PREL IMINARY

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

> Science Applications, Inc. Systems Analysis Division

> > October 3, 1983

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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:

- Letdown Control: Controlled removal of reactor coolant from the RCS and reduction of coolant temperature and pressure at a preset flowrate.
- Purification: Removal of impurities from the reactor coolant using boric acid saturated ion exchange resins.
- 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

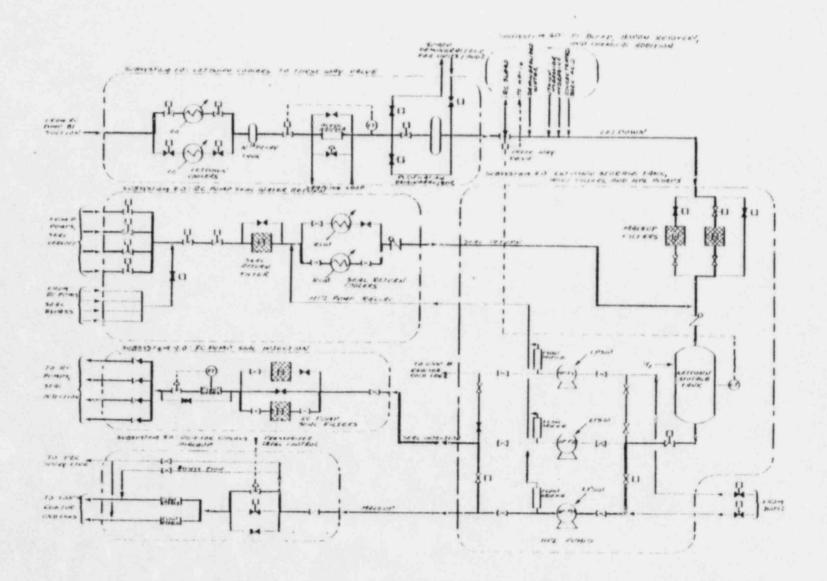


Figure 1. Makeup and Purification System Flow Sheet, Subsystems 1.0 - 5.0.

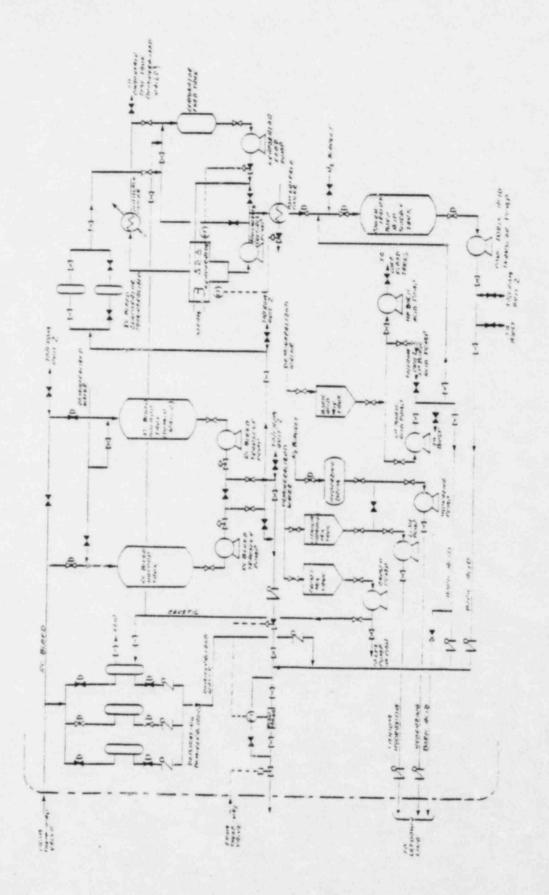


Figure 2. Makeup and Purification System Flow Sheet, Subsystem 6.0.

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:

- Intermittent letdown of reactor coolant to a holdup tank and replacement with demineralized water or continuous operation of a deborating demineralizer;
- 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

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 charical 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 AWALYSIS

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 Letdown Subsystem 1.1 In-Containment RC Leak or Small LOCA -Emergency procedures for small Piping decreasing pressurizer LOCA's must be followed. Letand LD tank levels, down flowpath is isolated and the HPI mode of operation decreasing RCS pressure, and high contaminent initiated automatically at an radiation alarms alert RCS pressure of 1500 psi. the situation. 1.2 LD Cooler Tube Emergency procedures for RCS RC leak or small LOCA -Failure decreasing pressurizer and leaks or small LOCA's must be LD tank levels and high CC followed depending on whether surge tank and radiation the leak rate exceeds the alarms alert operator to capacity of the Makeup System. Automatic isolation of the LD the situation. Until isolated, reactor coolant coolers from the RCS will not will pressurize the CC not occur. The operator must system resulting in the isolate the LD cooler(s) from in-containment CC relief the RCS based on high CC surge valves opening and distank level and pressure. The charging to the containment situation may be confused by high containment sump levels sump. 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 contain- ment. Leak flowrate will be limited to a small increase above existing flowrate. Local radiation	Emergency procedures for a letdown line failure outside containment must be followed (if they exist). Operator musisolate the break and open an

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 Ho which could result in fires or explosions.

alternate flowpath from the BWST to the HPI pumps. Procedures covering subsequent shutdown of the plant without letdown must be followed.

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

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

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 "runout". 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 H2 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.

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 Ho 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)

Effect

Remedial Actions

- 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 H₂ 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 H₂ release. BWST can supply RCS boric acid requirements if required.

TABLE 2. PLOW BLOCKAGES IN THE MAKEUP AND PURIFICATION SYSTEM

Effect

Remedial Actions

1. Letdown Subsystem

- 1.1 Letdown Path to Connection With 3-Way Valve Letdown-Makeup Operation or Operation With Deborating Demineralizers
- 1.2 Letdown Path to Connection with 3-Way Valve -Letdown to Bleed Holdup Tank Operation

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.

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 may require makeup to LD tank or throttling seal injection flow.

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 Flow to LD tank stops while Operator manually can transfer from Letdown to LD makeup to RCS continues at the 3-Way Valve to direct flow Tank to Coolant Proprevious flowrates. Low to the LD tank, open the bycessing and Storage LD tank level is alarmed pass line from the letdown Subsystem and the level signal may line to the makeup filters or automatically transfer provide makeup to the LD tank valve to original position. from the Coolant Storage Sub-Unless an alternate source system. If LD tank level cannot be maintained, the of makeup water to LD tank is provided, the LD tank operator must throttle makeup will be drained possibly flow to the RCS or trip the resulting in damage to the HPI pumps. operating HPI pumps. 2.2 3-Way Valve Switches LD tank level will Return 3-Way Valve to original position or isolate makeup from Letdown to increase and be alarmed Coolant Processing flow from Coolant Processing on high level. and Storage Sub-Subsystem to LD tank. system to LD Tank 3. HPI Subsystem 3.1 3-Way Valve to Reduced letdown from RCS Operator can establish an Connection With results in makeup flow alternate letdown flowpath throttled due to increasing Seal Return Lineor clear the flow blockage. pressurizer level. Seal Letdown-Makeup Minimum HPI pump flow recirinjection results in a Operation or culation must be maintained.

continued net injection of

20 gpm and an alarmed low

LD tank level.

Continued operation may

require throttling seal

injection flow.

Operation With

Demineralizers

Deborating

Effect

Remedial Actions

3.2 3-Way Valve to
Connection with
Seal Return LineLetdown 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 qpm seal injection flowrate to the RCS unless a letdown flowpath 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.

Failure Location		Effect	Remedial Actions	
3.4	LD Tank to HPI Pump Suction Piping	Low indicated makeup flow- rate and low seal injection flowrate alarms alert oper- ator 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 flow- rates and low seal injection flowrate alarms alert oper- ator 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	Operator may isolate letdown flow and start an alternate HPI pump after assessing the reason for the stoppage. Letdown flow may then be restored.	

RC pump seal return flow result in an increasing LD tank level and a decreasing pressurizer level.

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

Effect

Remedial Actions

 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 flowpath 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.

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. PLOW BLOCKAGES IN THE MAKEUP AND PURIFICATION SYSTEM (Continued)

Failure Location Effect Remedial Actions RC Pumps Seal Injection Seal injection flow to one Restore seal injection. Subsystem or more RC pumps will cease. Observe RC pump procedures Operator alerted to the for operation without seal situation by seal injection 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. 7. Coolant Processing and Storage Subsystem 7.1 Letdown Path Decreasing LD tank level Clear or bypass flowblockage Through Deborating will result in the autoand restore deborating Demineralizers demineralizer operation. matic transfer of the 3-Way Valve to the LD tank. 7.2 Letdown Path From Increasing pressurizer Operator manually can transfer 3-Way Valve to Bleed level will result in 3-Way Valve to the LD tank. Holdup Tank throttled makeup flowrate to RCS. LD tank level will increase. Pressurizer level will continue to increase due to net RC Pumps' seal injection flowrate.

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

Failure Location Effect Remedial Actions 7.3 Makeup Path to 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

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-W	ay Valve			
	2.1	3-Way Valve Switches from Letdown to LD Tank to Coolant Pro- cessing 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 Sub- system 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 Tark 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 Lb tank.	Reduce or isolate flow from boric acid or blead holdup tanks. Transfer letdown flow to LD tank if required.	
	3.2	Flowpath to HP1 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 auto- matically 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 Makeup valve to RCS opens Attempt to reduce letdown Holdup Tanks from in response to decreasing flowrate. If required, Letdown Subsystem pressurizer level. LD transfer 3-way valve position tank level decreases. to LD tank. 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. 7.2 Flowpath to HPI Letdown tank level Reduce or isolate flow from Subsystem from boric acid or bleed holdup increases. Excessive Coolant Processing addition of demineralized tanks. Transfer letdown flow and Storage Subsystem water will result in to LD tank if required. control rod insertion and automatic termination of demineralized water flow

to LD tank.

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)

8. Seal Injection Filters
Bypassed

Filter unavailable for removal of particulates removal of particulates prior to injection through RC pump seals. Unless bypassed, purification demineralizers and/or letdown filters can remove coolant particulates.

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

Effect

Remedial Actions

 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.

- 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 MALPUNCTIONS IN THE MAKEUP AND PURIFICATION SYSTEM (Continued)

Failure		e Effect	
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-126)	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 #2 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 MALPUNCTIONS IN THE MAKEUP AND PURIFICATION SYSTEM (Continued)

Failure Effect Remedial Actions 2.6 RC Seal Injection Small increase in flowrate Operator manually can throttle Flow Control expected. The long term HP-31. Circuit Opens effects on the RC pumps and Control Valve whether the increased flow HP-31 is sufficient to trip the high seal P alarms is not known. 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 (EP-120) and the turbine bypass valves and verifying other automatic actions.

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

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 Automatic control of makeup Power Branch HlX valve HP-120 operable. If to ICS/NNI 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 ___).

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 (EP-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 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.

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 Automatic transfer of the Branch HI to ICS/NNI makeup flow control to procedures for loss of H1. manual will occur. The These actions should include valve (HP-120) will remain in position. Numerous

other plant controls,

).

alarms and indicators are

deemergized (See Section

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 must follow applicable 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.

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)

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	re Effect	
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 Fump 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 Depending on the mode of motor bearing cooling for failure, the backup LPSW pump the three HPI pumps, cooling may be started, the HPSW system water to Unit 1 and 2 CC may be used or the cause of coolers (see Item 1), the RC failure (e.g., blocked LPSW pump motor bearing coolers, suction strainers, loss of AC emergency feedwater pump power) may be removed. and turbine coolers, LPI coolers, RB cooling units, etc., will be lost. 3. Recirculating Cooling Water (RCW) System Failures 3.1 Loss of RCW to Gradual increase in seal Restore RCW to operating cooler Operating Seal return temperature due to or place standby cooler in heat addition from RC pump Return Cooler operation. If seal return

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)

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 No 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

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 No 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

Effect

Remedial Actions

 4160 VAC Bus iTC 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)

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, Xl and TC. The air supply to serviced components is assumed to be provided by compressors 3 and C.

2. 4160 VAC Bus 1TD Deenergized

o Standby HPI pump PIB 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 PAILURES IN THE MAKEUP AND PURIFICATION SYSTEM (Continued)

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)	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.	Restore power to deenergized bus.
		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.	
7.	208 VAC Bus XS1	BWST isolation valve to the BPI 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 prop C HPI discharge valve (HP-27) deenergized and not able to open if required.	Restore Bus XS2 to service.

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

Remedial Actions Effect Failure

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. FMRA SUMMARY FOR SUBSYSTEM 1.0: LETDOWN COOLERS TO 3-WAY VALVE HP-14 (HP-710)

Effects at Subsystem Interface

Precipitating Faults/Failure Modes

- 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 HF-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)
- 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. FREA SUMMARY FOR SUBSYSTEM 1.0: LETDOWN COOLERS TO 3-WAY VALVE HP-14 (HP-V10) (Continued)

Eff	ects at Subsystem Interface	cts at Subsystem Interface Precip	
3.	Letdown Flow to 3-Way Valve EP-14 (EP-V10) is Terminated	a.	Internal component failures (manual or control valves which are NO fail closed obstructing letdown flow; resin beads in purification demineralizes 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 (marual 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	8.	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)	٤.	Loss of cooling water flow to the operating letdown cooler (HP-C1A or HP-C1B)

TABLE 9. FMEA SUMMARY FOR SUBSISTEM 1.0: LEADOWN 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 Rocm	a.	Internal component failures in transmitters
	- Letdown Flow - Cooler Discharge Temperature	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 lettown 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 soal raturn 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; cocler 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. PMEA 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	а.	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.	described above, HP-275
4.	Seal Return Flow From All RC Pumps Stopped	å.	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)

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

Eff	fects at Subsystem Interface		ects at Subsystem Interface		ects 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 SUBSISTEM 2.0: RCP SEAL WATER ENTURE

(Continued)

Effects at Subsystem Interface		ects at Subsystem Interface		Precipitating Faults/Failure Modes
Subsystem Not Is Lied 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)		
Seal Return Flow Continues to Letdown Storage Tank When Isolation is Demanded	а.	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 recurn 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)		
Potential Loss of Vent on RCP Vent Seals	а.	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		
Incorrect Process Signal to I&C System and	a.	Electric power supply to transmitters fails		
- Seal Leak-off Line Pressures - Seal Bypass Line Pressures - Seal Leak-off Line Flows	b.	Component fault within subsystem such as instrument connection leaks or internal transmitter failures		
	Subsystem Not Isal Led From Reactor Coolant System When Demanded (cont'd) Seal Return Flow Continues to Letdown Storage Tank When Isolation is Demanded Potential Loss of Vent on RCP Vent Seals Incorrect Process Signal to I&C System and Control Room - Seal Leak-off Line Pressures - Seal Bypass Line Pressures - Seal Leak-off Line Pressures - Seal Leak-off Line	Subsystem Not Is a led C. From Reactor Coolant System When Demanded (cont'd) Seal Return Flow a. Continues to Letdown Storage Tank When Isolation is Demanded b. C. C		

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 H₂ concentration in the reactor coolant wheup. 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 1 is 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: LETDOWE STORAGE TANK (LST) INLET FILTERS, AND HPI PUMPS

Eff	ects 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	a.	Transmitter failure or instrument connection leak (component fault within subsystem)
	- LST Level - LST Pressure	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. FMRA SUMMARY FOR SUBSYSTEM 3.0: LETDOWN STORAGE TANK (LST) INLET FILTERS, AND HPI PUMPS (Continued)

Eff	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 is 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 non-operating 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 $\rm H_2$ supply valve to the LST tank can fail closed, cutting off the $\rm H_2$ supply; and the vent valve on the LST can fail closed, allowing potential accumulation of non- $\rm H_2$ noncondensible gases in the LST and reduction of $\rm H_2$ 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 H2 addition, or allowing the LST level to drop, which could result in loss of NPSH to the HPI pumps and ultimate loss of subsystem dis-

charge 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

TARLE 12. FHEA SUMMARY FOR SUBSYSTEM 4.0: RC PUMP SEAL INJECTION

Effe	Effects at Subsystem Interface		ffects at Subsystem Interface Precipitating		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	а.	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 SUBSISTEM 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	а.	Component faults within subsystem such as instrument connection leaks and internal transmitter failures
	- Filter Drop Pressure - Injection Header Flow - Injection Line Flows	b.	Loss of electric power supply to transmitter

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

Eff	ects 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	а.	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. FHEA SUMMARY FOR SUBSYSTEM 5.0: REACTOR COOLANT (RC) MAKEUP (Continued)

Eff	ects at Subsystem Interface		Precipitating aults/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	e.	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 'n 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)

Effe	ects at Subsystem Interface		Precipitating Faults/Failure Modes	
10.	Incorrect Process Signal(s) to I&C System and Control Room - Makeup Header Flow	a.	Component fault within subsystem (transmitter failure or instrument connection leak)	
	- Bypass Line Flows	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 3.0) 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.

