternate flow path available
		6. Tank empties	--	No boric acid	No boric acid available to makeup filters, BWST	Alternate flow path available
		7. Tank vent, relief valves fail open	--	Cover gas release to vent header	None	None
		8. Drain, sample lines fail open	--	Decreased boric acid	Decreased boric acid available to makeup filters, BWST	Alternate flow path available
6.2.19	Level Transmitter	1. Electric power supply	Electric Power	No local level indication	No level indication to I&C system	None
		2. Connection leaks	Process Signal	Incorrect signal to transmitter	No level indication to I&C system	None
		3. Transmitter fails	--	No local level indication	No level indication to I&C system	None
6.2.20	Manual Isolation, Control Valves (CS-63, CS-64, CS-67)	1. Valves fail closed	--	No boric acid	No boric acid available to makeup filters, BWST	Alternate flow path available
6.2.21	Concentrated Boric Acid Transfer Pump (1WD-P22)	1. Electric power supply fails	Electric Power	Pump stops; no boric acid	No boric acid available to makeup filters, BWST	Alternate flow path available
		2. Pump fails	--	No boric acid	No boric acid available to makeup filters, BWST	Alternate flow path available
6.2.22	Manual Isolation Valve (CS-68)	1. Valve fails closed	--	No boric acid	No boric acid available to makeup filters, BWST	Alternate flow path available
6.2.23	Manual Isolation Valves (CS-72, CS-79)	1. Valves fail closed	--	No boric acid	No boric acid available to available to makeup filters, BWST	Alternate flow path available
6.2.24	Check Valve (CS-73)	1. Fails to prevent backflow	--	Possible backflow if pump is not running	None if concentrated boric acid available from LP boric acid pump	Close CS-72
6.3	RC Bleed Holdup Tanks and Transfer Pumps:					
6.3.1	Manual Control Valve (CS-41)	1. RC Bleed flow fails	RC Bleed Flow	RC bleed holdup tank could empty; no impact since rest of subsystem operates only on demand	None if alternate flow path available	Alternate bleed flow available
		2. Valve fails closed	--	RC bleed holdup tank could empty; no impact since rest of subsystem operates only on demand	None if alternate flow path available	Bleed flow can be diverted to 2WD-T21A

Reference Drawings: FSAR Figure 9.3-1 (Sheet 1)
FSAR Figure 9.3-2 (Sheet 3)
FSAR Figure 9.3-5 (Sheets 1,3,44)

6.0 SUBSYSTEM: RC BLEED, BORON RECOVERY, AND CHEMICAL ADDITION

	Component	Potential Failure Mode: Mode	Potential Failure Mode: Interface Involved	Immediate Effects: Within Subsystem	Immediate Effects: At Subsystem Interface	Remedial Action Within Subsystem
6.3.2	RC Bleed Holdup Tank (1WD-T21A)	1. N_2 blanket system fails	N_2 Blanket	Tank cannot be purged; no impact since rest of subsystem operates only on demand	None if alternate flow path available	None
		2. Tank leaks	--	Possible flooding; eventual loss of suction pressure to pump; no impact since rest of subsystem operates only on demand	None if alternate flow path available	Alternate bleed flow available
		3. Tank empties	--	No flow; no impact since rest of subsystem operates only on demand	None if alternate flow path available	Alternate bleed flow available
		4. Tank vent, relief valves fail open	--	Cover gas release to vent header	None	None
6.3.3	Level Transmitter	1. Electric power supply fails	Electric Power	No local level indication	No level indication to I&C system	None
		2. Connection leak	Process Signal	Incorrect signal to transmitter	No level indication to I&C system	None
		3. Transmitter failure	--	No local level indication	No level indication to I&C system	None
6.3.4	Miscellaneous Piping	1. Electric power supply to trace heating fails	Electric Power	Boric acid may crystallize; small potential for plugging and loss of flow; no impact since rest of subsystem operates only on demand	None if alternate flow path available	Restore trace heating; unplug lines; alternate bleed flow available
		2. Trace heating fails	--	Boric acid may crystallize; small potential for plugging and loss of flow; no impact since rest of subsystem operates only on demand	None if alternate flow path available	Restore trace heating; unplug lines; alternate bleed flow available
6.3.5	Waste, Drain, Sample Lines	1. Lines fail open	--	Decreased flow; no impact since rest of subsystem operates only on demand	None if alternate flow path available	Alternate bleed flow available
6.3.6	Manual Isolation Valves (CS-42, CS-148, CS-44)	1. Valves fail closed	--	No flow to pump; no impact since rest of subsystem operates only on demand	None if alternate flow path available	Alternate bleed flow available
6.3.7	RC Bleed Transfer Pump (1WD-P21A)	1. Electric power supply fails	Electric Power	Pump stops; no flow to boron recovery	None if alternate flow path available	Alternate bleed flow available
		2. Pump fails	--	No flow to boron recovery	None if alternate flow path available	Alternate bleed flow available
6.3.8	Check Valve (CS-45)	1. Fails to prevent backflow	--	Possible backflow if pump is not running	None if alternate flow path available	Close control valve CS-46

