Pressurized Water Reactor
B&W Technology
Crosstraining Course Manual

Chapter 3.0

Makeup and Purification System

And

Component Cooling Water System

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3.0 MAKEUP AND PURIFICATION SYSTEM and COMPONENT COOLING WATER SYSTEM

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Learning Objectives:

1. List and explain the purposes of the makeup and purification system.

2. List in flow path order and state the purpose of the following major components of the makeup and purification system:

   a. Letdown heat exchanger
   b. Letdown flow control valve
   c. Prefilter
   d. Demineralizers (ion exchangers)
   e. Filter
   f. Makeup tank
   g. Makeup pumps

3. Identify the components in the makeup and purification system that are used to purify the reactor coolant and the types of contaminants each is designed to remove.

4. Define the following terms:

   a. Boration
   b. Dilution
   c. Batch
   d. Feed and bleed

5. Explain the feed and bleed interlocks.

6. Explain why the following chemicals are added to the reactor coolant system and identify the plant conditions that would require their use:

   a. Lithium hydroxide
   b. Hydrogen
   c. Hydrazine

7. Explain how seal injection flow is maintained to the reactor coolant pumps on a loss of the operating makeup pump.

8. State the purpose of the connection between the decay heat removal system and the makeup and purification system.

9. List the plant operations that result in large amounts of influent into the boron recovery system.

10. Identify the changes in the makeup and purification system that occur on the receipt of an engineered safety features actuation signal.

11. Explain how the makeup and purification system is designed to prevent the following:

    a. Loss of suction to the makeup pumps.
    b. High temperature in the ~~demineralizers~~Demineralizers.

12. List the automatic action initiated by the makeup tank level instrumentation.

3.1 Makeup and Purification System Introduction

The makeup and purification system performs the following functions:

1. Purification of the reactor coolant system.
2. Soluble poison control.
3. Reactor coolant chemistry control.
4. Reactor coolant pump seal injection supply.
5. Volume control of the reactor coolant system.
6. High-pressure injection during an accident.

The letdown portion of the makeup and purification system originates from a connection on the suction side of one of the reactor coolant pumps ~~-~~(RCPs). The normal flowpath is as follows: cooler, pressure reducer, prefilter, ion exchangers, purification filter~~,~~ and makeup tank to the makeup (high-pressure injection) pump. The return flow to the reactor coolant system is split from the discharge of the makeup pumps, with most of the flow passing through the reactor coolant pump seal injection filters and seal injection flow control valves. This flow is injected into the reactor coolant pump seal area. The remaining flow passes through the makeup control valve and is injected into the reactor coolant system.

Reactor coolant inventory control is accomplished by varying the makeup flowrate in response to changes in pressurizer level. Reactor coolant system boron changes are performed through system interconnections with the chemical addition and boron recovery system. Chemicals are injected into a point between the ion exchangers and the purification filters to control reactor coolant system corrosion. In addition to the makeup and purification system, the feed and bleed interlocks are also discussed in this chapter.

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3.2 Makeup and Purification System Description

The makeup and purification system is shown in Figure 3-1.

3.2.1 Letdown

The letdown piping is connected to RCP ~~reactor coolant pump~~ 2 suction piping and travels to the letdown coolers. The piping on the inlet to each letdown cooler contains a motor-operated isolation valve (V-1A or V-2B), which is operated remote manually and individually interlocked to close automatically when component cooling water temperature control valves on the shell side outlet of the letdown cooler are 100% closed. When closed by this mode, the valve(s) will remain closed until the closing signal has been cleared, at which time operator action is required to reposition the valve. This protects the downstream components from excessive temperature exposure in the absence of cooling water.

Two letdown coolers, each sized for one-half of full letdown flow (200 gpm), are cooled by the component cooling water (CCW) system and provide the necessary temperature reduction (from about 570°F to less than 120°F) of the letdown stream for proper ion exchanger operation. Both coolers are in service at all times to preclude the severe transient of bringing on line an idle cooler every time a letdown flow of greater than 100 gpm is required. The motor-operated letdown cooler outlet valves (V-3A and V-4A) are closed by an Engineered Safety Features Actuation Signal (ESFAS). The letdown piping joins downstream of the cooler outlet valves and leaves the reactor building.