Effe	cts at Subsystem Interface		Precipitating Faults/Failure Modes
6.1	Chemical Addition:		
1.	No N _{2H4} Available to Makeup Filters	a.	N2 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
	no aroze temp nequal ea	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 1:0H Avail- able to Makeup Filters	a,	Sampling, waste lines downstream of tank fail open
5.	Incorrect LiOH Concen- tration Available to Makeup Filters	2.	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

Effe	cts at Subsystem Interface		Precipitating Faults/Failure Modes
7.	No Caustic Available to LPI Pumps, RC Bleed Evaporator Feed Tank,	a.	Demineralized water supply to mix tank fails
	Deborating Demineralizers	b.	Manual isolation valves fail olosed
		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

Effe	ects 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 Avail- able to Core Flood Tank	a.	Electric power supply to HP boric acid pump fails
		b.	HP boric acid pump fails
H		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	a.	Demineralized water supply to boric acid mix tank fails
	Required as Boric Acid	b.	Manual isolation valves fail closed
	Source (Internal Sub- system Effect Only)	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
		е.	Mix tank empties and not refilled. Leaks from tank will eventually lead to same effect
5.	Incorrect Process Para- meters to I&C System and Control Room	a.	Electric power supplies to transmitters fail
	- Boric Acid Mix Tank Level, Temperature	b.	Transmitter signal connection leaks
	- LP Boric Acid Pump Discharge Pressure - Concentrated Boric Acid Storage Tank Level	c.	Transmitters fail

(Continued)

Precipitating Faults/Failure Modes Effects at Subsystem Interface 6.3 RC Bleed Holdup Tanks and Transfer Pumps: a. Manual isolation and control valves fail No Demineralized Water closed to Makeup Filters b. Demineralized water supply to demineralized water holdup tank fails c. No 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 No Demineralized Water k. Flow orifices plug 1. to Makeup Filters (cont'd) a. Waste, drain, or sample lines downsteam Decreased Demineralized 2. of holdup tank fail open Water to Makeup Filters a. Control valves HP-15 and HP-16 fail Increased Demineralized 3. open (control signal fails to close Water to Makeup Filters

valve or spurious signal to open valve)

Eff	ects at Subsystem Interface		Precipitating Faults/Failure Modes
4.	Alternate Flow Path	a.	RC bleed flow from letdown fails
	Through Unit 2 Bleed Holdup Tank Required	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 li es 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	b.	Transmitter connection leaks
	Level - RC Bleed Flow - Demineralized Water Holdup Tank Level - Demineralized Water Flow	c.	Transmitter fails

Effe	cts at Subsystem Interface		Precipitating Faults/Failure Modes
6.4	Boron Recovery:		
1.	Alternate Flow Path Through Second Evaporator	a.	Manual isolation valves fail closed
	Demineralizer Required (Internal Subsystem	ba	Demineralizer resin fill fails
	Effect Only)	c.	Demineralizer tank or tank vents leak
2.	RC Bleed Evaporator Feed Tank Required to be Full at Beginning of Boron	a.	Electric power supply to trace heating or trace heating fails leading to plugged lines
	Recovery Cycle (Internal Subsystem Effect Only)	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,	a.	Cooling water supply to distillate cooler fails
	Condensate Test Tank (Demineralized Water)	ъ.	Loss or degraded heat transfer capability in disti
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
	(Dominor original and)	b.	Distillate cooler leaks
		c.	Evaporator distillate flow fails; see effects 5 and 6
5.	Boron Recovery Stops; Concentrated Boric Acid Storage Tanks Required	a.	Evaporator concentrate flow returned to feed tank or evaporator
	to be Full (Internal Subsystem Effect Only)	b.	Evaporator feed tank empties and not refilled. Leaks from tank, including ver and relief valves failed open, will evaluably lead to same effect
		c.	Manual isolation valves fail closed

Precipitating Faults/Failure Modes Effects at Subsystem Interface d. Electric power supply to evaporator feed 5. Boron Recovery Stops; pump or concentrate pump fails Concentrated Boric Acid Storage Tanks Required e. Evaporator feed pump or concentrate to be Full (Internal pump fails Subsystem Effect Only) 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 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 a. Electric power supply to trace heating, 6. Boron Recovery Rate trace heating, or evaporator heating Decreases; Concentrated fails leading to plugged lines Boric Acid Storage Tank Required to be Full b. Evaporator tubes blocked or tube rupture (Internal Subsystem leading to decreased flow or steam Effect Only) release to vapor space c. Concentrate cooler leaks a. Cooling water supply to concentrate 7. No Temperature Control cooler fails of Concentrate Returned to Boric Acid Storage b. Loss or degraded heat transfer Tanks (Internal Subcapability in concentrate cooler system Effect Only)

c. Temperature transmitter control signal to cooling water control valve fails

Effe	cts at Subsystem Interface		Precipitating Faults/Failure Modes
6.5	Deborating Demineralizer:		
1.	No RC Return to Makeup	a.	RC bleed flow from 3-way valve fails
	1 44 001 0	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; Alter- nate 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	a.	Manual isolation, control valves fail closed
	Demineralizer Required	b.	Tank empties. Leaks from tank; including vent and relief valves failed open, will eventually lead to same effect.
		с.	Electric power supply to trace heating, trace heating fails leading to plugged lines
4.	Decreased Return Flow to Makeup Filters; Alter-	s.	Waste, drain, sample lines fail open
	nate Flow Path Through Second Demineralizer Required	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

- 1982 Revision Oconee Nuclear Station, Final Safety Analysis Reports, Revision 18.
- 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 1.04 LETDOWN COOLERS TO THREE-WAY VALVE

1.0 SUBSTSTEM: LETSONN COOLERS TO 3-WAT WALPR HP-18 (HS-910)

1.1.1

	Component		Fotential Failure Mode Siche Inter	e Hode Interface Involved	Immediate Effects Within Subsystem	Effects At Subsystem Interface	Remedial Action
1.1	Letdown Coolers:						
2	Miscellaneous Norsally Closed, Hanual Valves Such as MP-329 (Including Double Isolation Valves Such an MP-32 and MP-359)	÷	Open due to fatta open due to faternal feuit	Vent or Brain	Reduced Jaidoun flow rate;	Some latdown flow is diverted to sumpe; hence, reduced latdown flow to 3-way walve RP-14 (MP-V10) and RC leck	Though detection is difficult, close or repair when found
1.1.2	Valve HP-1 (NO) (HP-V:A)	÷	Fails closed due to internal fault	1	Letdown flow to Ltdn Cooler HP-C1A obstructed	Letdown flow to 3-way valve HP-18 (HP-910) is terminated	Open HP-VIC and use Ltdn Cooler NP-CIR
		~i	Spuriously closed	Control Signal	Letdown flow to Lide Cooler HF-C1A obstructed	Letdown flow to 3-way walve HP-14 (HP-910) is terminated	Open dP-V1A
		m.	Falls to close when required due to internal fault		Unobatructed letdown flow to Ltdm Cooler HP-CIA. Ltdm Cooler HP-CIA cannot be feolated if valve HP-I (HP-VIA) is open	If HP-CiA has experienced a loss of cooling water, then letdown fluid temperature will increase; letdown flow to 3-way valve HP-14 (HP-VIO) will continue until series isolation valve HF-3 (HP-VA) or HF-3 (HP-VA) or HF-3 (HP-VA) is closed to protect HP-XI. If	Close series isolation vaive
						UP-C1M has experienced a tube rupture, then an RC leak to CCW system will occur	
		•	Falls to close when evalured due to unevallability of electric power	Slectric Power	Unobstructed letdokn flow to Ltdn Cooler HP-C14. Ltdn Cooler HP-C14 cannot be leciated if valve HP-1 (HP-F1A) is open	If H7-C18 has experienced a loss of cooling water, then letdown fluid temperature will increase; letdown flow to 3-way waive HF-14 (HF-W10) will continue until series isclation waive HF-3 (HF-W2A) (powered from separate bus or manually olsed) or HF-5 (HF-W3) is	Jooletion valve
						If HF-CIA has experienced a tube rupture, then an RC leak to CDM system	Restore electric power

1.0 SUBSTEMS: LETDOWN COOLERS TO 3-MAY VALVE HP-14 (HP-V10) (Continued)

		1	Potential Failure Mode	- Mode	Innediate	Immediate Effects	
	Component		Mode	Interface Involved	Within Subsystem	At Subsystem Interface	F.medial Action Within Subsystem
=	Valve HP-2 (MC) (MP-VIB)	-	Falls open due to internal fault	,	Unobatructed letdown flow to Ltdn Cooler HP-C:8	Unless component cooling water provided to Ltdn Cooler HF-Cills letdown temperature will increase possibly resulting in letdown isolation, i.e., termination of letdown flow to 3-way walve	Close RP-4 (HP-V2B)
		~	Spuriously opened	Control Signal	Unobstructed letdown flow to Ltdn Cooler HP-C18	HP-1% (HF-V10) Unless component cooling water provided to Ltan Scoler HF-ClB, letdown temperature will increase possibly resulting in letdown leoixtion, 1.e., termination of letdown flow to 3-way valve	Close HP-2 (HP-VIB), close HP-4 (HP-V2B)
		m.	Fails to open when required due to internal fault	1	Use of Lide Cooler HP-C1B prevented	Hay result in increased letdown temperature or continued letdown	None (isolate and repair)
		*	Fails to open when required due to unavailability of alectric power	Electric Power	Une of Ltdn Cooler HP-C18 prevented	May seatt in increased letters temperature or continued letters isolation	Restore electric power
F	Operating Letdown Cooler NP-C1A (or HP-C1B)		Loss of cooling water flow	Component Cooling Water System	Increased letdown Lemperature. High temperature sensed on IT-3 resulting in mutcastic closure of inclution valve HP-5 (HP-Y3) 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)	lablate HP-C1A and utility HP-C1B if cooling water available to HP-C1B. Reatore letdown flow if it has
		'n	Reduction in heat transfer capability due to fouling	ī	Increased istition temperature. High temperature sensed on IT-3 and indicated in control room	Increased letdo.m fluid temperature	Deem isolated Tsolate MP-Cia, utilize MP-CiB

1.0 SUBSISTEM: LKTDOWN COOLERS TO 3-WAT FALFE HF-14 (HF-F10) (Continued)

	1	Fotential Failure Mode Inter Mode Invol	Mode Interface Involved	Issediate Effects Withir Subsystem	Effects At Subsystes Interface	Remedial Action
Operating Letdown Cooler HP-CIA (or HP-CIB) (cont'd)	*	Tube rupture	Component Cooling Water System	Reduced letdown flow rate due to flow diversion	Reduced letdown flow to 3-way valve HF-19 (HF-WIG). Loss of resotor coolant to CCM system. Decreasing Lidn tank level, RCS pressure. Sarrty injection signal will not include letdown coolar. Increased CCW surge tank level., discharge of resetor coolant through CCW relief valves to RB	Close HP-1 (HP-VIA) and HP-3 (HP-VIA), and open path through HP-CIB
Standby Letdown Cooler HP-C18 (or HP-C18)	-	Tube rupture	Component Cooling Water System	due to flow diversion	Reduced letdown flow to 3-wsy valve HP-14 (HP-V10). Loss of resetor coolsan to CCW system. Becreasing Ltdn tank level, RCS pressure, Safety injection signal will isolate letdown cooler. Increased CCW surge tank level, discharge of resetor coolant through CCW relief valves to RB	Close or serify closure of HF-4 (HF-V2B); letdown flow through HP-C1A is possible once lesk is isolated
(HF-V2A)	-	Fails closed due to internal fault	1	Actdown flow through HF-C1A	Letdown flow to 3-x3y valve HP-14 (HP-110) is terminated	Close HP-1 (HP-VA), open HP-2 (HP-VIB) to divert letdown flow
	ri V	Spuriously closed	Control Signal	Letdown flow through HF-CIA	Salve HF-14 (HP-VIO) to	Open RP-3 (HP-V2A)
	÷	Fails to giose when required due to internal fault.		Frevents includion of	If RP-CIA has experienced a tube rupture, HF-1 (RP-91A) has been closed, and HF-CIB is to be used, then an RC leak to the CCW mystem will occur. If HF-CIA has experienced a loss of cooling water and HF-1 (HF-71A) can not be closed, then bot be closed, then letdown fluid temperature will increase and HF-5 (HF-W) will close and HF-5 (HF-W) will close.	Mone Automotic closure of HP-5 (HP-T3); HP-C14 cannot Le isolated until HP-3 (HP-P24) is repaired

1.0 SUBSTSTEM: LETDONE COOLERS TO 3-WAY TALVE HF-14 (RF-V10) (Continued)

			Potential Failure	Mode	lamedi	ate Effects	
	Component		Hode	Interface Involved	Within Subsystem	At Subsystem Interface	Remedial Action Within Supercion
1.1.6	Valve HF-3 (NO) (HF-V2A) (cont'd)	٠.	Fails to close when required due to unevailability of power on bus 1EXS21	Electric Power	Prevents isolation of HF-C1A	If HP-CIA has experienced a tube rupture, RF-1 (HP-VIA) has been closed, and HF-CIB is to be used, then an BC leak to the CC	None
						system will occur. If HP-C1A has experienced a loss of occling 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)	Automatic closure of HF-5 (HF-73); HF-C1A cannot be isolated until power is restored on bus 1EXS21
		5.	Fails to plose when required due to failure of ES signal	Engineered Safeguards Protective System (ESPS)	Prevents isolation of RF-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 BC leak to the CCW	None.
						mystem will occur. If HP-CIA has experienced a loss of cooling water and HP-1 (HP-VIA) counct be closed, then letdown fluid temperature will increase and HP-5 (HP-V3) will close terminating letdown flow to HP-IA (HF-VIO)	Automatic closure of HP-5 (HP-V3); HP-C1A cannot be isolated until FS signal is restored
1.1.7	Valve HF-4 (NO) (YY2B)	1.	Fails plosed due to internal fault		None	None	Circle HP-2 (HP-71B) to divert letdown flow through HP-CIA
		2.	Spuriously closed	Control Signal	None	None	Open RP-4
		3.	Fails to close when required due to Internal fault		Prevents isolution of MP-C:E	If HP-C1B has experienced a tube rupture, then an RC leak to the SCW system will occur	(HF-V2B) None; HF-C1B cannot be isolated until HF-b (HF-V2B) is repaired
		•	Fails to close when required due to unavailability of power on bus 1EXS21	Electric Power	Frevents isolation of BF-C1B	If HF-C1B has experienced a tube rupture, then an RC leak to the CCW system vill occur	None; HP-CIB cannot be isolated until power is restored on bus IEES21

1.0 SUBSYSTEM: LETDONN COGLERS TO 3-MAY WALVE RP-14 (RP-V10) (Continged)

	1	Fotential Failure Mode	Mode	immediate Effects	Effects	
Component		Mode	Interface	Within Subsystem	At Subsystem Interface	Remedial Action Within Subayates
1.1.7 Valve HF-N (NO) (NF-F2B) (cont.d)	×	Falls to close when Fallure of E3 signal	Engineered Safeguards Frotective System (ESPS)	Frewents inclution of RP-C1B	If HF-C1B has experienced a tube rupture, then an BC lenk to the CCW system will occur	Wone; HF-CIB cannot be isolated until ES signal is restored
1.2 Block Orifice:						
Normally Closed Henual Valves Such as NP-36 or HP-332	-	Opened or falls open due to internal fault	Vent or Brain	Reduced letdoom flow rate	Reduced letdown flow to 3-way valse dP-14 (HP-V10)	Though detection is difficult, close or repair when found
1-2.2 Valve HP-5 (NO) (HP-F3)	-	Fails closed due to internal fault	1	Letdown flow terminated	Letdown flow to 3-way waive HP-1% (NP-910) in terminated	Close HP-3 (HP-V2A), HP-4 (HP-V2B), and HP-6 (HP-V4)
	Ň	Spurtously closed	Control Signal	Letdown flow terminated	Letdown flow to 3-way walve HP-118 (HP-VIO) is terminated	Open HP-5 (HP-V3)
	ŕ	Falls to close when required due to internal fault		High temperature letdown flow to purification demineralizer to unobstructed. Increased letdown fluid temperature may result in melits, the reals blocking flow	High temporature letdown flow possibly causing flow blockage if resin beads in HF-Ki meit	Close HP-6 (HP-N), If purification resing dazged, use standby desineralizer
	•	Spuriously closed due to unavailability of instrument air (assumed)	Instrument Air	Letdown flow terminated	Letdown flow to 3-way walve HP-18 (HP-VIO) is terminated	Restore instrument eir, open HP-5 (HP-V3)
	*	Fails to close when required due to unavailability of letdoen temperature interlock	Plant Instru-	High temperature ictioun flow to purification demineralizer is unobstructed. Increased letdown fluid temperature may result in molting the rests beads in HP-R1 and thus blocking flow	High temperature letdown flow possibly causing flow blockage if resin beads in NF-Xi melt	Close NF-6 (HF-VA) and restore temperature interlock. If purification realms damaged, use standby destinantal ser

1.0 SUBSYSTEM: LATDOWN COOLERS TO 3-WAT VALVE RP-14 (RP-V10) (Continued)

			Potentisi Fallur	re Hode	Immediate	Effects	
	Component		Hode	Interface Involved	Within Subsystem	At Subsystem Interface	Remedial Action Within Subsystem
1.2.2	Valve HP-5 (NO) (RP-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 reducedant containment isolation vaives. High temperature letdown flow to purification demineralizer is unobstructed. Increased letdown fluid temperature may result in melting the resis beads in HP-X1 and thus blocking flow	None, if HP-6 (HP-VA) aucoessfully closes. Otherwise, high temperature letdown flow possibly causing flow blockage if resin beads in HF-It melt	Close HF-6 (MF-VA) and restore ES signal. If purification resine damaged, use standby domineralizer
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	HP-14 (HP-V10) is terminal ed unless HP-42	(HP-V5) for letdown
		2.	Spuriously closed	Control Signal	Letdown flow to purification deminoralizer is obstructed unless HP-N2 or HP-7 (HP-V5) is open	or HP-7 (HP-V5) is open Letdown flow to 3-way valve HP-1% (HP-V10) is terminated unless HP-%2 or HP-7 (HP-V5) is open	Open HP-6 (HP-VA) or HP-7 (HP-V5)
			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 latdown flow has not been odoled, then temperature of letdown flow to HP-14 (HP-V10) will continue to increase and resin beads in HP-II may melt causing flow blockage	Close HP-8 (HP-VT) to protect purification demineralizer HP-X1
			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-1% (HP-V10) will continue to increase and resin beads in HP-X1 may melt causing flow blockage	Close @%-8 (HP-V7) to protect purification desineralizer HP-II; restore instrument air
1.2.4	Block Orifice	1.	Fails plugged		Letdown flow to purification demineralizer is obstructed if PP-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	flaat Isatru- mentation	None	Incorrect information sent to plant operators	Isolate and repair
		2.	fails we to loss of power	Electric Power	None	Incorrect information sent to plant operators	Restore electric

(Continued)
HP-410)
HP-14 (
F VALVE
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ESTEM: 1
1.0 5083

		-	corentral failure nous	e Mode	Ismediate Effects	Effects	
	Component		Mode	Interface	Within Subsystem	At Sube stem Interface	Remedial Action Within Subsystem
1.2.6	Valve HP-39 (NO)	*	Falls closed due to internal fault	ı	Letdown flow to purification demineralizer is obstructed if HP-42 and HP-7 (HP-95) are closed	Letdown flow to 3-may walve HP-14 (HP-W10) is terminated if HP-42 and HP-7 (HP-75) are closed	Open HP-7 (HP-V5)
1.2.1	Valve 52-42 (NC)	-	Falls open due to internal fault	1	Unobstructed letdown flow through oritine bypans to purification demineralizer	Increased letdown flow to 3-way valvo HP-13 (HP-V10)	Isolate block orifice to reduce letdown flow
1.2.8	Valve HF-NG (NG)	÷	Fails closed due to internal fault	ı	Leidown flow to HP-7 (HP-75) is obstructed	Rone, 1f HP-7 (RP-V5) (NC) is closed. Otherwise, reduced letdown flow to 3-way valve HP-14 (HP-V10)	Open HP-42, 1f required
1.2.9	Valve HP-7 (MC) (HP-V5)	2	Falls open due to Internal fault	ı	Block orifice bypassed, increased letdown flow	Increased letdown flow to 3-way valve HP-14 (HP-W10), and potentially increased letdown temporatures	Close HP-NO and/ or HP-N1 and repair
		ri .	Spuriously opened	Control Signe?	Block orifice bypassed, increased letdown flow	Increased letdown flow to 3-way valve HP-14 (HP-VIO)	Close HP-7 (HP-VS)
		÷	Fails to open when required due to internal fault	1	Additional letdown flow not provided	Additional latdown flow not provided	Open HP-42 if required, close HP-40 and HP-41
		•	required due to unavailability of instrument air (assumed)	Instrument Air	Additional letdown flow not provided	Additional latdown flow not provided	Utilize HP-42, if required; restore instrument air
.2.10	1.2.10 Unive HP-81 (NO)	-	Falls closed due to internal fault	1	Obstructs letdown flow to purification demineralizer Af HP-7 (HP-VS) is open	Reduced letdown flow to 3-way valve HP-14 (HP-V10) 1f HP-7 (HP-V5) is open	Utilize HP-42 1f required
1.2.11	Radiation Monitor Loop	-	Mormally closed manua: drain valve opened, fails open, or not closed after maintenance, or relief valve spuriously opens	Migh Activity Sesse Tank, Miscellaneous Waste Tank	Diversion of letdown flow when radiation scultoring loop used	Reduced letdown flow to 3-way valve HP-1% (HP-VIO); flow diverted to Hiscellancous Waste Tank or High Activity Waste Tank	laciate Loop; close valve or repair when found; sampling svallable at cther points in
		e,	Loop becomes plugged		Reduced lettown flow; radiation monitoring prevented	Reduced letdown flow to 3-way valve HP-1% (HP-V10)	Unplug when found; sampling available at other points in subsystem