Reference Drawings: FSAR Figure 9.3-1 (Sheet 1)
FSAR Figure 9.3-2 (Sheet 3)
FSAR Figure 9.3-5 (Sheets 1,3,4)

6.0 SUBSYSTEM: RC BLEED, BORON RECOVERY, AND CHEMICAL ADDITION

	Component	Potential Failure Mode: Mode	Potential Failure Mode: Interface Involved	Immediate Effects: Within Subsystem	Immediate Effects: At Subsystem Interface	Remedial Action Within Subsystem
6.3.9	Flow Orifice	1. Orifice plugs	--	No flow to boron recovery	None if alternate flow path available	Alternate bleed flow available
6.3.10	Flow Transmitter	1. Electric power supply fails	Electric Power	No local flow indication	No flow indication to I&C system	None
		2. Connection leak	Process Signal	Incorrect signal to transmitter	No flow indication to I&C system	None
		3. Transmitter failure	--	No local flow indication	No flow indication to I&C system	None
6.3.11	Manual Control Valve (CS-46)	1. Valve fails closed	--	No flow to boron recovery	None if alternate flow path available	Alternate bleed flow available
6.3.12	Manual Isolation Valves (CS-80, CS-172, CT-1)	1. Valves fail closed	--	No flow to boron recovery	None if alternate flow path available	Alternate bleed flow available
6.3.13	Manual Isolation Valve (CT-88)	1. Demineralized water supply fails	Demineralized Water	Demineralized water holdup tank could empty	No demineralized water to makeup filters	Alternate demineralized water flow path available
		2. Valve fails closed	--	Demineralized water holdup tank could empty	No demineralized water to makeup filters	Alternate demineralized water flow path available
6.3.14	RC Demineralized Water Holdup Tank (1WD-T21B)	1. N_2 blanket system fails	N_2 Blanket	Tank cannot be purged and is unavailable	No demineralized water to makeup filters	Alternate demineralized water flow path available
		2. Tank leaks	--	Possible flooding; eventual loss of suction pressure to pump	Eventual loss of demineralized water to makeup filters	Alternate demineralized water flow path available
		3. Tank empties	--	No demineralized water	No demineralized water to makeup filters	Alternate demineralized water flow path available
		4. Tank vent, relief valves fail open	--	Cover gas release to vent header	None	None
6.3.15	Level Transmitter	1. Electric power supply fails	Electric Power	No local level indication	No level indication to I&C system	None
		2. Connection leak	Process Signal	Incorrect signal to transmitter	No level indication to I&C system	None
		3. Transmitter failure	--	No local level indication	No level indication to I&C system	None
6.3.16	Waste, Drain, Sample Lines	1. Lines fail open	--	Decreased demineralized water	Decreased demineralized water to makeup filters	Alternate demineralized water flow path available

Reference Drawings: FSAR Figure 9.3-1 (Sheet 1)
FSAR Figure 9.3-2 (Sheet 3)
FSAR Figure 9.3-5 (Sheets 1,3,44)