A motor-operated letdown isolation valve (V-5B) is installed on the outside of the reactor building to provide redundant isolation of the letdown line penetration. This valve is also closed by an ESFAS signal. In addition to the automatic ESFAS closure, the valve is interlocked with letdown line temperature. If the temperature of the letdown stream exceeds 135°F, the letdown isolation valve closes to protect the ion exchanger resin beds.

From the letdown isolation valve, the letdown line passes to the letdown flow control valve (FCV-7), which maintains the desired letdown flow rate and reduces the pressure of the letdown stream from reactor coolant system pressure to about 125 psig. A flow rate of 50 gpm is sufficient to purify approximately one reactor coolant system volume in a 24-hour period. The letdown flow control valve is provided with a normally closed bypass valve which may be manually positioned for flow control. The flow control valve provides a method of increasing letdown flow during those periods when a flow rate of greater than 50 gpm is required. Letdown flow is administratively limited to a maximum of 200 gpm. This flow rate is chosen to allow a power maneuver of 100% to 50% to 100% while compensating for xenon reactivity changes with soluble poison control. Both letdown coolers are required when maximum letdown is used.

Two letdown line instruments are located in the line between the flow control valve and purification prefilters. The first of these instruments is a flow transmitter used to provide letdown flow indication in the main control room. The second instrument is a temperature transmitter that provides the high-temperature interlock for the letdown line isolation valve (V-5B) and temperature indication in the control room.

The purification prefilters are installed to remove corrosion products from the letdown system, thus preventing their deposition in the ion exchangers. The prefilters are capable of handling full letdown flow. A pneumatic valve, not shown in Figure 3-1, parallels the prefilters to maintain flow during filter changes. Provisions are also available for bypassing both prefilters. From the purification prefilters, the letdown stream is directed to the ion exchangers.

The ion exchangers function to remove ionic impurities from the reactor coolant. The three ion exchangers are designed for parallel operation, with each ion exchanger sized for one-half maximum letdown flow. Two of the ion exchangers are mixed-bed units; that is, they contain both anion and cation resin. The third unit might only contain the cation resin. This cation ion-exchanger would be placed in service when a reduction in lithium, cesium, yttrium~~,~~ or molybdenum is required. The use of the prefilter upstream of the ion exchangers limits the activity buildup in the resin beds due to crud. The prefilter and ion exchangers accomplish the purification function of the makeup and purification system.

Downstream of the ion exchangers are two valves that are used in conjunction with the addition of demineralized water or boric acid to control the soluble poison (boron) concentration of the reactor coolant. The valves are the trim bleed valve (V-16) and the ~~three-way~~ bleed diversion valve (V-81).

The trim bleed valve, when opened, provides a parallel flowpath for the letdown stream, with most of the flow passing through the purification filters and the remaining flow being directed to either the deborating ion exchangers or to the bleed holdup tanks. The trim bleed valve is used when small changes in reactor coolant system boron concentration are required. The trim bleed valve is a throttle valve~~,~~ and its position is controlled from the main control room.

The ~~three-way~~ bleed diversion valve, V-81, is used when it is desired to direct all letdown flow to either the deborating ion exchangers or the bleed holdup tanks. The ~~three-way~~ bleed diversion valve is interlocked to prevent the simultaneous, continuous feeding of demineralized water into the reactor coolant system while bleeding letdown to either the deborating ion exchangers or bleed holdup tanks, unless the control rods are within a specified band. The interlocks are described ~~covered~~ in Section 3.2.8. The letdown stream normally flows from the ~~three-way~~ bleed diversion valve to the purification filters.

Penetrations into the piping between the ~~three-way~~ bleed diversion valve and the purification filters provide a means for borating/deborating the reactor coolant system and adding corrosion-inhibiting chemicals.

The purification filters are designed to remove impurities that may have been added by the chemical injection systems into the letdown stream. Each filter is designed to handle one-half the maximum letdown flow. The pressure drop across the filters is monitored in the control room, and each filter has a remotely controlled inlet valve that allows the operator to place the standby filter in service from the control room as necessary. The effluent from the purification filters combines with makeup pump recirculation and RCP seal return flow and enters the makeup tank.