1.0 SUBSISTEM: LETDON COCLERS TO 3-MAY WALVE HP-14 (RP-V10) (Continued)

1.2.12 Boron Meter Loop 1. Normally closed Interfect Int			-	Potential Fallura Kode	* Node	Immediate Effects	Effects	
1. Normally closed activity between the same decimal from the same decimal from the same decimation of the faths, the same decimation of reliance, or reliations of reliance, or reliations plugged Latdown flow to purification Letdoun flow to prevented decimated activities in the same decimation and the same decimation flower failure that the same f		Component		Mode	Interface	Within Subsystem	At Subsystem Interface	Remedial Action Within Supsystem
2. Loop becomes plugged Reduced letdoun flow; boron Reduced letdoun flow to unification Demineralizer: Flow Nozzle 1. Fail plugged Letdour flow to purification Letdoun flow to 3-way walve demineralizer: Flow Transmitters 1. Internal fault Plant instru- None None None None None Room Incorrect algust Feetric Power Mone None None None None Room Incorrect algust Feetric Power Mone None None None None None None None N	.2.	2 Boron Meter Loop	-	Mormally closed manual drain valve opened, fails open, or not closed after saintenance, or relief valve anuriconty contraction of the contraction	High Activity OF Tank, Miccellanceus Wacte Tank		Reduced letdown rlow to 3-wsy ware HP-14 (HP-916); flow diverted to Hig. Activity DR Tank o. Miscellaneous Waste Tank	leolate Loop; olose valve or repair whor found; sampling available at other points in
Flow Norzie 1. Fail plugged Latdown flow to purification Latdown flow to 3-vay valve deafneralizer in increase deafneralizer in increase deafneralizer in increase at a fact failure Electric Fower None None None Freshre dauge 1. Internal fault Electric Fower None None None None Freshre dauge 1. Internal fault Electric Fower None None None Rentation Electric Fower None None None None Rentation Rentatio		Turification Desinara	× 1		1	Reduced letdom flow; boron content measurement prevented	Reduced letdown flow to 3-way walve HP-14 (HP-V10)	Unplug when found; sampling swallable at other points in subsystem
Flow Transmitters 1. Internal fault Plant Instru- None None None FT-6, FT-6F, and Incorrect signal sentation None None None Incorrect signal Incorrect signal Incorrect signal Fault Instru- None None Relation Incorrect Signal In	3.	Flow Nozzle	-		1	Letdown flow to purification demineralizer in obstructed	Letdoun flow to 3-vsy valve RP-1% (HF-VIO) is reduced or terminated	
Pressure Gauge 1. Internal fault Flant Instru- None None Re- FQ-73 Incorrect Results in mentation None Re- Results in mentation Re- Results in Re- Results i	3.5		+	Internal fault results in incorrect signal	Plant Instru- mentation	None	Жоле	determine FT-29 to determine latdom flow (requires HP-7 (HP-W5) and HP-R2 be shut), repair transmitters;
Pressure dauge 1. Internal fault Plant Instru- None Mone PG-73 incorrect measurement			'n	Control power failure results in incorrect signal	Electric Power	Fone	None	electric power
	3.3		2	Internal fault results in incorrect measurement	Plent Instru-	Youe	Rone	Repair when detected

1.0 SUBSYSTEM: LETDOWS COGLERS TO 3-WAY VALVE HP-14 (RP-VIO) (Continued)

			Potential Failur	e Hode	Immediate i	Effects	
	Component		Hode	laierface Involved	Within Subsystem	At Subsystem Interface	Remedial Action Within Subsystem
1.3.7	Valve HP-196 (NC)	1.	Fails open due to internal faul?	Outlet of Letdown Filter NP-Fi&	Neduced letdown flow to purification demineralizer	Reduced letdown flow to 3-way valve HP-14 (HP-VIO). (Letdown flow bypasses HP-X1 and HF-14 (HP-VIO))	Close HP-57
1.3.8	Valve HF-197 (NC)	1.	Fails open due to internal fault	Eniet 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-1* (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 HF-1% (HF-V10) is terminated if HF-X1 is plugged	Open HP-9 (1HP-V6) and HP-11 (1HP-V9) and use HP-X2 if available
		•	Potential feilure to open due to unaveilebility of instrument air (assumed)	Instrument ifr	Purification demineralizer MP-I1 bypass unavailable if required	Letdown flow to 3-way walve HP-1% (HP-V10) is terminated if HP-X1 is plugged	
1.3.10	Valve HP-8 (NO) (HP-V7)	1.	Fails closed due to internal fault	-	tetdown flow through purification demineralizer HP-X1 is obstructed	Letdown flow to 3-way valve HP-1% (HP-V10) is terminated	Open HP-9 (1HP-VB) and HP-11 (1HP-V9) and utilize purification domineralizer HP-X2 if not being used by Unit 2
		2.	Spuriously closed	Control Signal	Letdown flow through purification domineralizer HP-X1 is observed	Letdown flow to 3-way valve EP-14 (HP-V10) is terminated	

8

P. S SUBSTISTEM: LETS-SAN COOLERS TO 9-SET FALFE HP-14 (HP-F10) (Continued)

		- 1	Poceaciel Tailure Mode	e Mode	Issaediste Effects	Effects	
116	Component		Hode	Interface Involves	Within Subsystem.	At Subsystem Interface	Remedial Action Within Subaystem
1.3.10	(HP-47)	÷ ÷	Falls to close when required due to internal fault Falls to close when require, due to unsatisbuilty of instrument air (casumes)	Instrument Air	Purification demineralizer HP-II isolation is unavailable Purification demineralizer HP-II isolation is unavailable	Continued letdown Flow to 3-way valve HP-14 (HP-110) Continued letdown flow to 3-way valve HF-14 (HF-110)	Close HP-47; Close HP-47; restore instrument sir
1.3.11	Purification Dealneralizer HP-E1	f	Fail plugged	1	Letdown flow is blooked in purffication demineralizer RP-Xi	Letdown flow to 3-way walve MP-14 (MP-V10) is terminated	Isolete HP_X1 using HP_8 (HF-V7) and use HF-X2 if available or bypass by opening HF-13 (HF-85) (reduced chesistry
1.3.12	Stop Check Valve		Fails plugs.3	1	Letdown flow through purification dealneralizar MP-E1 is obstructed	Latdown flow to waive RP-14 (hP-V10) is terminated	Isolate HF-E using HF-E (HF-T) and use HF-IZ if available or bypase by opening HF-H3 (HF-E) (reduced chemistry control)
8.5.8	(1HP-VB)	÷ ~	fails open due to internal fault. Spuriously opened	Control Signal	desineralize: RF-IZ 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 lardown flows if purification flows of the being used by unit 2, then the letdown flows of the two units may be mixed depending on the pressure difference between the two	Increased or reduced letdown flow to 3-way waive HP-1% (HP-VIO) letdown flow to 3-way waive HP-1% (HP-VIO)	Remedial action dependent on Unit 2 operating requirements (INP-W8)

1.0 SCRSTSTAM: LATICOMM COCR.PM. TO 3-MAY VALVE HP-14 (RF-V16) (Continued)

	1	Potential Failure Mode	2 Node	Ismediate Effects	ffects	
Component		Mode	Interface	Within Subsystem	At Subsystem Interface	Remedial Action Within Subsystem
1.3.13 Valve HP-9 (MC) (1HP-V8) (cont'd)	ń	Fails to open when required due to internal facial	1	Prevents use of spare purification demineralizer NF-X2 by unit i	Potential reduction in chemistry control	Continue to use HP-X1 if available or open HP-13 (HP-W5) and
	*	Potential failure to eyes due to unevallability of instrument air (assumed)	Instrument Bir	Prevents use of spare purification demineralizer HP-X2 by unit 1	Chemistry control	Continue to use HP-X1 M available or open HP-13 (HF-K5) and bypass HP-X1; restore instrument air
1.3.14 Valve HP-11 (NC) (1HP-79)	-	Fells open due to Internal Casat	1	of purification demineralizer HF-I2 is heigh used by unit 2, then the letdown flow of unit 2 will letdown pressure is greater than unit 1 letdown pressure is letdown pressure.	Increased letdown flow to 3-way valve HP-14 (HF-V10)	Close HP-10 (2HF.W6) and HP-12 (2HP-W9) depending on Unit 2 operating requirements
	'n	Spuriously opened	Control Signal	If purification demineralizer HF-I2 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)	(1HP-F9)
	-	Falls to open when required due to internal fault	1	Prevents use of spare purification demineralizer HP-X2 by unit 1	Potentisi reduction in chemistry control	Continue to use RP-X1 if available or open HP-13 (HP-W6) and
	*	Potential failure to open due 30 unavailability of instrument air (assumed)	Instrument Air	Prevents use of spare purification demineralizer HP-X2 by unit i	Potential reduction in chemistry control	Continue to use HP-K1 of available or open HP-13 (HP-W6) and bypass HP-K1; restore instrument air

APPENDIX B

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

2.0 SUBSISTERS: SCP SEAL WATER RETURN

			The second secon				
-	Component		Mode	Interface	Within Subsystem	At Subsyntem Interface	Remedial Action Within Subsystem
2.1 Se	Seal Leak-off Line(s) (% Total	(a To	otal, 1/RCF):				
2.1.1	Pressure Transmitter(s)	÷	Instrument connection	ı	Small loss of reactor coclast	Incorrect pressure eignal	If accessible, repair
	1PT-21, 1PT-22	ni .	Transmitter failure due to intertel faults	1	No effect	Incorrect pressure signal to I&C system and	If accessible, repair
		ė.	Incorrect output due to lose of power	Mc System, Sleeter Fower Mcggly	No effect	Incorrect pressure signal to 1&C system and confrol room	Restore power
2.1.2	Motor Operated Isolution Falve(s) HP-226 (IHF-V43A), HP-332 (IHF-V43B),	2	Closes on spurious signai	14C System	Flow stopped in single lesk-off line	Seal leak-off flow from a single RC pump blocked, control room mlarm	Attempt to gen failed valve or open seal bypass valve
		Ň	Inadvertantly	1	Flow stopped in single leak-off line	Seal leak-off flow from a single RC pump blocked,	Reopen valve
		÷	Fails closed due to internal fauit		Flow stopped in single leak-off line	Seal leak-off flow from a single RC pump blocked, control room slarm	Open seal bypass valve (HF-275)
		÷	Valve fails to close when required due to co rol s.gnul failure	18C System	Flow not isclated	Subsystem not Included from RCS	Close local valves on affected line
		ń	Valve fails to close on desaid	Picotrio Power	Flow not isolated	Subsystem not isolated from ACS	Restore power, close local valves on
		ė	Valve fails to close on desand due to internal fault		Flow not inclated	Subsystem not isolated from RCS	Close local valves on affected line
2.1.3	Manuel Boolation Valves (2/11ne) HP-205, HP-201, HP-219, HP-211, HP-219, HP-221,	-	Walve falled closed (plegging, dsmesed, etc.)	1	Flow stopped in single lest-off line	Seal leak-off flow from a single RC pump blocked, control room alarm	Open bypass valve around falled valve (local action)
2.1.3	Flow Trainmitter(s) 1F7-19, 1FT-20, 1FT-21, 1FT-22, 1FT-113, 1FT-114, 1FT-115, 1FT-116	-	Instrument connection leak	1	Small loss of reactor coolent	Incorrect flow algraits to 18C system and central rocc	If accessible, isolate leaking transmitter(s), flow bypase available (local sotion just outside of secondary whielding)

2.0 SUBSISTEM: RCP Sole, MATER RESIDEN (Continued)

		-	Potential Failure Mode	Mode .	Immediate Effects	Effects	
	Component		Mode	Interface	Within Subsystem	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, (cont.d)	ń ń	Incorrect output due to loss of power Transmitter fallus due to internal	Etectric Possi Supply, isc System	No effect	Incorrect flow signal to I&C system and control room incorrect flow signal to I&C system and control room	Restore power supply If accessible, utilities bypeas, isolate component and repair (local section just outside of secondary shielding)
60	2.2 Seal Bypass Line(s) (Normally	Drag	lly Closed, Open When #1	Sont-Leakoff Rat	Closed, Open When #1 Snat-Leakoff Rate is Too Low) (# Total, 1/RCP):	10	
2.2.1	Fressure Transmitter(s) 1PT-19, 1PT-20.	-	Instrument connection leak	1	Small loss of reactor coolant	Incorrect pressure signal transmitted to I&C and	If accessible,
	1PT-21, 1PT-22	'n,	Incorrect outsat due to loss of power	Supply, 14C	No effect	Incorrect pressure signal transmitted to Ikc and	Restore power supply
		m.	Transmitter failure due to locurnal fault		No effect	Incorrect pressure signal transmitted to I&C and control room	If secessible, repair compenent
2.2.5	Check Valve(s) HP-263, HP-266, HP-269, HP-272	-	Valve failed oldered (plugged, damaged, etc.)	ī	Flow is a single hypass line stopped	Seal bypess flow path blocked from a single BC puer	If accessible,
		'n	Paive fails to prevent backflow	ı	No offsot during steady state	No effect during steady state	Repair component at shutdown
2.2.3	Manual Isolation Valvos (2/line) HP-264, HP-265, HP-270, HP-271, HP-273, HP-274	-	Walve falls 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.	Flow Transmitter(s) 1FT-109, 1FT-110, 1FT-111, 1FT-112	÷	Instrument connection leak		Small loss of reactor coclant	Incorrect flow signal transmitted to I&C	If accessible,
		'n	Transmitter failure due to internal fault	ı	No effect	Incorrect flow eignal transmitted to I&C	If accessible, repair
		÷	Incorrect output due to loss of power	Electric Fower Supply, 185 System	So effect	Incorrect flow signal transmitted to 15C and control room	Restore power supply

Recommend				Potontial Pailure Mode	. Myde	Insediate Effects	Effects	
Noter Operated 1. Taive fails in open 14.5 Spring Saal return bypass flow Interesting 1. Taive fails in open 14.5 Spring Saal return bypass flow Interest signal on desact or offices or offices and descond deston of the saal return bypass flow interesting to one specific action of the saal return bypass flow interesting the sail of the saal return bypass flow interesting the sail of the saal return bypass flow interesting the sail of the saal return flow and base of the saal return flow and base of the sail of the saal return flow and base of the saal return flow and saal return flow for all sail sail sail sail sail sail sail	9 . [2]	Совронен	- : 1	Mode	Interface involved	Within Subsystem	At Subsystem Interface	Reservatel Action Within Subsystem
Hoter Operated 1. Nature failth colored Spanish to control signal failures or loses on agustions afront on agustion agustio	2.3	Seal Bypass Return Hea	der					
2. While fails to open condemned or closes on demand due to internal fails to open condemned due to internal fails to open condemned or closes of the condemned due to internal fails to obe condemned due to internal fails to obe condemned due to internal condemned due condemned due to internal condemned	2.3.1	Motor Operates Isolation Valve HF-275 (HF-V48)	-		He System	Seal return bypass flow blocked	Seal return bypass flow path unavailable to all RC pumps	Rone
3. White fails to open on demand due to cheeked the control of demand due to cheeked the control of demand due to cheeked the control of demand due to cheeked the			'n	Valve falls to open on demand or closes on spurious algusi	Electric Poest Supply	Seal return bypass flow blooked	Seal return bypans flow path unavailable to all RC pumps	Restore power
Relate falls occase when required Poser Jupply			ri,	Walve fails to open on demand due to internal facit		3eal return bypass flow blocked	Seal return bypass flow path unavailable to all RC scaps	Repair component
Hotor Operated to the fails open to and the fails of the fails of the fails of the fails and the fails and the fails of the fails to of the fails of the fails of the fails to of the fails to of the fails to of the fails of the f			-	Valve fails open or fails to close when required	dec System, Electric Power Supply, Internal	Stanfact	No effect	Repair component if accessible
and Makeup HP-276 2. Agive opens on the color of a seek return flow stopped to seek re	.3.2	Motor Operated Isolation Valve to Stand Pipe Fill	-	Valve fails open due to internal fault		Stand pipe fill lines open to seal return flow	Potential loss of went on RCF went seal	None
Hotor Gparated 1. Valve falls close 3 — Seal return flow alopped due to internal fact System, E3 Seal return flow alopped falls to close on demand to close for demand for falls to close falls fal		and Hakeup HP-276 (RP-V49)	r,	Valve opens on spurious signel	tac System		vent	Fone
HP-20 (MP-NT2) 2. Walve closes on apurious signal apurious states of the to internal fault faul	#.	eal Water Cooler Jule	t Hea	ider:				
2. Walve closes on 14C System, E3 Seal return flow stopped 3. Valve fails to close 4. Valve fails to close 5. Walve fails to close 6. Walve fails to close 7. Valve fails to close 7. Valve fails to close 8. System 8. Seal return flow stopped 9. Valve fails to close 9. Va	-	Notor Operated Isolation Valve NP-20 (NP-V12)	÷	Valve fails closed due to internal fault	1	Seal return flow stopped	Seal return flow from all RC purps stopped	Repair componen
4. Valve fails to close to degraded to the flow stopped to close to close to demand to close the required to close the required to close t			×.	Valve closes on spurious signs!	iac System, ES	Seal return flow atopped		None
A. Valve fails to close Elektric Power Rector building isolation Seal return flow continues degraded when required to close ES supply Reactor building isolation and required to close IAC System Reactor building isolation Seal return flow continues degraded, seal return flow continues and sasuming valve is air-to-open) 2. Nalve closes of System Seal return flow stopped Seal return flow from all solation Walve air-to-open) 3. Nalve closes of ES system Seal return flow stopped Seal return flow from all spurious signal solation and store of Seal return flow from all seal return flow stopped Seal return flow from all RC pumps stopped Seal return flow from all RC pu			÷	Valve inadvertantly olosed	1	Seal return flow stopped	Seal return flow form ill	Reopen valve
5. Valve fails to close 45 Seat return flow stoped 6. Valve fails to close 45 Seat return flow stoped 6. Valve fails to close 45 Seat return flow stoped 6. Valve fails close 46 Seat return flow a letter flow from all 46 System 6. Valve close 6. Valve close 6. Valve close 6. Valve fails close 6. Valve 6. Valv			÷	Valve fails to close on demand	Electric Fores	Reactor building isolation degraded	Seal return flow continues to letdown storage tank	Bestore power
6. Valve fails to close 16C System Reactor building isolation Seal return flow continues degraded, seal return flow to letdown storage tank not isolated from coolers on demand due to not degraded, seal return flow to letdown storage tank not isolation valve allowed is allowed instrument Str. (HP-VI3) 2. Valve close of linitiment Str. Saul return flow stopped allowed stopped air-to-open) 2. Valve close of linitiment Str. Saul return flow stopped Seal return flow from all appurious signal signal stopped Seal return flow from all spurious signal stopped Seal return flow from all RC pumps stopped Seal return flow flow from all RC pumps stopped Seal return flow flow from all RC pumps stopped Seal return flow flow from all RC pumps flow from all RC pum			'n	Valve fails to close when required	23	Seactor building incintion degraded	No effect provided, redundant valve closes	None
7. Valve fails to close. — Reactor building isolation Seal return flow continues on demand due to another flow in lettown storage tank not isolation Valve (assuming valve is apurious signal 3. Valve close on 18C System Seal return flow stopped Seal return flow from all squared signal sign			9	Valve fails to close when required	18C System	Seastor building isolation degraded, neal return flow not isolated from coolers	Seal return flow continues to letdown storage tank	
Phoumatic Operated 1. Valve fails closed Instrument Str Saul return flow scoped Seal return flow from all Scolation Valve all-seal stores on 18C System Seal return flow stopped Seal return flow from all square all-seal stores on 18C System Seal return flow stopped Seal return flow from all square closes scopes on spurious scopes on 18C System Seal return flow stopped Seal return flow from all square closes scopes on 18C System Seal return flow stopped Seal return flow from all squares scopes of seal return flow stopped Seal return flow from all squares scopes of seal return flow stopped Seal return flow flow from all squares scopes of seal return flow stopped Seal return flow flow from all squares scopes of seal return flow stopped Seal return flow flow from all squares scopes of seal return flow stopped Seal return flow flow from all squares scopes of seal return flow stopped Seal return flow flow from all squares scopes of seal return flow stopped Seal return flow flow from all squares scopes of seal return flow stopped Seal return flow flow from all squares scopes of seal return flow stopped Seal return flow flow from all squares scopes of seal return flow flow from all seal return flow flow flow from all seal return flow flow from all seal return flow flow from all seal return flow flow flow flow flow flow flow flow			-	Valve fails to cluse 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	
Walve alwaes on 16C Systom Seal return flow stopped Seal return flow from all Attempt spurious stopped Seal return flow atopped Seal return flow from all Attempt spurious widness to seal return flow from all Attempt spurious widness to seal return flow from all Attempt spurious widness to seal return flow from all Attempt spurious widness to seal return flow from all Attempt spurious widness to seal return flow from all Attempt spurious widness to seal return flow from all Attempt spurious widness to seal return flow from all Attempt spurious widness to seal return flow from all Attempt spurious widness to seal return flow from all Attempt spurious widness to seal return flow from all Attempt spurious widness to seal return flow from all Attempt spurious widness to seal return flow from all Attempt spurious widness to seal return flow from all Attempt spurious widness to seal return flow from all Attempt spurious widness to seal return flow from all Attempt spurious widness to seal return flow from all Attempt spurious widness to seal return flow from all Attempt spurious widness from all Attempt spurious widne	7.5	Fneumatic Operated Isolation Valve RP-21 (HP-V13)	÷	Valve fails closed (assuming valve is mir-to-open)	Instrument fir	Seal return flow alopped	Seal return flow from all AC pumps stopped	Attempt to open
Walve closes on ES Seal return flow stopped Seal return flow from all Attempt apurious sources someway.			ć	Valve aleses on apurious Aignal	IAC System	Seal return flow stopped		
and the same of th			m	Valve closer on apurious sugner	F25	Seal return flow stopped		