6.0 SUBSYSTEM: RC BLEED, BORON RECOVERY, AND CHEMICAL ADDITION

		Potential Failure Mode		Immediate Effects		
	Component	Mode	Interface Involved	Within Subsystem	At Subsystem Interface	Remedial Action Within Subsystem
6.3.17	Miscellaneous Piping	1. Electric power supply to trace heating fails	Electric Power	Boric acid may crystallize; small potential for plugging and loss of flow	No demineralized water to makeup filters	Restore trace heating; unplug lines; alternate demineralized water flow path available
		2. Trace heating fails	--	Boric acid may crystallize; small potential for plugging and loss of flow	No demineralized water to makeup filters	Restore trace heating; unplug lines; alternate demineralized water flow path available
6.3.18	Manual Isolation Valves (CS-52, CS-149, CS-54)	1. Valves fail closed	--	No demineralized water to pump	No demineralized water to makeup filters	ternate demineralized water flow path available
6.3.19	RC Bleed Transfer Pump (1WD-P21B)	1. Electric power supply fails	Electric Power	Pump stops; no demineralized water	No demineralized water to makeup filters	Alternate demineralized water flow path available
		2. Pump fails	--	No demineralized water	No demineralized water to makeup filters	Alternate demineralized water flow path available
6.3.20	Flow Orifice	1. Orifice plugs	--	Decreased demineralized water	Decreased demineralized water to makeup filters	Alternate demineralized water flow path available
6.3.21	Manual Control Valve (CS-56)	1. Valve fails closed	--	No demineralized water	No demineralized water to makeup filters	Alternate demineralized water flow path available
6.3.22	Flow Transmitter	1. Electric power supply fails	Electric Power	No local flow indication	No flow indication to I&C system	None
		2. Connection leak	Process Signal	Incorrect signal to transmitter	No flow indication to I&C system	None
		3. Transmitter failure	--	No local flow indication	No flow indication to I&C system	None
6.3.23	Check Valve (CS-55)	1. Fails to prevent backflow	--	Possible backflow if pump is not running	No demineralized water to makeup filters	Close control valve CS-56

Reference Drawings: FSAR Figure 9.3-1 (Sheet 1)
FSAR Figure 9.3-2 (Sheet 3)
FSAR Figure 9.3-5 (Sheets 1,3,44)

6.0 SUBSYSTEM: RC BLEED, BORON RECOVERY, AND CHEMICAL ADDITION

		Potential Failure Mode		Immediate Effects		
	Component	Mode	Interface Involved	Within Subsystem	At Subsystem Interface	Remedial Action Within Subsystem
6.3.24	Manual Isolation Valves (CS-83, CS-85, CS-100)	1. Valves fail closed	--	No demineralized water	No demineralized water to makeup filters	Alternate demineralized water flow available
6.3.25	Check Valve (CS-86)	1. Fails to prevent backflow	--	Possible backflow if pump is not running	No demineralized water to makeup filters	Close CS-85
6.3.26	Control Valve (HP-15)	1. Control signal fails to open valve	Control Signal From Flow Orifice	Loss of flow to makeup filters	No demineralized water to makeup filters	None
		2. Control signal fails to close valve	Control Signal From Flow Orifice	Loss of flow control to makeup filters	Increase in demineralized water to makeup filters	Close manual isolation valves; close HP-136
		3. Instrument air supply fails	Instrument Air	Loss of flow to makeup filters	No demineralized water to makeup filters	None
		4. Electric power supply fails	Electric Power	Loss of flow to makeup filters	No demineralized water to makeup filters	None
		5. Spurious signal to open valve	Control Signal From Flow Orifice	Loss of flow control to makeup filters	Increase in demineralized water to makeup filters	Close manual isolation valves; close HP-136
		6. Spurious signal to close valve	Control Signal From Flow Orifice	Loss of flow to makeup filters	No demineralized water to makeup filters	None
		7. Internal valve failure	--	Loss of flow to makeup filters	No demineralized water to makeup filters	None
6.3.27	Manual Isolation Valves (HP-191, HP-192)	1. Valves fail closed	--	No flow to flow orifice	No demineralized water to makeup filters	None
6.3.28	Manual Isolation Valves (HP-52, HP-53)	1. Valves fail closed	--	No flow to flow orifice; potential control signal failure	No demineralized water to makeup filters; alternate flow path available	Open HP-54
6.3.29	Manual Isolation Valve (HP-54)	1. Valve fails open	--	No flow to flow orifice; potential control signal failure	Loss of control of demineralized water to makeup filters	Close HP-136 if HP-15 should be closed
6.3.30	Flow Orifice	1. Orifice plugs	--	No flow; potential control signal failure	No demineralized water to makeup filters; alternate flow path available	Open HP-54
6.3.31	Flow Transmitter	1. Electric power supply fails	Electric Power	Incorrect signal to flow control valve (see 6.3.26)	No flow indication in I&C system	None
		2. Connection leaks	Process Signal	Incorrect signal to transmitter	No flow indication in I&C system	None

Reference Drawings: FSAR Figure 9.3-1 (Sheet 1)
FSAR Figure 9.3-2 (Sheet 3)
FSAR Figure 9.3-5 (Sheets 1,3,44)