3.2.2 Makeup Tank

The makeup tank provides a collection point for reactor coolant system letdown flow; makeup pump recirculation flow~~,~~ and RCP ~~reactor coolant pump~~ seal return flow. Makeup tank influent is passed through a spray nozzle. The makeup tank gas space contains hydrogen gas, and the spraying action of the fluid as it enters helps to maintain the required hydrogen concentration in the reactor coolant system. (The hydrogen concentration is maintained to scavenge oxygen.) The hydrogen gas is added to the makeup tank from the plant hydrogen storage banks through a pneumatic control valve. Connections are made to the tank to allow venting to the waste gas system. The makeup tank is sufficiently elevated to provide the required net positive suction head (NPSH) for the makeup pumps.

Tank status is monitored by pressure indication, high- and low-pressure alarms, level indication, high- and low-level alarms, temperature indication, and high-temperature alarm. All makeup tank indication and alarms are displayed in the control room. An interlock on low makeup tank level will reposition the ~~three-way~~ bleed diversion valve, (V-81), from the bleed position to the makeup tank position at MUT Level of 32 inches. The MUT high and low level alarms have no interlock functions.

The makeup tank outlet valves (V-136A and V-137B) close on an ESFAS ~~signal~~ to isolate the makeup tank from the suction headers of the makeup pumps.

3.2.3 Makeup Pumps

Three centrifugal pumps are installed in the makeup and purification system. The suction and discharge piping for the three makeup pumps is designed to provide isolation capabilities for system redundancy in both the normal and emergency high pressure injection modes and also to provide system flexibility by cross-connection lines that allow pump 3C to replace either of the other two pumps. During normal reactor plant operations, either pump 1A or 2B may be in operation with the other pump in immediate standby. Pump 3C can be powered by either emergency bus when the pump normally powered by that bus has been taken out of service for maintenance or repairs.

The makeup pumps are normally supplied with a suction from the makeup tank. However, a suction supply from the borated water storage tank (BWST) for the injection phase of a loss-of-coolant accident (LOCA) and a suction supply from the Low Pressure Injection (LPI) pump discharge for the recirculation phase of a LOCA are also provided. The makeup pump suction is automatically swapped to the BWST on receipt of an ESFAS start. A recirculation flowpath to ensure pump cooling is routed back to the makeup tank inlet line. This The recirculation line is isolated by an ESFAS signal.

Makeup pumps A and B are powered from separate vital 4160-Vac supplies. The motor circuit breakers are interlocked with pressure switches for pump protection against: (1) low suction pressure (to provides protectionprovide protection in the event of a low makeup tank level or low LPI discharge pressure during recirculation phase), (2) high discharge pressure (to provide protection in the event of a closed dischargeclosed discharge valve, (3) time delayed low discharge pressure if the pump stated from a standby condition (to provide protections in the event of a pipe break at the pump discharge), and (4) low lubricating oil pressure. These interlocks are bypassed on receipt of an ESFAS start signal. The makeup pumps aligned to the emergency busses are automatically started (1) on an ESFAS and (2) as part of the load sequence following a loss of offsite power without a concurrent ESFAS. The standby makeup pump will also start if RCP seal injection flow is low on three or more RCPs after about a 1 minute time delay. The time delay (allows adequate lube oil pressure buildup in the standby makeup pump).

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The makeup pumps aligned to the emergency busses are automatically started as part of the load sequence following a loss of offsite power without a concurrent ESFAS signal. One makeup pump can provide sufficient makeup and seal injection flow, and 100% of the high-pressure injection requirements. The makeup pumps discharge to the reactor coolant system makeup header, the seal injection header, and the high-pressure injection headers. Normal reactor coolant system makeup and seal injection is described covered in the following sections of this chapter, and high-pressure injection is discussed in Section 4.2 of this manual.

3.2.4 Normal Reactor Coolant System Makeup

The normal makeup to the reactor coolant system consists of a makeup flow control valve, a makeup isolation valve, and a makeup penetration to the reactor coolant system. The makeup control valve (V-14) is modulated by the pressurizer level control signal to maintain pressurizer level at setpoint. The makeup isolation valve (V-208B) provides isolation of the normal makeup flowpath during an accident condition. To prevent unnecessary reactor coolant system piping penetrations, the normal makeup line forms a tee with the high-pressure injection line. A flow transmitter provides the operator with makeup flow indication.