2.4 SURCESTRM: GCP SEAL BATER RETURE (Continued)

Properties Pro			-	Potential Fathure Mode	• Hode	Immediate Effects	Rffeots	
A valve falls closed described descr		Component		Mode	Interfece	Within Subsystem	At Subsystem Interface	Remedial Action Within Subsystem
Cont. 4 State falls to close Gagraded, seat return flow to defend atoms and degraded, seat return flow continues on design does to return concers	2.2		-	Valve fails closed due to internal fault	1	Neal return flow stopped	Seal return flow from all RC pumps stopped	Repair comperant
6. Naive fails to close k3. Reaction building isolation to effect the fails to close have required to the requ		(cont.d)	ě,	Valve fatta to close on demand due to interns! fault	ı	Esector building isolation degraded, seel return flow one laolated from seel return coolers	Seal return flow continues to letdown atorage tank	Utilize valve HP-20
Filter Thottle (plugged, descond the tendency of the tendency			÷ ÷	Valve fails to close when required Velve fails to close when required	140 Syries	Reactor building isolation degraded. Real return flow not isolated from coolers	No effect provided redundant valve closes Seal return flow continues to letdown storage tank	None Utilize valve HP-20
Seal Return 1. Filter Fails. Glosed Seal return flow reduced or Seal Return flow from all Operation 1. Filter plugged Seal Return flow reduced or Stock return flow from all Operation 1. Filter plugged Seal Return flow reduced or Stock return flow from all Operation 1. Filter plugged Seal Return flow reduced or Stock return flow from all Operation 1. Mark and and and Seal return flow reduced or Stock return flow from all Operation 1. Mark and and and Seal return flow reduced or Seal water flow from all Operation O	.3		-	Valve failed closed (plugavd, damegrd, etc.)		Seal return flow reduced or stopped	Seal return flow from all AC pumps reduced or atopped	Repair component
Seal Return 1. Filter plugged stopped atopped atopped atopped stopped atopped	-	Seal Return Filter Isolation Valva(s) HF-278, HF-279	-	Valve faxlelosed (plugged, .saeged, etc.)	ţ	Seal return flow reduced or stopped	Seal return flow from all RC pumps reduced or stopped	Open bypess valve (RF-286) around filter (local action)
Herra isolation 1. Valve fails closed Seal return flow reduced or Seal water flow from all RC Valve(s) HP-75, atc.) Operating RC Seal 1. What exchanger tubes blucked tubes blucked tubes blucked state at the failure. Spare HP-CIA 2. Tube failure. SCM System Loss of tractor coolant to Resetor coolant to Resetor coolant to along tank aforego cash water return to letdown along tank at the failure.		Seal Return Filler	÷	Filter plugged	1	Seal return flow reduced or stopped	Scal return flow from all RC pumps reduced or atosped high transmitted on 1FF-119	Ocen bypans valve (HP-280) around filter (local action)
Manual isolation 1. Valve fails closed Seal return flow reduced or Seal water flow from all RC We study of the study of	10	Seal Return Cooler(s):						
Operating RC Seal 1. What exchanger Seal return flow reduced or Seal water flow from all BC We Return Cooler tubes blunked at the Spare HP-C18 (or Spare HP-C18) 2. Tube failure. NOW System Loss of reactor coolant to Resetor coolery teduced Seal water return to letdown storage tank		Manual Isolation Valve(3) HP-72, HP-74, HP-75,	-	Valve fails olosed (plugging, desaged, stuck closed, sto.)	1	Seal return flow reduced or stopped	Seal water flow from all MC pumps reduced or alopped	Valva in spure cooler (losal action)
Tube failure. SCM System Loss of reactor coolant to Resolve coolent light to Wa RCW system, reduced cash water return to letdown storage tank	v.	Operating RC Seal Return Cooler RP-C1B (or Spare NP-C1A)	-	Meat exchanger tubes blucked	1	Seal return flow reduced or alopped	Seal water flow from all MC pumps reduced or stopped	Wal- : in scare cooler (local action) and repair blocked
			ň	Tube failure.	NOW Ayestee	Loss of reactor coolast to ALM	Resolut coolett talvage to RCM system, reduced cest water return to letdown storage tank	Valve in spare cooler (local action) or isolate seal retorn header from cooler of required and take appropriate precentions for alopping

2.6 SUBSYSTEM: ACP SEAL WATER RETURN (Continued)

			Potential Failure	Hode	Immediate	Effects	
	Component		Hode	Interface Involved	Within Subsystem	At Subsystem Interface	Remedial Action Within Subsystem
2.5.2	Operating RC Seal Return Cooler RP-C1B (or Spare RF-C1A) (cont'd)		Loan of RCW	RCW System	Loss of seal return cooling (high cooler discharge temperature)	High temperature discharge to leidown storage tank, high temperature reading on IT-45 or IT-46	Valve in spere cooler if NCW is available to it (local action)
		*.	Loss of heat transfer capability due to internal damage		Los of seal return cooling (high cooler discharge temperature)	High temperature discharge to letdown storage tank, high temperature reading on IT-45 or IT-46	Isolate affected cooler and valve in spare (local action)
		5.	Vapor lock in occler		Reduction in seal return cooling capacity (high cooler discoverge nemperature)	High temperature discharge to letdown storage tank, high temperature reading on TT-45 or TT-46	Isolate affected cooler and velve in spare (local action)
2.5.3	Cooler Discharge Header Check Valve 39-189	1.	Valve fails closed (plugging, demaged, etc.)		Seal return flow reduced or stopped	Seal return flow to letdown storage tank reduced or stopped, seal return flow from all BC pumps reduced or stopped	Repair component
		2.	Valve fails to prevent backflow	Seal Water Coolers, Setdown Serage 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 Sy	stem Inlet Flows:						
2.6.1	Seal Injection Flow	1.	Loss of flow	Seel injection (Subsystem 4.0), RC Pumps	Seel 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 Sy	atem Piping:						
2.7.1	Vents, Drains, Piping, Instrument Connections, etc.	1.	System losks	*	Loss of reactor coolant	Loss of reactor coolant, slightly reduced flow to letdown storage tank	Isolate leaks end repair as needed

APPENDIX C

FAILURE MODES AND EFFECTS ANALYSIS

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

3.6 SUBSISTEM: LETDOWN STORAGE VANE (LST), INLET FILTERS, AND RPI PUMPS

		Potential Potiure Hode			Immediate Effects		
	Component.		Hode	Inter ace involved	Within Subsystem	At Subsystem Interface	Remedial Action Within Subsystem
3.1 L	etdown (Makeup) Filte	rs (:	2):				
.3,1.1	Presumatic Operated Inlet Valve(s) HP-57 (HP-V29A), HP-18 (HF-V29B)	1.	Valve fails closed (assumed valve is mir-to-open)	Instrument Air	Loss of flow to LST from letdown, chemical mddition, and myetem makeup	Reduction and eventuel loss of available makeup in LST	Utilize spare filter, open valve locally, bypans to LST, or switch to BWST if LST level is unacceptably low
		2.	Velve falls 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	filter, bypass to LST, or switch to BWST if LST level is unacceptably low
		3.	Valve closes on spurious signal	1&C System	Loss of flow to LST from latdown, 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 SUST if LST level is unsceeptably low
		*	Valve inadvertantly closed		Lors 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 35 Mose when required	Power Supply, Internal	Cannot isolate filter for asintenance	No effect	Repair component
3.1.2	Makeup Filter P Transmitter 1PT-15	1.	Transmitter feilure due to internal faukt	-	Potential for undetected filter plugging	Incorrect pressure drop signal to IAC and control roce	onitor pressure drop with local
		2.	Incorrect output due to toss of power	Electric Fower Supply, 140	Potential for undetected filter plugging	Incorrect pressure drop signal to I&C and control room	Monitor pressure drop with local
		3.	Instrument connection leak	*	Small loss of reactor cuclant and small reduction in flow to LST	Incorrect pressure drop signal to I&C and control room	Repair leak
3.1.3	Filter(s) RP-F1A, BP-F18	1.	Filter plugged		Letdown, chemical addition, and system makeup flow induced or stopped	Reduced inventory in LST and high pressure drop signal to 1&C from 1PT-15	Utilize spere filter or hypess filters via HF-19

3.0 SUBSTSTEM: LETDOWN STORAGE TARE (LST), INLET FILTERS, AND BPI PUMPS (Continued)

	Component.	Potentiel Failure Mode			Immediate Effects		
			Hode	Interface Involved	Within Subsystem	At Subsystem Interface	Remedial Action Within Supsystem
3.1.4	Manual Filter Discharge Block Valve(s) HP-57, HP-58	٤.	Valve railed closed (plugging, damaged, eto.)	-	Loss of flow to LST from letfown, obcales? addition, and system not sup	Reduction and eventual loss of availab.e makeup in LST	Utilize spare filter path or bypass filters via HF-19
3.2 L	etdown Storage Tank:						
3.2.1	Inlet Check Valve NP-78	ŀ	Walve 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)	Honitor LST level, switch to SWST if LST level is unacceptably low
		2.	Valve fails to prevent backfrow	(Scal Return)	Wone during steady state	None since theck valve HF-18 in Subsystem 2.0 is a backup	Regair component
3.2.2	Tank Went Globe Valve HP-80	1.	Valve failed closed (plugged, damaged, etc.)	Ebemical Addition (Subsystem (3.0)	Loss of normal LST vent path, buildup of moncondensible gases in LST, potential reduction in H ₂ mass transfer rate into reactor coolent	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	Menual H ₂ /R ₂ Supply/feolation Valve B-111	1.	Value failed closed (plugged, damaged, etc.)	Bulk Starage, W Blanketine System	Loss of H ₂ advistion to LST	deduction in H ₂ concentration in reactor coclant and reduction in 0 ₂ scavenging capability	Repair compensat
3.2.4	Level Transmitters 1LT-33F1, 1LT-33F2		Transmitter failure due to internal fault		If melected transmitter indicates low flow from 3-way valve automatically transfers letdown flow to LST and persfor may increase LST level with breed holdup. Potential for LST tank overfilling, H2 addition blockage, and lower H2 concentration in BCS. If transmitter indicates high, operator may decrease letdown flow and potentially reduce NFSH on HPI pumps	Loss of or incorrect LST level indication, incorrect signal to 3-way valve Seterlock circuit and potential for reduced H ₂ concentration in BCS. Operator response may also result in decreased letdown flow	Monitor with redundant transmitter

3.0 SUBSISTEM: LETHONE GYORAGE YARE (LSE,, PRILET FILTERS, AND RES PURPS (Continued)

			Potential Failure	e Hode	Immediate	Effects	
	Component		Hode	interface Involved	Within Subsystem	At Subsystem	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, 1&C System	If relected transmitter indicates low flow from 3-way value automatically transfers detdown flow to 05T and operator may thorease LST level with bised holdup. Potential for LST tank overfilling. He addition blockage, and lower He concentration to RCS. If transmitter indicates high, operator was decrease letdown flow and potentially reduce HPSN on HPI pumps	Loss of or incorrect LST level indication, incorrect signed to 3-way valve interlock circuit and potential for reduced H, 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 transmittere affected. If selected transmitter indicates low flow from 3-way valve sutomatically transfers letdown flow to LST and operator may increase LST level with bleed holdup. Totential for LST tank overfilling, H2 addition blockage, and lower H2 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 BCS. Gperator 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	Supply, 14C System	to effect	Loss of or incorrect LST pressure indication	Rentore power supply
		2.	Transmitter fallurs		No cifect	Loss of or incorrect LST	Repair component
		3.	Instrument connection leak	-	Small loam of LST inventory	pressure indication Less of or incorrect LST pressure i dication	Repair component
3.3 H	PI Pump Suction Header	181					
3.3.1	Motor Operated Isolation Valve HP-23 (HP-V21)	1.	Walve fails closed	-	Fire to HPI pumps stopped, leas of NPSH to HPI pump resulting possible to jump damage	Immediate loss of flow to RC makeup and RC pump seals	Align supply from BMST via motor operated valves and align alternate HFI pump if required

3.0 SUBSISSIEM. LETTONS STORAGE TARK (LOST), IMLET FILTERS, AND HER PUMPE (Continued)

State Stat			!	Potential Fallura Mode	3 Mode	Immediate Effects	Erfects	
Hotor Operated 1. Valve fails to 2. Valve fails to 3. Valve fails to 4. Valve fails to 5. Valve fails to 6. Sanot remotaly liquid to NFT pump it atopped, if the use pump it atopped, if th		Component		Mode	Interface	Within Subayatem	At Subsystem Interface	Remedial Action Within Subsystem
A. Falve fails to the first purp resulting possible in purple fails to fails to fails to fails for the fails of the fails to the fails of the fails the fails to	15		~	-	IAC System	Flow to HFI pumps stopped, loss of HFSH to HFI pump resulting possible in pump damage	Smedists loss of flow to MC makeup and MC pump seals	Menually open valve or align supply from EWSI via motor operated valves and align alternate HPI pump if
Check Valve falls to Effective Four Supply. Check Valve 1. Valve falls closed Free Four Four Four Four Four Four Four Four			÷		ı	Flow to MFI pumps stopped, loss of MFSH to MFI pump resulting possible in	Issuediste loss of flow to SC wakeup and RC pump coals	Reopen valve, align alternate HFF pump if
Check Walve Valve fails stone Flow to HPI pump stopped, Is readting in possible pump damage Prevent backflow We effect during stendy No prevent backflow We effect during stendy No state operation We effect during stendy No state We effect during stendy We effect during stendy No state We effect during stendy W			•		Mac System, Electric Power Supply, Jevernsk Freit		No effect	Utilize local valves for isolation
Hotor Operated 1. Valve falls load Hotor Operated 1. Valve falls load HP-98 (HP-98a) 2. Walve linedvertantly closed 3. Valve closes on lac System Flow to HPI pump 1A stopped, 1f spursolate apurious signal damaged A. Valve falls to close or demand Sannot remotely isolate No pump HP-1A for naintenance additionance	3.2		•		1	Flow to MFI pump stopped, loss of NFSH to HFI pump resulting in possible pump damage	lamediate loss of flow to BC makeup and RC pump meals	Align mupply from BWST wim motor operated valves and align alternate HPI puw if
Hotor Operated 1. Valve fails load 1. Valve fails load 2. Valve instruction 2. Valve instruction 3. Valve closes on 14C System Flow to HFI pump 1A stopped, 1F spurious signal 4. Valve fails to close or demand Prost to HFI pump 1A stopped, 1F Seansged 4. Valve fails to close or demand Prost to HFI pump 1A stopped, 1F Seansged Asserted Seansged Asserted Seansged Asserted No pump HP-FIA for sealstenance			~	Prevent backflow	1	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
Valve inadvertantly Flow to MFI pump is stopped, if if use pump is stopped, if demand walve closes on is a stopped in the close on demand walve fails to Sennot remotely isolate No pump is for saintenance saintenance	3.3	Motor Operated Jaciation Valve HP-98 (HP-V26A)	-		ı	Fice to HPI pump 1A stopped, if in uso pump 1A may be demaged	If HC-PIM in use, loss of flow to MC makeup and seal injection. Of HC-PIM in use, no effect	Trip MFI pump 1A and use pump 1B
Walve closes on 1&C System Flow to HPI pump 1A may be damaged damaged Walve fails to Sennot remotely isolate No pump HP-PiA for saintenance			ć.		ı	Flow to HFI pump 1A stopped, if in use pump 1A may be demaged	If HF-PIA in use, loss of flow to RC makeup and seel injection. If	Trip HPI pump 1A and use pusp 1B
Valve fails to Cannot remotely isolate No pump HF-PiA for saintenance			m.	Valve closes on spurious rignel	14C System	Flow to HPI pump 14 stopped, if in use pump 14 may be damaged	If HP-PiA in use, loss of flow to MC makeup and seal injection. If	Trip HPI pump 18 and use pump 18
				•	1	Sannot remotely isolate pump IIP-P1A for maintenance	No effect	Isolate pump HF-FIA with manual velves. If deskred, utilize one of 2 remaining HPI pumps