6.0 SUBSYSTEM: RC BLEED, BORON RECOVERY, AND CHEMICAL ADDITION

	Component	Potential Failure Mode: Mode	Potential Failure Mode: Interface Involved	Immediate Effects: Within Subsystem	Immediate Effects: At Subsystem Interface	Remedial Action Within Subsystem
6.3.31	Flow Transmitter (cont'd)	3. Transmitter fails	--	Incorrect signal to flow control valve (see 6.3.26)	No flow indication in I&C system	None
6.3.32	Control Valve (HP-16)	1. Control signal fails to open valve	Control Signal From 3-Way Valve	Loss of flow to makeup filters	No demineralized water to makeup filters	None
		2. Control signal fails to close valve	Control Signal From 3-Way Valve	Loss of flow control to makeup filters	Increase in demineralized water to makeup filters	Close manual isolation valves; close HP-192
		3. Instrument air supply fails	Instrument Air	Loss of flow to makeup filters	No demineralized water to makeup filters	None
		4. Electric power supply fails	Electric Power	Loss of flow to makeup filters	No demineralized water to makeup filters	None
		5. Spurious signal to open valve	Control Signal From 3-Way Valve	Loss of flow control to makeup filters	Increase in demineralized water to makeup filters	Close manual isolation valves; close HP-192
		6. Spurious signal to close valve	Control Signal From 3-Way Valve	Loss of flow to makeup filters	No demineralized water to makeup filters	None
		7. Internal valve failure	--	Loss of flow to makeup filters	No demineralized water to makeup filters	None
6.4	Boron Recovery:					
6.4.1	Manual Isolation Valves (CT-3, CT-5)	1. RC bleed flow fails	RC Bleed Flow From Holdup Tank	No flow to feed tank. Tank has 8-hour capacity; boron recovery will continue until tank is empty	None if feed tank is full	Alternate flow path available
		2. Valves fail closed	--	No flow to demineralizer; no effect since second demineralizer available	None if alternate flow path available	Alternate flow path available
6.4.2	RC Bleed Evaporator Demineralizer	1. Resin fill fails	Resin Fill	No demineralizing capacity; no effect since second demineralizer available	None if alternate flow path available	Alternate flow path available
		2. Tank leaks	--	Decreased flow; no effect since second demineralizer available	None if alternate flow path available	Alternate flow path available
		3. Tank vent fails open	--	Decreased flow; no effect since second demineralizer available	None if alternate flow path available	Alternate flow path available
6.4.3	Manual Isolation Valves (CT-4, CT-6)	1. Valves fail closed	--	No flow; no effect since second demineralizer available	None if alternate flow path available	Alternate flow path available
6.4.4	Manual Isolation Valve (CT-14)	1. Valve fails closed	--	No flow to feed tank. Tank has 8-hour capacity; boron recovery will continue until tank is empty	None if feed tank is full	Establish recirculation flow from evaporator

Reference Drawings: FSAR Figure 9.3-1 (Sheet 1)
FSAR Figure 9.3-2 (Sheet 3)
FSAR Figure 9.3-5 (Sheets 1,3,&4)