3.2.5 Reactor Coolant Pump Seal Injection

The seal injection system is shown in detail in Figure 3-2. As shown in this figure, the injection system may be supplied from any normal makeup pump. Low seal injection flow signals are used to start the standby makeup pump after a 1 minute time delay. This action is necessary to prevent a loss of seal injection due to the ~~because of a~~ loss of one vital 4160-Vac bus. As stated in Section 3.2.3, makeup pumps are powered from respective trains of vital 4160-Vac power. If the selected running pump bus were lost, then the makeup pump would be unavailable to supply seal injection. Without seal injection the reactor coolant pump seals could be damaged and, in turn, cause a LOCA. The ~~backup~~ seal injection being supplied ~~supply~~ from the standby makeup pump minimizes this possibility.

The amount of seal injection to the RCPs is governed by a flow control valve (FCV) in each supply line (FCV-52A, ~~FCV~~-52B, ~~FCV~~-52C, and ~~FCV~~-52D). The individual seal injection FCVs control seal injection flow to their respective RCPs. The control scheme consists of comparing seal injection flow from the flow transmitter upstream of the individual seal injection control valve with a setpoint supplied by the operator. The error signal that results from the comparison modulates the individual seal injection flow control valve.

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Two interlocks are supplied by the individual seal injection flow transmitters. First interlock ~~start~~s the standby makeup pump after a time delay if RCP seal injection flow is low on three or more RCPs (~~previously described~~ see Section 3.2.3 above). Second interlock ~~closes~~s ~~its~~ respective seal return valve if both seal injection flow and CCW flow to the seal heat exchanger is lost to a running RCP (see Section 3.2.6 below) Operator-controlled isolation valves ~~(V-237, V-238, V- 239 and V-240)~~ are installed in each seal injection line. Seal injection filters are provided to ensure a clean supply of seal water to the RCPs~~reactor coolant pumps~~.

3.2.6 Reactor Coolant Pump Seal Return

The seal return system consists of individual seal return isolation valves, a reactor building isolation valve, and the seal return coolers (Figure 3-1). The individual seal return isolation valves (V-282A, V-281A, V-280A, V-279A) are interlocked closed by the following signals:

1. With the combination of an idle reactor coolant pump and a low seal injection flow signal, the associated seal return isolation valve will close.

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2. If an RCP ~~reactor coolant pump~~ is running, the associated seal return isolation valve will close if both seal injection flow and CCW ~~component cooling water~~ flow to the seal heat exchanger are lost to the RCP~~reactor coolant pump~~.

3. Channels 1A/1B ESFAS will close ~~signal~~ the individual seal return valves

These interlocks prevent the flow of hot reactor coolant across the pump seal faces.

The seal return piping penetrates the reactor building and then connects to the seal return coolers. An isolation valve (V-283B) located in this line is closed by an ESFAS ~~signal~~ and provides redundant isolation for the individual seal return valves.

In the seal return coolers, the reactor coolant pump seal return is combined with the makeup pump recirculation flow. The seal return coolers are cooled by the CCW ~~component cooling water~~ system, and one cooler is sufficient to handle makeup pump recirculation and seal return flow. The recirculation line from the makeup pumps is isolated during accident situations by closing V-198A and V-199B, ensuring that all high-pressure injection flow enters the reactor coolant system. The effluent from the seal return coolers is returned to the makeup tank inlet line.

3.2.7 Soluble Poison Control

Boric acid concentration control of the reactor coolant system is used to compensate for fission product poison changes, to position the control rods within their operating band~~,~~ and to establish the required concentration to satisfy shutdown margin requirements. Figure 3-3 shows the piping and equipment that are installed to perform the boric acid concentration changes.

3.2.7.1 Letdown Bleed Paths

Two paths are available to letdown (bleed) ~~highly concentrated boric acid~~ from the reactor coolant system. The first path goes through the trim bleed valve, ~~(~~V-16~~)~~, and the second path goes through the ~~three-way~~ bleed diversion valve, ~~(~~V-81~~)~~.