3.0 SUBSTREET RETECHS STORAGE TARE (LST), IRLET FILTRES, AND BPI FUMPS (Continued)

			Potential Fallure Mode	e Mode	Immediate Effects	Effects	
	Coaponent		Mode	Interface	Within Subsystem	At Subsystem Interface	Rezedial Action Within Subsystem
3.3.3	Motor Operated Isolation Valva NP-98 (NF-V28A) (cont'd)	v.	Valve fails to close when required	IAC System	Cannot remotely isolate pump HF-PIA For maintenance	No effect	Isolate pump HF-PIA with manual valvos. If desired: utilize one of
		÷	Valve fails to close when required	Electric Power Supply	Cennot remotely isolate pump HP-PtA for meintenance	No wifeet.	pumpe He-PiA with menual valves. If desired, utilize one of 2 remaining HPI
3.3.4	Manual Isolation Valves HP-99 (GP-Y28B), HP-109 (HP-Y26C)	-	Valve-fails closed (plugging, dsmaged, etc.)	1	Suction to standby pump HF-PiC blocked. If pump is started, pump may be damaged	If pump HF-PIC in use, loss of itou to BC sakeup and seal injection. If other pump in use, no effect	Utilize alternata
3.3.5	Manual Isolation Valve RP-107 (HP-V268)	-	Valve follow cloned (plugging, demoged, etc.)	1	Suction to stendby pump HF-PiB blocked, If pump is started, pump may be demaged	If pump HP-FIB in use, loss of flow to 8C makeup and seal injection. If other pump in use, no affect	Utilize alternate HPI pump
3.3.6	Manual Isolation Valve HF-103 (HP-V26A)	-	Valve falls closed (plugging, dessged, etc.)		Flow to operating pump E2-F18 blooked, Unless cump is tripped, pump damage could occur	If pump HF-Pth in use, loss of flow to MC makeup and seal injection. If other pump in use, no effect	Trip HPI pump iA and utiliza pump iB
	5.4 Mr. Pumps and Discharge Mrnifold	e Hr	ilfold:				
3.5.	Operating HPI Pump HP-F1A		Mechanical fellure to operate Pusp falls due to loss of power	Electric Power Supply	No discharge flow from failed pump No discharge flow from failed pump	No flow to RC makeup or RC pump seals No flow to RC makeup or RC pump seals	Utilize alternate HPI pump Restore power or utilize an alternate HPI pump on another Power source
3.4.2	Spare NPI Pumps NP-P1B, NP-P1C	-	Fusp fails to etart, due to aignal failure	iaC Syntem	No discharge flow from pump demanded	lf pump is demanded because of failure with operating pump, no flow te RC makeup or RC pump seals. If pumps are just being switched, no effect	Utilize alternate HPI pump, repair oir sit

3.0 SUBSYSTEM: LEYDOWN STORAGE TARE (LAT), IMLET FILTERS, AND HPI PUMPS (Continued)

			Potential Feliure	Hode	Ismediate I	Effects	
	Component		Mode	Interface Involved	Within Subsystem	At Subsystem Interface	Remedial Action Within Subsystem
3.4.2	Spare HPI Pumps HP-PIB, HP-PIC (cont'd)	2.	Jump fails to start due to internal fault		No discharge flow from pump demanded	If pump is demanded because of feilure 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 ulternate HPI pump
		2.	Valve in standby pump discharge fails to prevent backflow	-	Backflow through a non-perating spare pump to suction of operating pump (potential HPI pump datage)	Reduced flow to seal injection and/or makeup	Isolate failed check valve (local action). Monitor critical flows
3.4.4	Recirculation Line(s) Associated Fits Pumpo: EI-PIA, HP-PIB, HP-PIC	1.	Line blookage due to plugged blook welve or orified	Seal Return Cooler Selet (Substitutes and 2.0)	Potential damage to HFI pump via pump descharge to makeup and seal injection is not enough for pump operation	Potential loss of BC makeup and scal injection	Htilize alternate HPI pump (other action available from outside the subsystem)
3.4.5	Discharge Block Valve(s) HP-106 (HP-V344), HP-110 (HP-V348), HP-114 (HP-V34C)	1.	Valve in operating pump discharge fails closed (plugged, ≪ammaged, etc.)	RCP Seals, Reactor Inleading Street Devs 1, 8 and Crossovers A and B	No discharge flow through feiled valve	No discharge flow from operating NPI pump to RC pumps sewls or RC makeup	Utilize elternate HPI pump
3.4.6	Hotor Operated Isolation Valve HP-115 (HP-V35A)	1.	Valve closes on spurious signal	IAC System	If pump HP-PIA operating, flow to seak injection is stopped. If pump HP-PIB is operating, flow to cormal RC makeup is stopped	If pump HF-P1A operating, flow to seal injection is stopped. If pump HF-P1B is operating, flow to normal RC makeup is atopped	If operating pump in MP-P1A, etart pump HP-P1B. If operating pump is HP-P1B, etart HP-P1A or (for unthrottled makeup) open valve HP-118 to reactor inlet LOOP B

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Angle Angl			-	rocential salinge hode	e Mode	Immediate Effects	Effects	
S. Faire fails closed on to internal control of the		Component		Mode	Interface	Witain Subsystem	At Sub-yetem	Remedial Action Within Subsyster
Faire Inderctantly 1. Lone of flow Subsystem Solid	9.4.	Motor Operated Relation Valve RP-115 (MP-835A) (cent'd)	ň			If pump HP-PIA operating, flow to smal injection is alooped. If pump HP-PIB is operating, flow to normal RC sakeup is atroped	If pump HP-Pid operating, flow to seal injection is stopped. If pump HP-PiB is operating, flow to normal RC makeup is stopped	
Faction Palve Faction			ń	Waive inadvertantly olosed	ı	If pump HF-P14 operating, flow to seal injection is stopped. If pump HF-P1B is operating, flow to normal RC makeup is	If pump AP-PiA operating, flow to seal injection is stopped. If pump HP-PiB in operating, flow to normal RC makeup is	LOOP B Reopen valve
He independent of the second			•	Walve fails to close when required	IAC System, Electric Fower Supply, or Internal Fault		stopped No effect on steady state operation	Utilize local faciation valvas
Reduction Walve 1. Walve fails closed 1. Walve fails closed 1. Walve fails closed 1. Walve fails closed 1. Loss of flow 1. Loss of flow 1. Loss of flow 2. Subsystem 1. Loss of flow 2. Subsystem 2. Subsystem 3. Subsystem 3. Subsystem 3. Subsystem 3. Subsystem 3. Loss of flow 3. Subsystem 3. Subsystem 3. Loss of flow 3. Subsystem 4. Subsystem	3.4.7	Isolation Walve HP-118 (HP-W35B)	4	Valve fails open (damaged, etc.)	1	Loss of separation between HPI injection paths A and B	No effect during normal operation since injection path B is normally closed	Utilize HF-117 for isolation
Reactor Coolant 1. Loss of flow Subsystem 1.0 Reduction and eventual loss Coleton flow to of available makeup in subsystem Littown Inlet Flow Coolant 1. Loss of flow Subsystem 6.0 If in letdown/bleed and Loss of batch inputs to reduction in LST level makeup RC Seal Return 1. Loss of flow Subsystem 2.0 Fartial loss of file to Potential long-term loss of LST level and recirculation recirculation to Bust switch to Bust swit	3.4.8	Jeolation Valve HP-117 (HP-V35C)	-	Walve fails closed (plugging, damaged, etc.)	ı	Loss of ability to use HP-PIB as spare for safety injection to cold leg B	Loss of ability to use HP-Fi3 as spare for safety injection to cold leg B	
Reduction and eventual loss of letdoun flow to of available makeup in subsystem Estdown Inlet Flow 1. Loss of flow Subsystem 6.0 If in letdown/bleed and Loss of batch inputs to feed operating mode, reduction in LST level makeup RC Seel Return 1. Loss of flow Subsystem 6.0 If in letdown/bleed and Loss of batch inputs to feed operating mode, last from RC bleed reduction in LST level makeup RC Seel Return 1. Loss of flow Subsystem 6.0 If in letdown/bleed and Loss of batch inputs to feed operating mode, last from RC bleed makeup Teduction in LST level and LST level and requirement to switch rectired and rectired and rectired and rectired and resident to BNST switch to BNST switch	10°	ystem Inlet Flows:						
1. Loss of flow Subsystem 6.0 If in letdown/bleed and Loss of batch inputs to Red Sperating ande, LST from RC bleed reduction in LST level makeup askeup LST, loss of flow to Potential long-term loss Holst, loss of filt pump cequirement to switch recirculation to BMST switch	3.5.1	Reactor Coolant Letdown Inlet 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	Menitor LST level and utilize supply from BWST, bleed holdup tank, or boric seid tank
RCF Seal Return 1. Lons of Clow Subsystem 2.0 Fartial loss of flow to Potential long-term loss Harlet Flow of LST lovel and LST, loss of HPI pump of LST lovel and recirculation requirement to switch to BWST switch	5.5	RC Bleed Makeup Feed Inlet Flow		Lone of flow	Subsystem 6.0	If in letdown/bleed and feed operating mode, reduction in LST level	Loss of batch inputs to LST from MC bleed makeup	Restore letdown flow to LST
	5.3	RCP Seal Return Inlet Flow		Leas of Clow	Subsystem 2.0	Fartial loss of flow to LST, loss of HPI pump recirculation	of LST level and requirement to switch to BWST suction	Monitor LST level, utilize RC bleed makeup or BWST if required

3.0 SUBSISTEM: LETDOWN STORAGE TAME (LST), IMLET FILTERS, AND HFI FUMFS (Continued)

	Potential F	Potential Failure Mode	Immediat	Ismediate Effects	
Component	Hode	Interface Involved	Within Subsystem	At Subsystem Interface	Remedial Action Within Subsystem
3.6 System Piping:					
3.6.1 Vents, Drains, Piping, Instrument Connections, etc.	I. System leaks	ı	Loss of reactor coolant, potential for loss of MPSH 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

A.O SUNSTSTEM: BC PUMPS SEAL INJECTION

	- 1	Potential Failure Mode	* Mode	Impediate Effects	Effects	
Component		Hode	Interface Involved	Within absystem	At Subsystem Interface	Remedial Action Within Subsystem
W.1 RC Pumps Seal Injection Header:	on Hea	ider:				
A.1.1 Seal Injection Reader Hanual Isolation Valve HP-126 (RP-V27B)	-	Valve fails closed (plugged, damaged, etc.)	1	Seal injection flow stopped	Seal injection flow to RC pumps stopped	Repair component
4.1.2 Seal Injection Header Pressure	÷	Incorrect output due to loss of power	IAC System, Electric	No effect	Incorrect pressure signal	Repair component
	'n	Instrument connection	Tridden sound	Small loss of reactor coolant	Incorrect pressure signal	Repair somponent
	3	Transmitter failure due to internal fault	1	No effect	Incorract pressure signal	Repair component
N.2 NC Pump Seal Filters:						
A.2.1 Operating Filter Henual Isolation Valves HP-29, HP-132, HP-133,		Valve fails closed (plugged, damaged, etc.)	1	Flow through filter stopped	Seal injection flow to BC pumps stopped	Walve on spare fixer path, or bypass both main and stendby filters (local action)
4.2.2 Operating Soal Filtor HP-F-18 (HP-F-1A Standby)	-	Filter plugged	1	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	-	Valve fails to open on demand	ţ	No effect during normal operation. Loss of spare or bypass especity	No effect during normal operation when spare or bypass is not demanded	If one of these backups has falled, utilize the remaining
A.2.4 Standby Filter Manual Isolation Valves HP-129, HP-130, HP-131	÷	Valve fails closed (plugged, damaged, etc.)	1	Flow through btandby filter prevented	No effect	Valve in filter byfase if required (local action)
4.3 Seal Injection Flow Control:	ontro					
4.3.1 Flow Orifion	-	Orifice plugged	1	Seal injection flow reduced or stopped and control signal to throttle valve snoorset	Seal injection flow to RC pumps stopped	Repair component

		- 1	Potential Failure Hode	apole .	Immediate Effects	Effects	
	Component		Hode	Interface Involved	Within Subsystem	At Subsystem Interface	Remedial Action Within Subsystem
1.3.2	Flow Controller/ Transmitter 1FT-75	+	Transmitter failure	Electric Power Supply, 1aC System, Internal Fault	Incorrect aignal to flow costrol valve, potentially resulting in too much or too little flow.	Negligable effect for high flow since flow in threttled downstream. On low flow, reduced seal injection flow to NC pumps. Incorrect signal to 1&C system	Honitor and control flow from individual seal injection lines if required
1.3.3	Flow Control Palve HP-31 (HP-VA2)	4	Valve fails open (valve assumed air-to-close)	Instrument Air	Full RFI pump discharge flow to individual seal injection lines	Negligable effect on seal injection supply	Manually control seal flow with HF-140 or with Individual seal in jection line throttle valven
		'n	Valve fails open	Control Signal from 1FT-75, Electric Power Supply	Full HFI pump discharge flow to individual scal injection lines	Regligable effect on seal injection supply	(local action) Manually control and flow with iP-140 or with individual seal injection line throttle valves
		÷	Walve fails open due to internal damage	1	Full HFI pump discharge flow to individual seal injection lines	Regligable effect on seal injection supply	(local action) Manually control acal for with HP-140 or with individual seal injection line throttle valves
			Valve falls closed	Control Signal from 1FT-75, Electrio Power Supply	Seal injection flow reduced or stopped	Seel injection flow to MC pumps atopped	(local action) Walve in bypass and menually control seal flow from hadder (HP-140) or from individual seal injection lines
		¥.	Walve falls closed due to internal damage or plugging, etc.		Seal injection flow reduced or stopped	Seal injection flow to RC pumps stopped	(local action) Walve in bypass and manually control seal flow from header (HP-140) or from individual seal injection lines (local action)

N.O SURSISTEM: RC PUMPS SEAL INJECTION (Continued)

Herman labelation Falve fails closed Involved Falve face Falve fails closed Involved Falve fails closed Involved I				Potential Fallure Node	Node	Inmediate Effects	Effects	
Falve(1) F-136 Course		Caponent		Mode	Interface	Within Subsystem	At Subsystem Interface	Remedial Action Within Subsystem
Individual RC Pump Seal Injection Lines (* Total, 1/RC Pump): Flow Frankstter(a) Incorrect clutput due IdC System, Ro effect Incorrect flow signal Reserved Flower Supply Saal Injection Connection Fower Supply Flow Frankster Fails closed Flow Frankster Fails closed Flow Frankster Fails closed Flow Instant Flow In	*3.4			Valve falls closed (plugged, desaged, etc.)	i	Seal injection flow atopped	Seal injection flow to RC pumps atopped	Valve in bypass and manually control seal flow from beader (HF-1AG or from individual sea injection line (loom action)
Flow Transmitter(s) 1. Incorrect cutput due Electric Flow fransmitter(s) Flow Transmitter Fall Flower Supply Power Supply Pow	-	Individual RC Pump Seal	I Inj	ection Lines (4 Total,	1/RC Pump):			
2. Transmitter failure description occident control room again to control room fault flow in the fault control room fault flow of fault control room fault flow of fault control room fault flow to internal flow of fault control room fault flow of fault control room flow flow flow flow flow flow flow flow	3		÷	Incorrect output due to loss of power	IAC System, Electric Power Supply	No effect	Incorrect flow signal to control room	Seatore prwer
Paive(s) HF-64, (plugged, damaged, etc.) Raive fails closed Seal injection flow to one Re affected line stopped R-65, HF-65, HF-64, etc.) Check Valves 1. Valve fails closed Flow in affected line stopped R-74, HF-145, P-147, HF-145, 2. Valve fails closed Flow in affected line stopped R-74, HF-145, P-147, HF-145, 2. Valve fails closed Flow in affected seal single RC pump stopped stoppe			N m	Instrument connection leak Transmitter failure due to Internal fault	11.	Small loss of reactor goolant No effect	Incorrect flow aignal to control room Incorrect flow aignal to control room	Repair component if accessible Repair component if accessible
Check Valves Ch	5.5	Walve(s) HP-64, HP-65, HP-66.	÷	Valve fails closed (plugged, damaged,	1	Seal injection flow in affected line stopped	Seal injection flow to one RC pump stopped	Repair component
Check Valves (2/line) (3/line) (3/line) (4/line) (4/line) (5/line) (5/line) (6/line) (6		нг-67	~	Valve fells open	l.	Flow in affected line unthrottled	Seal injection flow to a cingle RC pump higher than setpoint	Wepsir component, utilize stop check valves in line on short term basis for flow throttling if required (look action)
Henual Isolation 1. Valve falls closed Flow in affected Soal Soal injection flow to a layers On Line to RC Pump HP-394, HP-285 System inlet Flows: Seal Injection 1. Loss of flow Subsystem 3.0 No flow to RC pumps to RC pumps to RC pumps	F. 3		- ~	Walve fails closed Walve fails to prevent backflow	.1.1	Flow in affected seal injection line stopped No effect since there are 2 check valves per line (one inside RR)	Seal injection flow to a single RC pump stopped No effect since there are 2 check valves per line	Repair component if accessible Repair component at soutdown
Seal Injection 1. Luss of flow Subsystem 3.0 No flow Loss of Seal Injection Flow From the RC pumps to RC pumps		Menual Isolation Valves On Line to RC Fump HP-39%, HP-285	4	Valve falls closed	1	Flow in affected Soal Injection line stopped	Seal injection flow to a single RC pump atopped	Repair component
	5.1	Seal Injection Flow From HPi Fumps	÷	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)

A.O SUBSTSTEM: NC PUMPS SEAL INJECTION (Continued)

	Potential Failure Mode	aflure Mode	Issediat	Issadiate Effects	
Component	Hode	Interface	Within Subsystem	At Subsystem Interface	Remedial Action Within Subsystem
4.6 System Piping:					
\$.6.1 Vents, Drains, Fiping, Instrument Connections, etc.	1. System leaks	1	Loss of reautor coolant	Loss of resolor coolant, potential for alight reduction in seal injection rate if leak is downstream of flow control valve (HP-31)	Isolate leaks and repetr as needed