6.0 SUBSYSTEM: RC BLEED, BORON RECOVERY, AND CHEMICAL ADDITION

	Component	Potential Failure Mode: Mode	Potential Failure Mode: Interface Involved	Immediate Effects: Within Subsystem	Immediate Effects: At Subsystem Interface	Remedial Action Within Subsystem
6.4.5	Miscellaneous Piping	1. Electric power supply fails	Electric Power	Boric acid may crystallize; small potential for plugging and loss of flow	None unless concentrated boric acid storage tanks are empty	Restore trace heating; unplug lines
		2. Trace heating fails	--	Boric acid may crystallize; small potential for plugging and loss of flow	None unless concentrated boric acid storage tanks are empty	Restore trace heating; unplug lines
6.4.6	Manual Isolation Valves (CT-16, CT-19, CA-88, CT-49, CT-36)	1. Evaporator demineralizer flow fails; CT-16 fails closed	Evaporator Demineralizer Flow	No flow to feed tank. Tank has 8-hour capacity; boron recovery will continue until tank is empty	None if feed tank is full	Establish recirculation flow from evaporator
		2. Caustic flow fails; CA-88 fails closed	Caustic Flow	Chemical imbalance in boron recovery system.	Chemical imbalance in boric acid to makeup filters, BWST	None
		3. Distillate flow fails; CT-49 fails closed	Distillate Cooler Flow	No flow to feed tank. Tank has 8-hour capacity; boron recovery will continue until tank is empty	None if feed tank is full	Establish recirculation flow from evaporator
		4. Concentrate flow back to feed tank; CT-36 fails open	Concentrate Flow	Concentrated boric acid returned to feed tank; no boron recovery	None unless concentrated boric acid storage tanks are empty	Close CT-38 to force concentrate flow to concentrate cooler
		5. Valve CT-19 fails closed	--	No flow to feed tank. Tank has 8-hour capacity; boron recovery will continue until tank is empty	None if feed tank is full	Establish recirculation flow from evaporator
6.4.7	Check Valves (CT-18, CT-37, CT-17)	1. Fail to prevent backflow	--	Possible backflow to concentrate pump, evaporator demineralizer	None unless concentrated boric acid storage tanks are empty	Close isolation valves CT-16 and CT-19
6.4.8	RC Bleed Evaporator Feed Tank (WD-T42)	1. Tank leaks	--	Decreased flow; eventual loss of suction pressure to pump. Tank has 8-hour, capacity; boron recovery will continue until tank is empty	None if feed tank is full	None
		2. Tank empties	--	No flow. Boron recovery stops until tank refilled	None unless concentrated boric acid storage tanks are empty	None
		3. Tank vent, relief valves fail open	--	Decreased flow. Tank has 8-hour capacity; boron recovery will continue until tank is empty	None if feed tank is full	None
6.4.9	Level Transmitter	1. Electric power supply fails	Electric Power	No local level indication	None	None
		2. Connection leak	Process Signal	Incorrect signal to transmitter	None	None
		3. Transmitter failure	--	No local level indication	None	None

Reference Drawings: FSAR Figure 9.3-1 (Sheet 1)
FSAR Figure 9.3-2 (Sheet 3)
FSAR Figure 9.3-5 (Sheets 1,3,&4)

6.0 SUBSYSTEM: RC BLEED, BORON RECOVERY, AND CHEMICAL ADDITION

	Component	Potential Failure Mode: Mode	Potential Failure Mode: Interface Involved	Immediate Effects: Within Subsystem	Immediate Effects: At Subsystem Interface	Remedial Action Within Subsystem
6.4.10	Manual Isolation Valves (CT-22, CT-23)	1. Valves fail closed	--	No flow to evaporator feed pump. Recirculation flow path can be established through evaporator but boron recovery stops	None unless concentrated boric acid storage tanks are empty	Establish recirculation flow from evaporator
6.4.11	RC Bleed Evaporator Feed Pump (WD-P46)	1. Electric power supply fails	Electric Power	Pump stops; no flow to evaporator. Recirculation flow path can be established through evaporator but boron recovery stops	None unless concentrated boric acid storage tanks are empty	Establish recirculation flow from evaporator
		2. Pump fails	--	No flow to evaporator. Recirculation flow path can be established through evaporator but boron recovery stops	None unless concentrated boric acid storage tanks are empty	Establish recirculation flow from evaporoator
6.4.12	Pressure Transmitter Fails	1. Electric power supply fails	Electric Power	No local pressure indication	None	None
		2. Connection leak	Process Signal	Incorrect signal to transmitter	None	None
		3. Transmitter fails	--	No local pressure indication	None	None
6.4.13	Manual Isolation Valve (CT-24)	1. Valve fails closed	--	No flow to evaporator. Recirculation flow path can be established through evaporator but boron recovery stops	None unless concentrated boric acid storage tanks are empty	Establish recirculation flow from evaporator
6.4.14	Control Valve (CT-24)	1. Control signal fails to open/ valve close	Control Signal From Evaporator Level	Loss of flow control to evaporator. Could flood evaporator or allow dryout. Recirculation flow paths to feed tank or evaporator can be established. Boron recovery stops	None unless concentrated boric acid storage tanks are empty	Establish recirculation flow to feed tank or evaporator
		2. Instrument air supply fails	Instrument Air	Loss of flow control to evaporator. Could flood evaporator or allow dryout. Recirculation flow paths to feed tank or evaporator can be established. Boron recovery stops	None unless concentrated boric acid storage tanks are empty	Establish recirculation flow to feed tank or evaporator

Reference Drawings: FSAR Figure 9.3-1 (Sheet 1)
FSAR Figure 9.3-2 (Sheet 3)
FSAR Figure 9.3-5 (Sheets 1,3,&4)