The trim bleed valve ~~(V-16)~~ is used to divert a small portion (up to 50 gpm) of the letdown flow to either the deborating ion exchangers or to the reactor coolant bleed holdup tanks. If the feed and bleed permit is not present, the trim ~~trip~~ bleed valve can be opened to either destination. (The feed and bleed permit is described in Section 3.2.8 below.) If the flowpath to the reactor coolant bleed holdup tank is chosen, then demineralized water or boric acid may be added to the makeup and purification system.

The ~~three-way~~ bleed diversion valve ~~(V-81)~~ is used to divert all letdown flow to either the deborating ion exchangers or the reactor coolant bleed holdup tanks, if proper interlocks are satisfied.

The deborating ion exchangers ~~are tanks~~ contain~~ing~~ anion-type resin and are used to reduce reactor coolant system boron concentration late in core life. At boron concentrations less than 100 ppm, use of the deborating ion exchangers is more economical than using ~~the boron recovery system because of~~ the large volumes of water required to change boron concentration.

As stated above, reactor coolant may be diverted to ~~he~~the reactor coolant bleed holdup tanks ~~provide~~ for storage ~~of reactor coolant system bleed~~. A boron recovery system was designed to transfer the fluid from ~~From~~ these tanks and then~~,~~ ~~the fluid is transferred~~transfer it to the bleed evaporators for processing. The pure water effluent from the evaporators would be ~~is~~ collected in the distillate storage tank and eventually reused as demineralized water. The boric acid would be ~~is~~ concentrated to 5 wt% (8,750 ppm) and pumped to the boric acid tanks.

3.2.7.2 Makeup Flow

Makeup is added to the makeup and purification system from two sources: (1) the distillate storage tank, which is the plants' supply of demineralized water, and (2) boric acid storage tanks that contain 5 wt% (8,750 ppm) soluble boric acid.

The distillate storage tanks contain demineralized water~~,~~ and were designed to be replenished from the distillate produced in the waste evaporators or from water received from the site water treatment plant. As shown on Figure 3-3, demineralized water is added via flow-control valve HIC-20. The operator controls the position of HIC-20 from the main control board~~-~~ to maintain a desired flowrate. Makeup flow is then directed through the totalizer outlet ~~makeup tank addition~~ valve, ~~(~~V-19~~)~~.

Boric acid is stored in the concentrated boric acid storage tanks and the boric acid addition tank. Two boric acid pumps take ~~a~~ suction on the tanks and deliver boric acid to the makeup and purification system. The boric acid pumps are redundant, with cross connections on the pump suction and discharge which allow either of the pumps to supply boric acid to the makeup and purification system. The boric acid pumps discharge through a filter to two points in the letdown line: the normal boration path and ~~the~~ an auxiliary boric acid injection path. The normal boration path consists of the boric acid control valve (HIC-21) controlled by the operator from the main control board and the totalizer outlet ~~makeup tank feed~~ valve, ~~(~~V-19~~)~~, discussed later. An auxiliary boric acid injection point is provided to the outlet of the makeup tank to allow the addition of boric acid if the normal flowpath is unavailable. The valve used for this addition must be operated locally.

3.2.7.3 Boron Concentration Changes

Two methods are available to change the boron concentration of the reactor coolant system; the batch method and the feed and bleed method.

The batch method consists of diverting the letdown stream to the reactor coolant bleed holdup tanks ~~(holdup tanks)~~. Either the trim bleed valve, ~~(~~V-16~~)~~ , or the ~~three-way~~ bleed diversion valve, ~~(~~V-81,~~)~~ may be used to initially lower makeup tank level. The normal seal injection and makeup flow will decrease makeup tank level until sufficient volume exists in the makeup tank to accommodate the batch size. The required quantity of boric acid or demineralized water is then added to the makeup and purification system. The addition is controlled by the batch controller. In addition, the operator must open the ~~makeup tank addition~~ totalizer outlet valve, ~~(~~V-19,~~)~~ and the control valve for boric acid, ~~(~~HIC-21,~~)~~ or the control valve for demineralized water (HIC-20). When the quantity added equals the batch size, the totalizer outlet ~~makeup tank addition~~ valve ~~(V-19)~~ closes so that the desired batch size is not exceeded. The operator must then close either the boric acid control valve (HIC-21) or the demineralized water control valve (HIC-20).