APPENDIX E

FAILURE MODES AND EFFECTS ANALYSIS
SUBSYSTEM 5.0: REACTOR COOLANT MAKEUP

5.0 SUBSISTEM: REACTOR COOLANT (RC) MARKUP

			Potential Failure	Hoge	Immediat	te Effects	
	Component		Mode	Interface Involved	Within Subsystem	At Subsystem Interface	Remedial Action Within Subsystem
5.1 R	eactor Inlet Line Lo	op A I	Header:			The second secon	
5.1.1	Manual lectation Valve HP-118 (전우-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 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 ail 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 MPI pump NPSH	Manually close valve (local action)
		2.	Valve opens on spurious signal	£3	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 1s not throttled	Increased makeup flow, increased prescurizer level, drop in LST level, potential loss of HPI pump NPSH	Close valve
		٠.	Walve fails open due to internal fault	-	Hakeup flow is not throttled	Increased makeup flow, _noreased pressurizer level, drop in LST level, potential loss of HPI pump NFSH	Isolate with HP-118 (local action) (will stop makeup flow)
		(Ho	des involving failure t	o open are part o	f emergency HPI and now incl	uded here)	
5.2 M	inimum Flow Bypans Lo	eqoo:					
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 apray line or cold leg inlet nozzles, no effect on makeup capacity	Repair component

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

			Potential Pailure Mode	Hode	Immediate Effects	Effects	
	Component		Mode	Interface	Within Subsystem	At Subsystem Interface	Remedial Action Within Subsystem
5.5.5	Flow Transmitters 1FT-117, 1FT-118	- ~	Instrument connection leak Incorrect output dus to loss of power	Electric Power Supply, 14G	Small loss of coolant.	Incorrect flow signal to centrol recom Incorrect flow signal to centrol recom	Repair component Restore power supply
		m.	Transmitter failure due to interral fault	System	No effect	Incorrect flow signal to control room	Repair component
5.2.3	Manual Throttle Valve HP-241	÷	Valve fails closed (plugging, damaged,	1	Minimum flow path blocked to one of two reactor cold less inlet rocales	No cooling flow to one cold leg falet nozzle	Repair component
		~	Valve falls open	1	Minians flow path unthrottled to one of two resetor cold leg inlet nozzles, automatic reduction in flow through normal makeup valve	Excess flow (full HFI pump discharge to minimum flow loop) to one reactor cold leg inlet nozzle, potential drop in LST level	If required valve NP-234 available to block flow into loop (loom) action), repair component
5.2.4	Manual Throttle Valve HP-235	4	Valve fails closed (plugging, damaged, etc.)	1	Ninters flow path blocked to pressurizer spray line and one of two reactor cold hag inlet mozzles	No effect on reactor makeup, but no cooling flow to pressurizer sprey line or to one cold reg inlet nozzle	Repair component
		ň	Valve falls open	ī	Minieum flow path unthrottled to pressurizer spery line acs one of two reactor cold legs, automatic reduction in flow through normal	Excess flow to pressurizer agray line and to one reactor cold log inlet norzie, potential drop in LST level	Close valve HP-234, or valves HP-340 and HP-356 in reactor building (local action)
5.2.5	Mamual Isolation Valve HP-340	÷	Valve fails closed (plugging, damage, etc.)	1	Minimum flow path blocked to pressurizer spray line	No bypass flow to pressurizer spray line	Repair component
5.2.6	Menual Isolation Valve HF-356	÷	Valve fails closed (plugging, damage, etc.)	1	Hinimum 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 norzal makeup)	Repair component
10	5.3 Normal Makeup Flow Control Loop	trol	Loop:				
5.3.1	Flow Transmitter 1FT-10, 104, 108	÷	Instrument connection		Small loss of coolant	Incorrect flow eignal from all transmitters	Monitor flow with FT-7, repair component
		~	Incorrect output due due to loss of	Electric Power Supply, 14C	No effect	Incorrect flow signal from all transmitters	Monitor flow with FT-7, restore
		÷	Transmitter failure		None	Incorrect flow signal from failed transmitter	Monitor flow with FT-7, repair

5.0 SUBSISTEM: REACTOR COOLART (RC) MAKEUP (Continued)

		- 1	Potential Failure Mode	e Mode	Immediate Effects	Rffects	
	Component		Hode	Interface	Within Subsystem	At Subsystem Interface	Remedial Action Within Subsystem
5.3.2	Flow Control Valve HP-120 (HP-V23)	÷	Valve fails olosed (accuming valve is air-to-opes)	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
		ri .	Walve fails closed due to internal fault	1	Normal flow to reactor inlete stopped, flow through minimum flow loop continues	Oypass flow continues. Overall significant reduction in makeup flow	If required, manually control with bypass valve
		e,	Valve closes down due to incorrect control signal	14C System	Normal flow to reactor inlets reduced, flow through minimum flow loop continues	Bypans flow continues. Overall significant reduction in makeup flow	If required, manually control with bypass valve
		•	Valve falls open due to internal fault	í.	Excess makeup flow to RCS	Excess wakeup flow to BCS, temporary decreased bypess flow to pressurizer spray line, potential drop in LST holder, potential loss	HP-26 Isolate valve RF-120 and manually control flow with bypass valve HP-26
		ń	Valve opens up due to incorrect control signal	1&C System	HPI flow not throttled. Excess makeup flow to RCS	Excess makeup flow to RCS, temporary decreased bypass flow to pressurizer apray line, potential drop in LST holdup, potential loss of NPSH to NPI pump	Isolate valve HF-120 and manually control flow with bypass valve HF-26
5.3.3	Manual Isolation Walves RP-119, HP-121	-	Walve fails closed (plugging, desage, etc.)	1	Mormal makeup flow to RCS atopped, bypass flow through minimum flow loop continues	Bypass flow continues. Overall significant reduction in makeup flow	Isolate valve HF-120 and manually control Tlow with bypase valve HF-26
5.3.4	Check Valve	-	Valve falls closed (plugging, damage, etc.)	1	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
		'n	Valve fails to prevent backflow		No effect during steady state operation	No effect during steady ntate operation	Repair component at shutdown
5.3.5	Inlat Line Orifices	-	Orifice plugged	1	Normal flow to one of two cold legs stepped 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 SUBSISIEM: REACTOR COOLANT (MC) MAKEUP (Continued)

		Fotential Failure Mode	re Mode	Immediate Effects	ffsots	
Component		Mode	Interface Involved	Within Subayatem	At Subayetem Interface	Remedial Action Within Subsystem
5.3.6 Inlet Line Check Valves HF-126, HF-127	-	Walve failed closed (plugging, damage, etc.)	1	Normal flow to one of two reactor cold legs stopped or reduced, increased flow to the other cold leg	, Flow imhalance between the two reactor cold legs	Repair component
5.4 Subsystem Input:						
5.4.1 Flow From HPI Pusps	-	Loss of flow	Subsystem 3.0	Loss of makeup flow and flow to pressurizer spray	Loss of makeup flow and bypass flow to	None
	ri .	Reduced flow	Subsystem 3.0	Reduced makeup flow and reduced flow to pressurizer spray line	Reduced makeup flow and bypass reduced flow to pressurizer apray line	Kone
5.5 System Piping:						
5.5.1 Vente, Braine, Piping, Instrument Connections, wie.	÷	System lesks		Loss of reactor coolant	Loss of reactor coolant, potential for reduction in reactor coclant makeup rate	Isolate leaks and repair as needed

APPENDIX P

FAILURE MODES AND EFFECTS ANALYSIS

SUBSYSTEM 6.0: RC BLEED, BORON RECOVERY AND CHEMICAL ADDITION

6.0 SUBSTSTEM: RC BLERD, BORON RECOVERT, AND CHEMICAL ADDITION

Component Hode Involved Involved Involved Involved Involved Valve (H-83) 2. Valve falls closed	Immediate Effects	Effects	
Hanual Control 1. Rablanket system 1. Falls to prevent Check Valve (R-8A) 2. Valve falls closed Check Valve (R-8A) Hanual Isolation 1. Falls to prevent CA-8B CA-8B Hanual Isolation 1. Falves fall closed CA-8B CA-B	Interface Involved Within Subsystem	At Subsystem Interface	Remedial Action
Hanual Control All Sails and Sails			
Check Valve backflow Hydrazine Drum 1. Drum leaks Hanual Isolation 1. Folue amptied Ca-85 Hanual Isolation 1. Folues fall closed Ca-85) Hydrazine Pump 1. Electric power Electric Power CA-84) CA-84) CA-84) CA-84 Hydrazine Pump 1. Electric power Electric Power P mupply falls CA-84) CA-84 1. Falls to prevent CA-85 Hanual Isolation 1. Desineralized water Desincralized Manual Isolation 1. Desineralized water Desincralized Manual Isolation 1. Tank leaks CA-85 Hanual Isolation 2. Valve falls open Sampling, Waste 1. Lines fall open Desine matter Lious Manual Isolation 1. Tank leaks Lious Falls open CA-73) CA-73 CA-73 CA-74 CA-75 CA-75 CA-76 CA-77		No Mode available to makeup filters Frobably none	Close control valve N-83
Hanual Isolation 2. Drue amptied 2. Drue amptied CA-45) Hanual Isolation 1. Falves fall closed CA-54) Hanual Isolation 1. Falls to prevent CA-54) CA-54) Ilydrazine Pump 1. Electric power and process falls closed CA-54) CA-54) CA-57 CA-58 1. Falls to prevent CA-58 Check Valve CA-59 CA-79 CA-79 1. Falls to prevent Deaineralized water beaction Supply falls 2. Fump falls closed By Water Nater Nater Nater Nater Liou Hix Tank 1. Tank leaks 2. Tank empties Residenting By Residenting Residenting -	" N2Ha backflow; possible explosive mixture	No NoHe available to makeup filters	Close control
Hanual Isolation 1. Felves fall closed CA-M5) Hanual Isolation 1. Valves fall closed CA-M5) Hanual Isolation 1. Felctric power CA-SA) CA-SA) CA-SA) CA-SA) CA-SA) CA-SA) CA-SA) CA-SA) CA-SA) Anual Isolation 1. Falls to prevent CA-SA) CA-SA) Anual Isolation 1. Falls to prevent Desineralized water CA-SA) 2. Yalve falls open CA-T3) 3. Valve falls open CA-T3) 2. Tank tempties CA-T3) 2. Tank empties 1. Lines fall open CA-T3)	2	Eventuel loss of Nolla available to makeup	Isolate drum and
Hanual Isolation 1. Valves fall closed Ca-45) Hanual Isolation 1. Valves fall closed Ca-45) Hanual Isolation 1. Electric power (Ca-54) (Ca-64) Ca-64) Ca-64) Ca-65 Ca-75) Check Valve 1. Falls to prevent Check Valve (Ca-56) Hanual Isolation 1. Demineralized water Valve (DW-121) 2. Yalve falls open Ca-73) 2. Tank empties Ca-73) 2. Tank empties Ca-73) 3. Lines fall open Ca-73	No.	filters No NoHy available to makeup filters	Isolate drum and replace
1. Electric power Electric Power aupply falls 2. Fump falls 1. Falls to prevent backflow 1. Desineralized water begineralized supply falls 2. Valve falls open 1. Tank leaks 2. Tank empties 1. Lines fall open 1. Lines fall open	1	No No Mp available to makeup filtere	None
Check Walve Check Walve Check Walve 1. Fails to prevent Check Walve CA-56) Manual Isolation 1. Desineralized water Supply fails 2. Valve fails closed LiOH Mix Tank 1. Tank leaks 2. Tank empties Sampling, Waste 1. Lines fail open	1	None if alternate flow path available	Open CA-%6; crossover to pump CA-P3
Check Valve (CA-56) Hanual Isolation 1. Fails to prevent backflow Hanual Isolation 1. Demineralized water Supply fails 2. Valve fails open 3. Valve fails open 4. Tank leaks 2. Tank empties 3. Tank empties 1. Lines fail open	Electric Power Pump stops; no N ₂ II _k	None if alterrate flow path available	Open CA-46; Grossover to
Check Valve 1. Fails to prevent backflow harvel 13 Demineralized water Demineralized Walve (DW-121) 2. Valve fails closed	No M2Hw	None if alternate flow path available	pump CA-P3 Open CA-M6; crossover to pump CA-P3
Manual Isolation 1. Demineralized water Demineralized Valve (DW-121) 2. Valve fails closed 3. Valve fails open L10H Hix Tank 1. Tank leaks (CA-T3) 2. Tank emptles Sampling, Waste 1. Lines fail open	Possible backflow to drum if pump is not running	No NoHa available to	Close CA-54
LiOH Hix Tank 1. Tank leaks (C4-T3) 2. Tank empties	Deminoralized No Water	No LiuM available to makeup filters No LiGM or incorrect LiGM concentration available	Mone Concentration checked via
(C4-T3) (C4-T3) 2. Tank empties	Dilutes LiOH in tank	to makeup filtern Incorrect LiON concentration available to makeup filters	concentration checked via
Sampling, Waste 1. Lines fall open	Eventual loss of suction pressure to pump	Eventual loss of Little available to makeup	None
Sampling, Waste 1. Lines fail open	No LLOH	No Lion svallable to makeup filters	None
	Peoreaned LION	Vecreased LiOH evailable to makeup filters	None

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

			Potential Failu	re Hode	Immediate	Effects	
	Component		Mode	Interface Involved	Within Subsystem	At Subsystem Interface	Remedial Action Within Subayatem
6.1.11	Hanual Isolation Valve (CA-44)	1.	Valve fails closed	***	No FTOH	No Lick evailable to makeup filters	None
6.1.12	Hanual Isolation Valve (CA-47, CA-49)	1.	Valves fall closed		No LiOH	None if alternate flow path available	Open CA-46; crossover to pump CA-P4
6.1.13	L10R 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
		2.	Pump fails		No L10H	None if alternate flow path available	Open CA-P4 Open CA-46; orossover 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 (DM-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		So 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		filutes 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-31)	1.	Tank leaks		Eventual loss of suction pressure to pump	Eventual loss of caustic available to LPI pumps	None
		2.	Tank emptles		No caustic available to boron recovery	No caustic available to	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	None
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