6.0 SUBSYSTEM: RC BLEED, BORON RECOVERY, AND CHEMICAL ADDITION

	Component	Potential Failure Mode		Immediate Effects		
		Mode	Interface Involved	Within Subsystem	At Subsystem Interface	Remedial Action Within Subsystem
6.4.14	Control Valve (CT-24) (cont'd)	3. Spurious signal to open/valve close	Control Signal From Evaporator Level	Loss of flow control to evaporator. Could flood evaporator or allow dryout. Recirculation flow paths to feed tank or evaporator can be established. Boron recovery stops	None unless concentrated boric acid storage tanks are empty	Establish recirculation flow to feed tank or evaporator
		4. Internal valve failure	--	Loss of flow control to evaporator. Could flood evaporator or allow dryout. Recirculation flow paths to feed tank or evaporator can be established. Boron recovery stops	None unless concentrated boric acid storage tanks are empty	Establish recirculation flow to feed tank or evaporator
6.4.15	Check Valve (CT-29)	1. Fails to prevent backflow	--	Possible backflow if pump is not running	None unless concentrated boric acid storage tanks are empty	Close control valve CT-28
6.4.16	Waste, Drain, Sample Lines	1. Lines fail open	--	Decreased flow to evaporator. Recirculation flow path can be established through evaporator but boron recovery stops	None unless concentration boric acid storage tanks are empty	Establish recirculation flow to evaporator if required
6.4.17	RC Bleed Evaporator (WD-EV1)	1. N_2 blanket system fails	N_2 Blanket	Possible explosive mixture forms	None	None
		2. Steam supply fails	Steam	Evaporator floods. No boron recovery	None unless concentrated boric acid storage tanks are empty	Establish recirculation path to feed tank
		3. Blocked tubes	--	Decreased heat transfer; decrease in boron recovery	None unless concentrated boric acid storage tanks are empty	Establish recirculation path to feed tank
		4. Tube rupture	--	Steam released to evaporator vapor space; decrease in boron recovery	None unless concentrated boric acid storage tanks are empty	Establish recirculation path to feed tank
		5. Loss of heat transfer capability	--	Evaporator floods. No boron recovery	None unless concentrated boric acid storage tanks are empty	Establish recirculation path to feed tank
		6. Electric power supply fails	Electric Power	Concentrate heater fails; potential plugging and loss of flow	None unless concentrated boric acid storage tanks are empty	Restore heater; unplug lines

Reference Drawings: FSAR Figure 9.3-1 (Sheet 1)
FSAR Figure 9.3-2 (Sheet 3)
FSAR Figure 9.3-5 (Sheets 1,3,&4)

6.0 SUBSYSTEM: RC BLEED, BORON RECOVERY, AND CHEMICAL ADDITION

Component	Potential Failure Mode: Mode	Potential Failure Mode: Interface Involved	Immediate Effects: Within Subsystem	Immediate Effects: At Subsystem Interface	Remedial Action Within Subsystem
6.4.17 RC Bleed Evaporator (WD-EV1) (cont'd)	7. Inlet flow from feed pump fails	--	No boron recovery	None unless concentrated boric acid storage tanks are empty	Establish recirculation flow path until feed flow restored
	8. Evaporator leaks	--	Eventual loss of suction pressure to pump	None unless concentrated boric acid storage tanks are empty	None
	9. Evaporator empties	--	Possible damage to evaporator; no boron recovery	None unless concentrated boric acid storage tanks are empty	Shut off steam flow
	10. Evaporator vent, relief valves fail open	--	Cover gas release to vent header	None	None
6.4.18 Evaporator Level Transmitter	1. Electric power supply fails	Electric Power	Incorrect signal to evaporator feed pump discharge flow control valve (see 6.4.14)	None unless concentrated boric acid storage tanks are empty	None
	2. Connection leaks	Process Signal	Incorrect signal to evaporator feed pump discharge flow control valve (see 6.4.14)	None unless concentrated boric acid storage tanks are empty	None
	3. Transmitter fails	--	Incorrect signal to evaporator feed pump discharge flow control valve (see 6.4.14)	None unless concentrated boric acid storage tanks are empty	None
6.4.19 Temperature Transmitter	1. Electric power supply fails	Electric Power	Incorrect signal to transmitter and concentrate cooler discharge flow control (see 6.4.26)	See 6.4.26	None
	2. Connection leaks	Process Signal	Incorrect signal to transmitter and concentrate cooler discharge flow control (see 6.4.26)	See 6.4.26	None
	3. Transmitter failure	--	Incorrect signal to transmitter and concentrate cooler discharge flow control (see 6.4.26); no local temperature indication	See 6.4.26	None
6.4.20 Distillate Cooler (WD-C9)	1. Cooling water supply fails	Cooling Water	High temperature distillate returned to feed tank	None	Establish recirculation path to feed tank
	2. Blocked tube	--	Decreased heat transfer; high temperature distillate returned to feed tank	None	Establish recirculation path to feed tank

Reference Drawings: FSAR Figure 9.3-1 (Sheet 1)
FSAR Figure 9.3-2 (Sheet 3)
FSAR Figure 9.3-5 (Sheets 1,3,44)

6.0 SUBSYSTEM: RC BLEED, BORON RECOVERY, AND CHEMICAL ADDITION

Component	Potential Failure Mode: Mode	Potential Failure Mode: Interface Involved	Immediate Effects: Within Subsystem	Immediate Effects: At Subsystem Interface	Remedial Action Within Subsystem
6.4.20 Distillate Cooler (WD-C9) (cont'd)	3. Tube rupture	--	Cooling water released to distillate; dilutes feed tank concentration	None	Establish recirculation path to feed tank
	4. Loss of heat transfer capability	--	Decreased heat transfer; high temperature distillate returned to feed tank	None	Establish recirculation path to feed tank
	5. Cooler leaks	--	Decreased distillate flow	Decreased distillate available to condensate test tanks (demineralized water)	Establish recirculation path to feed tank
	6. Inlet flow fails	Evaporator Distillate	No distillate flow	No distillate available to condensate test tanks (demineralized water)	None
6.4.21 Concentrate (Recirc.) Pump (WD-P4)	1. Electric power supply fails	Electric Power	Pump stops; no concentrate flow	None unless concentrated boric acid storage tanks are empty	None
	2. Pump fails	--	No concentrate flow	None unless concentrated boric acid storage tanks are empty	None
6.4.22 Check Valve (CT-35)	1. Fails to prevent backflow	--	Possible backflow if pump is not running	None unless concentrated boric acid storage tanks are empty	Close CT-38, CT-40
6.4.23 Pressure Transmitter	1. Electric power supply fails	Electric Power	No local pressure indication	None	None
	2. Connection leaks	Process Signal	Incorrect signal to transmitter	None	None
	3. Transmitter fails	--	No local pressure indication	None	None
6.4.24 Manual Isolation Valve (CT-38)	1. Valve fails open	--	Concentrate flow recirculated to evaporator. No boron recovery; possible evaporator flooding	None unless concentrated boric acid storage tanks are empty	Open CT-40 to divert flow through concentrate cooler
	2. Valve fails closed	--	Possible flooding of concentrate cooler; loss of temperature control in evaporator	None	Flow can be diverted through CT-36 back to feed tank
6.4.25 Concentrate Cooler (WD-7)	1. Cooling water supply fails	Cooling Water	High temperature boric acid returned to concentrated boric acid storage tanks	None	Close control valve CT-40
	2. Blocked tube	--	Decreased heat transfer; high temperature boric acid returned to concentrated boric acid storage tanks	None	Close control valve CT-40

Reference Drawings: FSAR Figure 9.3-1 (Sheet 1)
FSAR Figure 9.3-2 (Sheet 3)
FSAR Figure 9.3-5 (Sheets 1,3,&4)

6.0 SUBSYSTEM: RC BLEED, BORON RECOVERY, AND CHEMICAL ADDITION

Component		Potential Failure Mode: Mode	Potential Failure Mode: Interface Involved	Immediate Effects: Within Subsystem	Immediate Effects: At Subsystem Interface	Remedial Action Within Subsystem
6.4.25	Concentrate Cooler (WD-7) (cont'd)	3. Tube rupture	--	Cooling water released to concentrate; dilutes boric acid concentration	None	Concentration can be adjusted from boric acid mix tank
		4. Loss of heat transfer capability	--	High temperature boric acid returned to concentrated boric acid storage tanks	None	Close control valve CT-40
		5. Cooler leaks	--	Decreased concentrate flow	None unless concentrated boric acid storage tanks are empty	None
		6. Inlet flow fails	Evaporator Concentrate	No concentrate flow	None unless concentrated boric acid storage tanks are empty	Close control valve CT-40
		7. Cooling water control valve fails	Control Signal From Concentrate Cooler Discharge Temperature	No concentrate flow	None unless concentrated boric acid storage tanks are empty	Close control valve CT-40
6.4.26	Temperature Transmitter	1. Electric power supply fails	Electric Power	No signal to cooling water control valve	No signal to cooling water control valve; see 6.4.24	See 6.4.24
		2. Connection leaks	Process Signal	No signal to transmitter	No signal to cooling water control valve; see 6.4.24	See 6.4.24
		3. Transmitter fails	--	No signal to cooling water control valve	No signal to cooling water control valve; see 6.4.24	See 6.4.24
6.4.27	Control Valve (CT-40)	1. Instrument air supply fails	Instrument Air	Loss of concentrate flow control	None unless concentrated boric acid storage tanks are empty	Close cooling water control valve; divert concentrate flow back to evaporator through CT-38 or to feed tank through CT-36
		2. Control signal fails to open/close valve	Control Signal From Evaporator Temperature Transmitter	Loss of concentrate flow control	None unless concentrated boric acid storage tanks are empty	Close cooling water control valve; divert concentrate flow back to evaporator through CT-38 or to feed tank through CT-36