6.0 SUBSTRIBM: RC BLEED, BOROW RECOVERT, AND CHEMICAL ADDITION

Hole Interface Within Subsystes Interface Interface Interface aupply false Water Concentrated belong and the concentrated and the concentrated and the concentrated belong and the concentrated belong and the concentrated belong the concentrated belong and the concentrated belong and the concentrated belong the concentrated			1	Potential Failure Mode	e Mode	Immediate Effects	Effects	
1. Designative dater bearing the force and or concentrated berion and storage tend of concentrated berion and attended tends in the force and storage tend of concentrated berion and attended tends in the force and storage tend of concentrated berion and storage tend tends tends and storage tend tends to serial and concentrated berion and storage tend tends to serial and concentrated berion and storage tend tends to serial and concentrated berion and storage tends tends tends to serial and storage tends and storage tends and loans of flow to serial and serial storage tends and loans of flow to serial storage tends and loans of flow to serial and serial storage tends and loans of flow to serial and serial storage tends and loans of flow to serial and serial storage tends and loans of flow to serial and serial storage tends and loans of flow to serial and serial storage tends and loans of flow to serial and serial storage tends and loans of flow to serial and serial storage tends and serial serial and serial serial and serial serial and serial and serial serial and serial tends tends tends tends tends tends and serial tends tends tends tends tends tends tends and serial and serial tends tends tends tends tends and serial te		Component		Mode	Interface	Within Subsystem	At Subeystem Interface	Remedial Action Within Subsystem
1. Designative duter Raire leaf to berie acid or professional extraited anaphy falls open — Raire leaf to consentrated borie acid across taming tami	6.2 Be	oric Acid Addition:						
3. Valve fails closed Red concentrated borlo and accesses tank and accesses and acce	6.2.1	Manual Isolation	÷	Demineralized water	Demineralized	No demineralized water to	None if concentrated	Concentration
2. Valve fails closed		Valve (DM-118)		supply falls	Water	tank; no borte acid or	boric acid svailable	checked via
2. Valve falls closed —— Ro desireative for the concentration exists to concentrate the concentration exists to be for set of a free form exists to concentrate the concentration exists to concentrate the concentration exists the concentrated concentrated concentrated to concentrated the concentrated concentrated to concentrated to concentrated the concentrated concentrated concentrated concentrated to concentrate the concentrated concentrated concentrated concentrated concentrated concentrated concentrated concentrated to concentrated the concentrated concentrated asy crystallizes may be concentrated asy crystallizes as all concentrated asy crystallizes as all concentrated asy crystallizes and concentrated and concentrated and concentrated and concentrated concentrated borts are asylable and concentrated and concentrated concentrated borts are all concentrated concentrated borts are all concentrated and concentrated and concentrated and concentrated and concentrated concentrated and concentrated and concentrated and concentrated and concentrated concentrated borts are all concentrated concentrated borts are all concentrated concentrated and concentrated and concentrated and concentrated concentrated borts are all concentrated concentrated and concentrated concentrated and concentrated concentrated concentrated and concentrated concentrated conc						opposite to partiable	adonate concentrated	campi ing
2. Valve falls closed —— Redelineralized where to line in terestrated by the falls closed —— Redelineralized where to line redecing the concentrated of concentrated by the falls open —— Interest borlo acid are linestrated by the solution to concentrated by the solution to life solution t						to concentrated borte	borio acid atorage tank	
2. Valve falls closed No desirentized water to horize acid and accessory or concentrated borize acid and accessory or trated borize acid atorage tank and loss of flow to acid atorage tank and acid atorage tank and acid atorage tank and acid acid atorage tank and acid acid acid acid acid acid acid aci						sold storage tanks	inventory is available	
3. Valve falls open —— Electric Fower Heater falls; boric acid accountrated boric acid accountrated concentration available to adequate concentrated boric acid accountrated boric acid accountrated boric acid accountrated boric acid accountrated accountrated boric acid accountrated accountrated boric acid accountrated boric acid accountrated boric acid accountrated accountrated boric acid accountrated boric acid accountrated boric acid accountrated accountrated boric acid accountrated boric acid accountrated accountrated accountrated accountrated boric acid accountrated accountrated boric acid accountrated accountrated accountrated accountrated boric acid accountrated accountr			Ň	Valve falls closed	1	No demineralized water to	None if concentrated	Concentration
3. Valve falls open —— Electric Fower Heater falls boric acid storage tank inventory to adequate concentrated boric acid a forege tank inventory to available to concentrated boric acid storage tank inventory to available concentrated boric acid storage tank inventory to available form the falls are sential for plugging and loss of flow to acid acorage tank inventory to available potential for plugging and loss of flow to acid acorage tank inventory to available potential for plugging and loss of flow to acid acorage tank inventory to available plugging and loss of flow to acid available potential for plugging and loss of flow to acid available plugging and loss of flow to acid available pressure to pumps from brone recovery or acid available pressure to pumps from brone recovery or acid available for acid available pressure to pumps from brone recovery or acid available for acid available form and available form						tank; no boric acid or	borio acid available	checked via
3. Valve falls open Dilutes borie acid a concentrated one concentrated one concentrated borie acid access tasks and post acid access tasks and loss of flow to acid access task and loss of access task and loss of access task and loss of access task and acc						incorrect borte acid	from boron recovery or	Rompling.
3. Valve falls open Discrete table boric acid boric acid boric acid available concentrated boric acid acorace tank and accorace to the concentrated accorace task and accorace to task accorace ta						concentration available to	adequate concentrated	
3. Valve fails open Glauces boric said; Innectory is smalled anoresed boric said; Innectory is smalled anoresed boric said atomage tank innectory is smalled boric said and a smalled boric said and a smalled boric said atomage tank innectory is smalled boric said and storage tank innectory is smalled boric said and storage tank innectory is smalled boric said atomage tank innectory is smalled boric said atomage tank innectory is smalled boric said and loss of flow to account and storage tank innectory is smalled boric said atomage tank innectory is smalled boric said atomage tank innectory is smalled boric said storage tank innectory is smalled boric said storage tank innectory is smalled boric said storage tank innection recovery or adequate concentrated boric said storage tank innection recovery or adequate concentrated boric said storage tank innection pages. 1. Electric power Rolonal level indication to lack system concentrated boric said storage tank inventory is smallable said atomage tank inventory is smallable boric said storage tank inventory is smallable and supply falls and storage tank inventory is smallable seld atomagnetion lesks become recovery or adequate concentrated boric said storage tank inventory is smallable seld atomagnetic in the level indication to lack system to level indication to lack system transmitter falls and level indication to lack system transmitter falls and lack system in the level indication to lack system in the lack indication to lack system in the lack indication to lack system in the lack in						concentrated boric acid	borio acid storage tank	
1. Electric power Electric Power Heater fails; boric acid available concentration to concentrated appropriate fails are presented to concentrated any crystalitie; small portion acid available potential for plugging and loss of flow to acid available from a foreign tanks are presented and loss of flow to acid available from foreign tanks are presented and loss of flow to acid available from foreign tanks are presented and loss of flow to acid available from foreign tanks acid available from foreign tanks acid available from foreign tank acid available from foreign tanks acid available from foreign tanks acid available from foreign tank acid available from foreign tank acid available from foreign available from foreign tank acid available from foreign available foreign foreign available foreign from foreign available foreign foreign available from foreign available foreign foreign available foreign foreign available foreign foreign available foreign foreign foreign available foreign foreign available foreign foreign available foreign foreign available foreign foreign foreign available foreign foreign foreign fo						storage tanks	inventory to evallable	
1. Electric power Electric Power Heater fails; boric acid storage tank aupply fails say crystalitie; small boric acid storage tank inventory is available potential for plugging and loss of flow to acid available pringing and loss of flow to acid available for acid available pringing and loss of flow to acid available pringing and loss of suction acid available pringing and loss of suction acid available from the forment acid available pringing and loss of suction acid available from the forment acid available from the forment acid available from the forment acid available from ac			ř	Valve falls open	1	Dilutes borio acid;	None If concentrated	Concentration
1. Electric power Electric Fower Heater fails; boric acid storage tank aupply fails ————————————————————————————————————						concentration to concen-	from horon resources	checked via
1. Electric power Electric Fower Heater fails; boric acid storage tank inventory is available potential for plugging and loss of flow to acid available boric acid available and loss of flow to acid available for acid available and loss of flow to acid available boric acid available for acid available for acid available acid available acid flow to acid available for acid available for acid available acid available acid available for acid avail						trated borto actd aforner	adequate concentrated	Shir rdung
1. Electric power Electric Power Heater falls; boric acid supply falls supply falls better falls boric acid any crystallize; small from the concentrated and loan of flow to acid account or concentrated and loan of flow to acid account or concentrated and loan of flow to acid account or concentrated and loan of flow to acid account or concentrated bringing and loan of flow acid accompany or flow acid accompany or accompany						tacks out to sold acoust	sociate concentrated	
1. Electric power and load of flow to acid available potential for plugging and load of flow to according to acid any orystallize; small for plugging and load of flow to acid available purgiting and load of flow to acid according to acid any orystallize; assall potential for from if concentrated assall potential for from to concentrated bridging and load of flow if concentrated pressure to pumps from acid acid acid acid acid acid acid acid							inventory is available	
2. Heater fails and loss of flow to add available potential for plugging and loss of flow to add available storage tanks and loss of flow to add available borie acid acid available borie acid available concentrated available plugging and loss of flow free boron recovery or to storage tanks addquate concentrated borie acid storage tank inventory is available free boron recovery or adquate concentrated borie acid storage tank inventory available free boron recovery or adquate concentrated concentrated borie acid storage tank inventory is available free boron recovery or adquate concentrated concentrated borie acid storage tank inventory is available free boron recovery or adquate concentrated concentrated borie acid storage tank inventory is available free boron recovery or adquate concentrated concentrated borie acid storage tank inventory is available free boron recovery or audquate concentrated borie acid storage tank inventory is available free boron recovery or adquate concentrated borie acid storage tank inventory is available free boron recovery or adquate concentrated borie acid storage tank inventory is available free boron recovery or adquate concentrated borie acid storage tank inventory is available free formatiter fails indication to lace indication in lace indication in lace indication in lace indication in la	6 6 9	Bowle Antid		Flantato posses	Flactule Posts	Stanton Catler bords acted	Money of Company of the Company	Banklana handan
2. Heater fails Boric acid any orystallize; from boron recovery or and loas of flow to adequate somentrated assall promitial for plugging and loas of flow to adequate concentrated plugging and loas of flow from from from from from from from from	9.4.	Mix of	:	allocated Spells		and orders lies and	bords and available	negrace peacer
2. Heater fails —— Boric acid may organize on flow to adequate concentrated assall potential for from concentrated boric acid atorage tank and loss of flow to account to pumps and loss of flow to account to acid atorage tank and loss of flow to acid atorage tank and loss of flow to acid atorage tank and loss of flow to acid atorage tank and personne to pumps and loss of flow to acid atorage tank and acid acid acid available and available available available and available available available available availabl		(C4 42)		erun fiding		potential for planting	Series available	cault Saidun
2. Heater fails		10W-15)				and loss of flow to	adequate concentrated	
2. Heater fails Boric acid may crystallize; None if concentrated boric acid and loss of flow from boron recovery or to storage tanks investory is available pressure to pumps from boric acid atorage tank investory is available concentrated boric acid atorage tank investory is available acid atorage tank investory in available acid atorage tank investory in available acid atorage tank investory in						storage tanks	boric acid storage tank	
2. Heater fails Boric acid may crystallize; None if concentrated amail potential for to storage tanks and least of flow from borio acid storage tank inventory is available pressure to pumps from borio acid storage tank inventory is available borio acid available concentrated borio acid available concentrated borio acid available should supply fails from the following tank inventory is available acid storage tank inventory is available acid storage tank inventory is available from borio acid available acid storage tank inventory is available from borio acid available from borio ac							inventory is available	
3. Tank leaks Eventual loss of flow from borio acid available plugging and loss of flow from borio acid available pressure to pumps from borio acid available from empties Eventual loss of suction for acid available from concentrated borio acid available acid atorage tank inventory is available from borio acid available acid atorage tank inventory is available acid atorage tank inventory is available from borio acid available acid atorage tank inventory is available from borio acid available from borio acid available acid atorage tank inventory is available from borio acid available from borio acid available from borio acid available from from acid available from borio acid available f			5.	Seater fails	:	Boric seid any orystallize;	None if concentrated	Replace heater;
3. Tank leaks Eventual loss of suction horizontrated personne to pumps from borizontrated personne to pumps from borizontrated borizontrate						plusating and loss of floor	oldeliand blos olico	anbing Thes
3. Tank leaks Eventual loss of suction horic acid storage tank inventory is available pressure to pumps from boric acid available from boric acid available concentrated boric acid storage tank inventory is available from boric acid available acid storage tank inventory is available from boric acid available from supply falls Process Signal Incorrect signal to Incorrect signal savailable savaila						to storage tanks	adequate concentrated	
3. Tank leaks Eventual loss of suction none if concentrated pressure to pumps from from additional and satisfied from concentrated borto acid available from concentrated concentrated borto acid available from concentrated concentrated borto acid available from power additional concentrated borto acid available from power to local level indication to late system for local indication to late system for local indication to late system for local level indication to late late acid available late falls No local level indication to level indication indicatio							boric acid storage tank	
3. Tank leaks —— Eventual loss of suction None if concentrated pressure to pumps from borno actd available from bronce actd attrage tank inventory is available actd atorage tank inventory is available actd atorage tank inventory is available from borno actorage tank inventory is available actd atorage tank inventory is available from borno actorage tank inventory is available borno actorage tank inventory is available to supply fails from the from the leaks from the leaks indication to transmitter fails —— No local level indication to level indication indicatio							inventory is available	
A. Tank empties No boric acid flow to adequate concentrated boric acid atorage tank investory is available concentrated boric acid atorage tank investory is available from boron recovery or adequate concentrated boric acid available from boron recovery or adequate concentrated boric augply fails from the following form of the following from the following following following fails from the following			3.	Tank leaks	1	Eventual lons of suction	None if concentrated	None
A. Tank empties No boric acid flow to horic acid atorage tank investory is available concentrated concentrated boric from borne if concentrated concentrated boric acid available from borne concentrated boric acid available from borne concentrated boric acid available from power gigned indication to lace indication to transmitter falls No local level indication to						odwod on a moco id	from boron recovery or	
A. Tank empties No borio acid flow to hone if concentrated concentrated boric acid storage tanks from borio acid available acid storage tanks from borio acid available acid storage tanks acid storage tanks acid available from bower grower for long level indication to lace and available incorrect signal incorrect signal to level indication to transmitter falls No local level indication to level i							adequate concentrated	
N. Tank empties — No boric acid flow to hone if concentrated concentrated boric acid storage tanks from boron recovery or adequate concentrated boric acid, acouge tank incorporate indication to transmitter falls — No local level indication to transmitter falls — No local indication to transmitter — No local level indication to transmitter — No local indication —							borto acid atorage tank	
4. Tank empties No boric acid flow to hope if concentrated concentrated concentrated boric acid available from boric acid available acid storage tanks adequate concentrated boric acid available invention power Electric Power Ko lonal level indication to apply falls a Process Signal Incorrect signal to teamsitter indication to teamsitter falls No local level indication to teamsitter indication to teamsite indication to teamsitter indication to teamsite indication to team indication to team indication to team indication to team indication to teamsite indication to team indicatio							inventory is available	
1. Electric power Electric Power No local level indication to transmitter fells No local level indication to level indicati			*	Tank emptics	1	No boric acid flow to	None If concentrated	None
1. Electric power Electric Power No loval indication No level indication to transmitter falls No local level indication to level indication to transmitter falls No local level indication to level indication to transmitter falls No local level indication to						concentrated boric	boric acid systlable	
1. Electric power Electric Power to local tevel indication to level indication to a supply fails Process Signal Incorrect signal to Rolevel indication to transmitter and Rolevel indication to transmitter fails No local level indication to level indication to transmitter fails No local level indication to level indication to transmitter fails No local level indication to l						acid storage tanks	from poron recovery or	
1. Electric power Electric Power Ko lonal level indication No level indication to supply falls 2. Connection leaks Process Signal Incorrect signal to Rolevel indication to transmitter and Rolevel indication to transmitter falls No local level indication to level indication to							adequate concentrated	
1. Electric power Electric Power Ko local level indication No level indication to supply fails 2. Connection leaks Process Signal Incorrect signal to No level indication to transmitter [46] system 3. Transmitter fails No local level indication to							borte aria stor ge tank	
1. Electric power Electric Power Ko local level indication No level indication to supply fails 2. Connection leaks Process Signal Incorrect signal to No level indication to transmitter fails No local level indication to le							inventory is available	
2. Connection leaks Process Signal Incorrect signal to No level indication to transmitter [16]. Transmitter [18] No local level indication to	5.2.3	Level Transmitter	-	Electric power	Electric Power	Ko local level indication	No level indication to	None
Connection leaks Process Signel Incorrect signal to No level indication to Iransmitter [16] system No level indication to leve				supply fails			I&C system	
Transmitter falls No local level indication No level indication to			6	Connection leaks	Process Signal	Incorrect signal to	No level indication to	None
Transmitter falls No local level indication No level indication to						transmitter.	I&C system	
			3	Transmitter falls	1	No local level indication	No level indication to	Rone

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

			Potential Failur	e Mode	Immediate 8	Effects	
	Component		Mode	Interface Involved	Within Subsystem	At Subsystem Interface	Remedial Action Within Subsystem
6.2.4	Temperature Transmitter	1.	Electric power	Electria Power	No local temperature indication	Hone	None
		2.	Connection leaks	Process Signal	Incorrect signa! to	Hone	None
		3.	Transmitter (ails	**	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 Fiping	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 borio acid available from boron recovery or adequate concentrated borio 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
5.2.7	Maumal Isolation Valve (CA-5)	1.	Valve fails closed		No boric acid to concen- trated boric storage tanks; alternate flow path available	None	Alternate flow path through CA-P2B available
6.2.8	LP Boric Adid Pump (CA-P2A)	1.	Electric power supply fails	Electric Power	Pump steps; no boric acid to concentrated storage tanks; alternate flow path available	None	Alternate flow path through CA-P2B available
		2.	Pump feils		No boric acid to concen- trated boric acid storage tanks; alternate flow path available	None	Alternate flow path through CA-P2B sveilable
5.2.9	Manual Isolation Valve (CA-7)	1.	Valve fails closed		No boric soid to concen- trated boric acid storage tanks; alternate flow path available	None	Alternate flow path through C4-P28 available
6.2.10	Check Valve (C*-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

6.0 SSBSTSTEM: RC BLEED, BOROM RECOVERY, AND CHEMICAL ADDITION

			Potential Fallure Mode	e Mode	Immediate Effects	Effects	
	Component		Piode	Interface	Within Subsyntem	At Subsystem Interface	Remedial Action Within Subsystem
6.2.11	Namuel Isolation Valves (ICA-16, ICA-13, ICA-15, etc.)	÷	Valves fail closed	1	No borio seid to concen- trated boric seid storage tams	None if concentrated borie acid available from bores recovery or adequate concentrated boric acid storage tank inventory is available	Kone
6.2.12	Transmitter Transmitter	- ~ ~	Electric power supply fails Connection leaks Transmitter fails	Electric Poser Process Signal	No local pressure indication Incorrect signal to transmitter No local pressure indication	\$ 8 £	None Rone
6.2.13	Ca-85)	-	Falls to prevent backflow		Possible backlow if pump is not running	None if concertrated boric acid available from concentrated boric acid transfer pumps	Close 1CA-16, 1CA-18
6.2.11	Manual Isolation Valve (CA-25)	÷	Valve falls closed		No boric acid	No borio acai available to core flood tanks	None
6.2.15	HF Borlo Actd Pump (CA-PS)	- %	Electric power aupply falls Pump falls	Electric Power	Fump stops; no boric acid No boric acid	No boric acid available to core flood task No boric acid available to core flood tank	None None
6.2.16	Manual Isolation Valves (ICA-26, ICA-28)	-	Valves fail to open, fail closed		No boric acid	No boric acid sysilable to core flood tank	None
6.2.17	Manual Control Valve (CS-62)	-	Valve falls closed		No boric acid to concentrated boric acid atorage tanks	No borio acid available to makeup filters, BWST	Alternate flow path available
6.2.18	Concentrated Borio Acid Storage Tank (IWD-T22)	- ~	No blanket aystes falls Electric power supply to trace heating fails	R2 Blanket Electric Power	Possible boric acid backflow Boric acid crystallizes; getential plugging and loss of flow	None No boric acid available to makoup filters, BWST	Close control valve CS-62 Alternate flow path available
		÷.	Trace heating fails	1	Boric acid orystallizes; potential plugging and loss of flow	No boric acid available to makeup filters, BHST	Alternate flow peth available
		-	Inlet boric acid	Borte Acid From Mix Tank/RC Bleed Evaporator Concentrate	No borte acid	Mone unless concentrated boric acid storage tanks are empty	Alternate flow path svailable

6.6 SUBSYSTEM: RC BLEED, BORON MECOVERY, AND CHEMICAL ADDITION

			Potential Failur	e Mode	Immediate	Effecta	
	Component		Mode	Interface Involved	Within Subsystem	At Subsystem Interface	Remedial action Within Subsystem
6.2.18	Concentrated Borio Acid Storage Tank (IND-T22) (cont'd)	5.	Tenk 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.	Tunk empties		No boric sold	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 fatl open		Decreased borio acid	Decreased boric acid available to makeup filters, BWST	Alternate flow path available
6.2.19	Level Transmitter	1,	Electric power	Electric Power	No local level indication	No level indication to	None
		2.	Connection leaks	Frocesa Signal	Incorrect signal to transmitter	No level indication to IAC system	None
		3.	Transmitter falls		No local level indication	No level indication to IAC system	None
6.2.20	Manual isolation, Control Valves (CS-63, CS-6*, CS-67)	1.	Velves fall closed	-	We borie acid	No boric acid available to makeup filters, BWST	Alternate flow path available
6.2.21	Concentrated Borio	1.	Electric power supply fails	Electric Power	Pump stops; no boric acid	No borto acid available to makeup filters, BWST	Alternate flow path available
	(1WD-P22)	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 borie 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 1	Transfer Pumps:			And the court acts heap	
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 aiternate flow path available	Bieed flow can be diverted to SWD-T21A

6.0 SUBSTSTEM: NC BLEED, BORON RECOVERT, AND CHANICAL ADDITION

			Potential Failure Hode	e Mode	Immediate Effects	ffeots	
	Component		Mode	Interface Involved	Within Subayatem	At Suboystem Interface	Remedial Action Within Subsystem
6.3.2	RC Bleed Holdup Tank (1WD-T21A)	-	M ₂ blanket system falls	N ₂ Blanket	Tank cannot be purged; no impact since rest of subsystem operates only on desand	None if alternate flow path available	None
		2	Tank leaks	ı	Possible flooding; eventual loss of suction pressure to pump; no impact since rest of subsystem operates only on demand	Note if alternate flow path available	Alternate bleed flow available
		÷	Tank empties	1	No flow; no impact since rest of subsyntem operates only on demand	None if alternate flow path available	Alternate bleed flow available
		÷	Tank vent, relief valves fall open	1	Cover gas release to vent	None	None
6.3.3	Level Transmitter	÷	Electric power	Electric Power	No local level indication	No level indication to	None
		5	Connection leak	Process Signal	Incorrect signal to	No level indication to	None
		ě	Transmitter failure	1	No local level indication	No level indication to	Gena
6.3.4	Miscellaneous Piping	-	Electric power august to trace heating fails	Electric Power	Sorie acid may orystallize; small potential for plugging and loss of flow; no impact since rest of subsystem orderes only on demon't	None if alternate flow path available	Restore trace deating; unplus lines; alter- nate bleed flow avaliable
		~i	Trace heating feils	1	Boric acid ms. crystalifze; 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 alter- nate bleed flow avaliable
6.3.5	Waste, Drain, Sample Lines	-	Lines fall open	1	Decreased flow; no impact since rest of subsystem operates only on dreamd	None if alternate flow . path available	Alternate bleed flow available
6.3.6	Manual Isolation Valves (CS-42, CS-148, CS-44)	-	Valves fail closed	1	No flow to pump; no impact eince rest of aubayatem operates only on demand	None if alternate flow path available	Alternate bleed flow available
6.3.7	RC Bleed Transfer Pusp (1WD-P21A)	- ~	Electric power supply fails Pump fails	Electric Power	Fump stops; no flow to boron recovery No flow to boron recovery	None if alternate flow path available None if alternate flow path available	Alternate bleed flow available Alternate bleed flow available
6.3.8	Check Valve (CS-45)	÷	Fails to prevent backflow		Possible backflow if pump is not running	None if alternate flow path available	Close control valve CS-46