Reference Drawings: FSAR Figure 9.3-1 (Sheet 1)
FSAR Figure 9.3-2 (Sheet 3)
FSAR Figure 9.3-5 (Sheets 1,3,44)

6.0 SUBSYSTEM: RC BLEED, BORON RECOVERY, AND CHEMICAL ADDITION

	Component	Potential Failure Mode: Mode	Potential Failure Mode: Interface Involved	Immediate Effects: Within Subsystem	Immediate Effects: At Subsystem Interface	Remedial Action Within Subsystem
6.4.27	Control Valve (CT-40) (cont'd)	3. Spurious signal to open/close valve	Control Signal From Evaporator Temperature Transmitter	Loss of concentrate flow control	None unless concentrated boric acid storage tanks are empty	Close cooling water control valve; divert concentrate flow back to evaporator through CT-38 or to feed tank through CT-36
		4. Internal valve failure	--	Loss of concentrate flow control	None unless boric acid storage tanks are empty	Close cooling water control valve; divert concentrate flow back to evaporator through CT-38 or to feed tank through CT-36
6.5	Deborating Demineralizer:					
6.5.1	Manual Control Valve	1. RC Bleed flow fails	RC Bleed Flow	No flow to deborating demineralizer	No flow to makeup filters	None
		2. Valve fails closed	--	No flow to deborating demineralizer	None if alternate flow path available	Alternate flow path available
6.5.2	Manual Isolation Valve	1. Valve fails closed	--	No flow to deborating demineralizer	None if alternate flow path available	Alternate flow path available
6.5.3	Deborating Demineralizer	1. Tank leaks	--	Decreased bleed flow	None if alternate flow path available	Alternate flow path available
		2. Tank empties	--	No bleed flow	None if alternate flow path available	Alternate flow path available
		3. Tank vent, relief valves fail open	--	Decreased bleed flow	None if alternate flow path available	Alternate flow path available
		4. Resin saturates	--	No boron removal from bleed flow	None if alternate flow path available	Alternate flow path available
		5. Caustic flow fails	Caustic	No demineralizer regeneration	None if alternate flow path available	Alternate flow path available
6.5.4	Miscellaneous Piping	1. Electric power supply to trace heating fails	Electric Power	Boric acid may crystallize; small potential for plugging and loss of flow	None if alternate flow path available	Restore trace heating; unplug lines
		2. Trace heating fails	--	Boric acid may crystallize; small potential for plugging and loss of flow	None if alternate flow path available	Restore trace heating; unplug lines
6.5.5	Waste, Drain, Sample Lines	1. Lines fail open	--	Decreased bleed flow	None if alternate flow path available	Alternate flow path available
6.5.6	Manual Isolation Valves	1. Valves fail closed	--	No bleed flow	None if alternate flow path available	Alternate flow path available

Reference Drawings: FSAR Figure 9.3-1 (Sheet 1)
FSAR Figure 9.3-2 (Sheet 3)
FSAR Figure 9.3-5 (Sheets 1,3,4A)

6.0 SUBSYSTEM: RC BLEED, BORON RECOVERY, AND CHEMICAL ADDITION

	Component	Potential Failure Mode		Immediate Effects		
		Mode	Interface Involved	Within Subsystem	At Subsystem Interface	Remedial Action Within Subsystem
6.5.7	Check Valve (Outlet)	1. Fails to prevent backflow	--	Possible backflow to deborating demineralizer	None if alternate flow path available	Close manual isolation valve
6.5.8	Check Valve (CS-123)	1. Fails to prevent backflow	--	Possible backflow to deborating demineralizer	No flow to makeup filters	Close HP.16