6.0 SUBSISTEM: RC BLERD, BOROM RECOVERT, AND CHEMICAL ADDITION

			Potential Fallure Mode	e Node	Issediate Effects	Effects	
	Component		Hode	Interface Involved	Within Subsyntem	4t Subsystem Interface	Remedial Action Within Subsystem
6.3.9	Flow Orifice	-	Orifice plugs	1	No flow to boron recovery	None if alternate flow path evallable	Alternate bleed flow available
3.10	6.3.10 Flow Transmitter	÷	Electric power supply falls	Electric Power	No local flow indication	No flow indication to	Мель
		5	Connection leak	Process Signal	Incorrect signal to	No flow indication to	None
		÷	Transmitter failure		No local flow indication	No flow indication to	Kone
6.3.11	Manual Control Walve (CS-M6)	÷	Valve fails closed	1	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)	-	Valves fail closed	1	No flow to boron recovery	None if alternate flow path available	A) ternate bleed flow available
6.3.13	Hanual Isolation Valve (CT-88)	÷	Demineralized water supply fails	Demineralized Water	Demineralized water holdup tank could empty	No deminoralized water to makeup filters	Alternate demineralized water flow pack available
		'n	Walve fails closed	ı	Demineralized water moldup tank could empty	No designative unter- to makeup fälters	Alternate demineralized water flow path available
6.3.18	NC Dentseralized Nater Saldup Tank (1WD-T21B)	-	M2 blankel system fails	N ₂ Blanket	Tank cannot be purged and in unavailable	No demineralized water to makeup filters	Alternate demineralized water flow path
			Tank leaks		Possible flooding; eventual loss of suction pressure to pean	Eventual loss of demineralized water to makeup filters	Alternate desincralized water flow path
		m	Tank empties	ſ	No demineralized water	No demineralized water to makeup filters	Alternate demineralized water flow path available
		*	Tank vent, relief		Cover gas release to went header	None	None
3.15	6.3.15 Level Transmitter	- %	Electric power supply fails Connection leak	Electric Power Process Signal	No local level indication Incorrect signal to	No level indication to lac system No level indication to	None
		ń	Transsitter fallere	1	Cransmitter No local level indication	No level indication to	Мопе
6.3.16	Waste, Drain, Sample Lines	÷	Lines fall open		Ducreased deminoralized	Decreased demineralized water to makeup filters	Alternate desineralized water flow path available

6.0 SUBSISTEM: RC BLEED, BOROW RECOVERY, AND CHEMICAL ADDITION

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6.3.17 ML	Component		Mode	Interface	Within Subsystem	At Subsystem Interface	Remedial Action Within Subsystem
	Miscellaneous Piping	÷	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
		~	Trace heating fails	1	Boric acid may crystallize; small potential for plugging and loss of flow	No desineralized water to makeup filters	evallable Restore trace heating; unplug lines; alternate demineralized water flow path
6.3.18 Ma Va CS	Manual Isolation Valves (CS-52, CS-149, CS-54)	-	Valves fall closed	1	No demineralized water to pump	No demineralized water to makeup filters	ternate demineralized water flow path available
6.3.19 RC	Rc Bleed Transfer Pump (1WD-F21B)	-	Electric power supply fails	Electric Power	Pump stops; no demineralized water	No demineralized water to makeup filters	Alternate deminoralized water flow path
		ŕ	Pump falls	1	No demineralized water	No deminerally ed water to makeup filters	Alternate demineralized water flow path evailable
3.20 FI	6.3.20 Flow Orifice	2	Orifice pluga	1	Decreased domineralized water	Decreased demineralized water to makeup filters	Alternate demineralized water flow path available
6.3.21 Ha	Manual Control Walve (CS-56)	2	Valve falls closed	1	No demineralized water	No demineralized water to makeup filters	Alternate demineralized water flow path available
3.22 FI	6.3.22 Flow Transmitter	- 3	Electric power supply falls Connection leak	Electric Power Process Signal	No local flow indication Incorrect signal to	No flow indication to IAC system No flow indication to	None
		÷	Transmitter failure	1	No local flow indication	No flow indication to	Kone
3.23 Ch	6.3.23 Check Valve (CS-55)	ż	Fails to prevent backflow	1	Possible backflow if pump is not running	No demineralized water to makeup filters	Close control

6.0 SUBSTSTEM: RC BLEED, BORON RECOVERT, AND CHEMICAL ADDITION

		- 1	Potential Failure Mode	Mode	Inmediate Effects	Effects	
	Component		Mode	Interface	Within Subsystem	At Subaystem Interface	Remedial Action Within Subsystem
6.3.24	Manual Isolation Valves (CS-83, CS-85, CS-100)	÷.	Valves fail closed	ľ	Mo destreralized water	No deminoralized water to makeup filters	Alternate domineralized water flow available
6.3.25	Check Valve (CS-86)	2	Fails to prevent backflow	1	Possible teckflow if pump te not running	No demineralized water to makeup filters	Close CS-85
6.3.26	Control Valve (IIP-15)	÷	Control signal fails to open valve	Control Signal From Flow Orifice	Loss of flow to makeup filters	No demineralized water to makeup filters	None
		Č.	Control signal fails to close vaive	Control Signal From Flow Orifice	Loss of flow control to makeup filters	Increase in demineralized water to makeup filters	Close marnal isolation valves;
		ë.	Instrument air supply fails	Instrument Air	Loss of flow to makeup filters	No demineralized mater-	None Mr-136
		ä	Electric power supply falls	Electric Power	Lose of flow to makeup filters	No demineralized water to makeup filters	None
		è.	Spurious oignal 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
		9	Spurious signal to close valve	Control Signal From Flow Orifice	Loss of flow to wakeup filters	No demineralized water to makeup filters	None
		-	Internal valvo	ı	Loss of flow to makeup filters	No demineralized water to makeup filters	None
6.3.27	Manual Isolation Valves (HP-191, HP-192)	÷	Valves fail closed	1	No flow to flow orifice	No demineralized water to makeup filters	None
6.3.28	Manual Isolation Valves (HP-52, HP-53)	-	Valves fail cloued		We flow to flow orifice; potential centrel signal failure	No demineralized water to makeup filters; alternate flow path available	Open HP-54
6.3.29	Menual Isolation Valve (BF-54)	-	Valve falls open		No flow to flow orifice; potential control algual failure	Loss of control of demineralized water to makeug filters	Close HP-136 1f HP-15 should be closed
6.3.30	Flow Orifice	-	Orifice pluga	1	No flow; potential control signal failure	No demineralized sater to makeup filters; alternate flow path avallaste	Open IIP-54
3.31	6.3.31 Flow Transmitter	÷	Electric gover supply falls	Electric Power	Incorrect signal to flow control valve (see 6.3.26)	No flow indication in IAC system	Nosa
		5	Connection leaks	Process Signal	Incorrect signal to transmitter	No flow indication in 18C system	None

6.0 SUBSTSTEM: RC BLEED, BORON RECOVERT, AND CHEMICAL ADDITION

		-	Potential Fallure Mode	e Mode	Jamediate Effects	Effects	
	Component		Mode	Interface Involved	Within Subsystem	At Subsystem	Remedial Action Within Subsystem
6.3.31	Flow Transmitter (cont'd)	ě	Transmitter fails	1	incorrect eignal to flow control valve (see 6.3.26)	No flow indication in IAC system	None
6.3.32	Control Valve (HP-16)	ż	Control signal falls to open valve	Control Signal From 3-Way	Loss of flow to makeup filters	No demineralized water to makeup filters	None
		5	Control signal Salls 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
		m	Instrument air	Instrument Air	Loss of flow to	No demineralized water to makeup filters	None
		÷	Electric power	Electric Poser	Loss of flow to	No demineralized water to makeup filters	None
		ý	Spurious eignal to open valve	Control Signal From 3-Way	Lose of flow control to makeup filters	Increase in desineralized water to makeup filters	Close manual isolation valves;
			Spurious signal to close vaive	Control Signal From 3-Nay	Loss of flow to makeup fillers	No demineralized water to makeup filters	None Br-192
		÷	Internal valve	1	Loss of flow to makeup filters	No demineralized water to makeup filters	None
B B	6.4 Boron Recovers:						
6.4.1	Manual (solution Valves (CT-3, CT-5)	4	RC bleed flow	NC Bleed Flow Gros Holdep Tank	No flow to ferd tank. Tank har 8-boar capacity; boron recovery will continue until tank is emety	Hone if feed tank is full	Alternate flow path available
		~	Valves fall closed	L	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 Desineralizer	-	Reain fill fails	Reain Fill	No demineralizing capacity; no effect since second demineralizer available	None if alternate flow path available	Alternate flow path available
		2	Tank leaks	1	Decreased flow; no effect mince second demineralizer available	None if alternate flow path available	Alternate flow path available
		m	Tank vent falls open	1	Decreased flow; no effect since second demineralizer available	None if alternate flow path available	Alternate flow path evailable
6.4.3	Manual Isolation Valves (CT-4, CT-6)	÷	Valves fall closed	;	No flow; no effect since second demineralizor available	None alternate flow path railable	Alternate flow path available
6.4.4	Manual Isolation Valve (CI-14)	-	f. Valve fails closed	1	No flow to feed tank. Tank has 8-hour capacity; boron recovery will continue until tank is cepty	None if feed tank is full	Establish recircelation flow free evaporator

6.0 SUBSTSTEM: RC BLEED, BORON RECOVERT, AND CHIMICAL ADDITION

			Potential Failure	Hode	Immediate f	Effects	
	Component		Mode	Interface Involved	Within Subsystem	At Subsystem Interface	Remedial Action
6.4.5	Miscellaneous Piping	1.	Electric power supply fails	Electric Power	Borte seid may crystallize; small potential for plugging and loss of flow	None unless concentrated borio acid storage tanks are empty	Restore trace heating; unplug
		2.	Trace heating fails	7	Boric acid may crystallize; small potential for plugging and loss of flow	None unless concentrated boric acid storage tanks are empty	Restore trace heating; unplugations
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-hows capacity; boron recovery will continue until look 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 sold 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 ospacity; boron recovery will continue until tank is empty	None if feed tank is full	Establish recirculation flow from evaporator
		١.	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 borto 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 sold storage tanks are empty	Hone
		3.	Tank went, relief walves 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 fells	Electrin Power	No local level indication	None	None
		2.	Connection leak	Process Signal	Incorrect signal to	None	None
		3.	Transmitter failure		No local level indication	None	None

6.0 SUBSTSTEM: RC BLEED, BORON RECOVERY, AND CERMICAL ADDITION

			Fotential Failu	re Mode	Immediate i	Effects	
	Component		Hode	Interface Involved	Within Subsystem	At Subsystem Interface	Remedial Action Within Subsystem
6.4.10	Manual Isolation Valves (CT-22, CT-23)	1.	Valves fall closed		No flow to evaporator feed pump. Recirculation flow path can be established through evaporator but boron recovery stops	None unless concentrated borio acid storage tanks are empty	Establish recirculation flow from evaporator
6.4.11	RC Bleed Evaporator Feed Pump (WD-P46)	1.	Electric power aupply 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 soid storage tanks are empty	Establish recirculation flow from evaporoator
6.4.12	Pressure Transmitter Fails	1.	Electric power supply fails	Flectric Power	No local pressure indication	None	None
	Transmitter Falls	2.		Process Signal	Incorrect signal to	None	None
		3.	Transmitter fails		No local pressure indication	None	None
6.4.13	Manual Isolation Valve (CY-24)	1.	Walve falls 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 Icvel	Loss of flow control to evaporator. Could flood evaporator or allow dryout. Recirculation flow paths to reed 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 fir	Los. of flow control to evaporator. Could flood evaporator or allow dryout. Rectroulation flow paths to feed tank or evaporator can be established. Boron recovery stops	Wome unless concentrated borie acid storage tanks are empty	Establish recirculation flow to feed tank or evaporator

6.0 SUBSYSTEM: AC BLEED, BOROW RECOVERY, AND CHEMICAL ADDITION

			Potential Failure	* Mode	Immediate (Effects	
	Component		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 borio acid storage tanks are empty	Establish recirculation flow to feed tank or evaporator
		•	Internal velve 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 borio 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	Weste, 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	1.	N ₂ blanket system	N ₂ Blanket	Possible explosive mixture forms	None	None
	(WD-EV1)	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 zmpty	Establish recirculation path to feed tank
		۸.	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 aupply fails	Electric Power	Concentrate heater / *11s; potential plugging an' lose of flow	None unless concentrated boric acid storage tanks are empty	Restore heater; unplug lines

6.0 SUBSISIEM: RC HLEED, BORON RECOVERT, AND CHEMICAL ADDITION

		1	rotential failure Mode	e Mode	Immediate Effects	Effects	
	Component		Mode	Interface Involved	Within Subsyntem	At Subsystem Interface	Remedial Action Within Subsystem
6.4.17	RC Bleed Evaporator (WD-EVI) (conl'd)	÷	Inlet flow from feed pump falls	1	No boron recovery	Mone unless concentrated boric seid storage tanks are empty	Establish recirculation flow path until feed flow
		e.	Evaporator leaks	1	Eventual loss of suctional pressura to pump	None unless concentrated borlo acid storage tanks	None
		6	Evaporator empties		Foasible domage to evaporator; no boron recovery	None unless concentrated boric acid storage tanks	Shut off steam
		10.	Evaporator vent, relief valven fail open	1	Cover gas release to vent header	None	Rone
6.4.16	Evaporator Level Transmitter	-	Electric power supply falis	Electric Power	Incorrect eigns to evaporator feed pump dischurge flow control yalve (see 6.9, 18)	None unless concentrated borio acid storage tanks are empty	Kone
		ri .	Connection leaks	Process Signal	Incorrect eignal to evaporator feed pump discharge flow control valve (see 6.4.14)	Mone unless concentrated borio acid storage tanks are empty	None
		m.	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	Transmitter Transmitter	2	Electric power supply fests	Electric Fover	Incorrect signal to transmitter and concentrate cooler discharge flow control (see 6.3.26)	See 6.4.26	None
		~	Connection leaks	Process Signal	Incorrect signal to transmitter and concentrate cooler discharge flow control (ans 6 M.26)	See 6.4.26	None
		<u>.</u>	Transmitter failure	1	Incorrect signal to transmitter and concentrate cooler discharge flow control (see 6.4.26); no local temperature findication	See 6.8.26	Моне
6.4.20	(WD-C9)	÷	Cooling water supply falls	Cooling Water	High temperature distillate returns to feed tank	None	Establish recir- culation path
		~	Elocked tube	1	Decreased hear transfer; high temperature distillate returned to feed tank	None	to feed tank Establish recir- culation path to feed tank

6.0 SUBSTITIM: RC BLEED, BORON RECOVERT, AND CHEMICAL ADDITION

		10	Potential Failure	Hode .	Ismediate	Effects	
	Component		Hode	Interface Involved	Within Subsystem	At Subsystem Interface	Remedial Action Within Submystem
6.4.20	Distillate Cooler (WD-C9) (cont'd)	3.	Tube Pupture		Cooling water released to distillate; dilutes feed tank concentration	None	Establish recir- culation path to feed tank
		١.	Loss of heat transfer capability	-	Decreased heat transfer; high temperature distillate returned to feed tank	None	Establish recir- culation path to feed tank
		5.	Cooler leaks	-	Decreased distillate flow	Decreased distillate available to conden- sate tent tanks (deminoralized water)	Establish recir- sulation path to feed tank
		6.	Inlet flow fails	Evaporator Distillate	No distillate flow	Wo distillate available to condensate test tanks (demineralized water)	None
6.4.21	Concentrate (Recirc.) Pump	1.	Electric power supply fails	Electric Power	Pump stops; no concentrate flow	None unless concentrated boric acid storage tanks are empty	None
	(WD-P4)	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-18)	1.	Valve fails open		Concentrate flow recirculated to evaporator. No boron recovery; possible evaporator flooding	None unless concentrated boric sold 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.	Blooked tube	-	Decreased heat transfer; high temperature boric acid returned to concen- trated boric acid storage tanks	None	Close control valve CT-40

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

			Potential Fallure	Hode	Immediate	Effects	
	Component		Hode	Interface Involved	Within Subsystem	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 beric acid mix tank
		۸.	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 sold storage tanks are empty	None
		6.	Inlet flow fails	Evaporator Concentrate	No concentrate flow	Hone unless concentrated boric acid storage tanks are empty	Close control valve CT-40
		7.	Cooling water control valve fails	From Concen- trate Cooler Discharge Temperature	No concentrate flow	None unless concentrated boric soid 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	We 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 borio acid storage tanks are empty	Close cooling water control alve; 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 Temporatura 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 lank through CT-36

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

			Potential Failur	e Hode	Immediate	Effects	
	Component		Hode	Interface Involved	Within Subsystem	At Subsystem Interface	Rewedial Action Within Subsystem
6.4.27	Control Valve (CT-NO) (nont'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 mater control prive; divert concentrate flow back to evaporator through CT-36 or to feed tan through CT-36
		•	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 CI-38 or to feed tank through CT-36
6.5 De	borat' Deminerali	zer:					
6.5.1	Manual Centrol Valve	1.	AC Bleed flow falls	RC Bleed Flow	No flow to deborating demineralizer	No flow to makeup filters	None
		2.	Valve falls 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 fall open		Decreased bleed flow	None if siternate flow path available	Alternate flow path available
		٠.	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; nmall potential for plugging and loss of flow	None if alternate flow path available	Restore trace heating; unplu
		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
5.5.5	Waste, Drain, Sample Lines	1.	Lines fall open		Decreased bleed flow	None if alternate flow path available	Alternate flow path available
6.5.6	Manual Isolation	1.	Valves fail closed	-	No bleed flow	None if alternate flow path available	Alternate flow

6.0 SUBSTSTEM: RC BLEED, BOROW RECOVERY, AND CHEMICAL ADDITION

			Potential Fail		Immediate	Effects	
	Component		Hode	Interface Involved	Within Submystem	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	**	Fossible backflow to deborating demineralizer	No flow to makeup filters	Close HP. 16