The feed and bleed method consists of diverting the letdown stream to the reactor coolant bleed holdup tanks or the deborating demineralizers through the trim bleed valve or the ~~three-way~~ bleed diversion valve, while the simultaneous addition of boric acid or demineralized water is taking place.

3.2.8 Feed and Bleed Interlocks

It is desired to maintain rod control groups in a position that would allow the unit to have full maneuvering capabilities. The positioning of the control groups is such that load changes could be followed using only the control groups for reactivity control. This nominal control group position is shown on Figure 3-5 with respect to unit power level. This curve was developed in the early 1970s. Later in the mid 1970s core protection following a loss of coolant accident became a prime concern and led to the development of rod index limits. Above approximately 85% power, the rod index limits are more restrictive, calling for a rod position that is higher than the nominal position shown on Figure 3-5. Currently the reactor is usually operated at a steady state rod index of ~90% on Group 7 which would be well above the required minimum insertion limits. For this plant, a continuous feed and bleed (boration or dilution) will only be performed during low power operations.

Again, referring to Figure 3-5, the nominal rod position is shown in reference to a specific power level. A deadband of + 7% is set around the nominal position to account for some rod motion due to poison buildup or fuel burnout. Exceeding the deadband in either direction, above 15% power, actuates an annunciator telling the operator he needs to either borate or deborate. In addition, a feed and bleed permissive signal is sent to the ~~three-way~~ bleed diversion valve (V-81), the trim bleed valve (V-16), and the ~~makeup tank addition~~ totalizer outlet valve (V-19). This permissive signal can also be initiated when power is below 15% if certain conditions are met as shown on Figure 3-4. This signal is annunciated as low power enable.

The development of the feed and bleed permissive signal is shown on Figure 3-4. Four input signals are used:

1. Regulating group 5 position
2. Safety groups 1, 2, 3, 4 position
3. Reactor power from the integrated control system
4. Regulating group 7 position

These four inputs are combined to develop either a low power enable, borate enable, or deborate enable annunciator. All three signals initiate a feed and bleed permissive signal that is sent to the following valves (Figure 3-3):

- Trim bleed valve (V-16) - The feed and bleed permissive signal removes control from the main control board station and inserts a close signal. Therefore, trim bleed can only be done when the permissive signal is not present.

- ~~Three-way bleed~~ Bleed ~~valve~~diversion valve (V-81) - The feed and bleed permissive signal allows the operator to place the valve in the bleed position if the ~~makeup tank addition~~ Totalizer outlet valve (V-19) is open and the batch controller total is less than the preshutdown value. Loss of the permissive signal, closure of V-19, or batch total greater than pre-shutdown value automatically returns the valve to the non-bleed position.

- Totalizer outlet ~~Makeup tank addition~~ valve (V-19) - The feed and bleed permissive signal does not affect the opening of this valve. With the ~~three-way~~ bleed diversion valve (V-81) in the bleed position, a loss of the feed and bleed permissive signal will cause the valve to close. The valve will also close when any addition is being made and the batch total reaches the shutdown setpoint. This prevents adding more liquid than was intended.

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3.2.9 Chemical Addition

Provisions are provided to add lithium hydroxide for pH control and hydrazine for oxygen control of the reactor coolant system. These chemicals are added through an injection point upstream of the purification filters (Figure 3-1). The addition of hydrazine is required only during cold shutdown conditions, less than 200°F. Above 400°F, hydrazine breaks down into its constituent parts. Hydrogen in the makeup tank gas space is used to control reactor coolant system oxygen when reactor coolant system temperature is greater than 200°F.

3.2.10 Reactor Coolant System Volume Control

The volume of the reactor coolant system is controlled by the makeup and purification system. A pressurizer level signal controls the makeup control valve (V-14).

If pressurizer level is greater than setpoint, the makeup control valve throttles makeup flow. With makeup flow throttled, letdown flow restores pressurizer level to normal. The excess reactor coolant system volume increases makeup tank level. If makeup tank level reaches the high alarm setpoint, the operator positions the trim bleed valve to reactor coolant bleed tanks until makeup and seal injection flow returns makeup tank level to normal.

If pressurizer level is lower than setpoint, the makeup control valve opens to increase makeup flow. The additional reactor coolant system volume is supplied by the makeup tank. If tank level drops to the low level alarm, the operator initiates batch makeup. Normal inventory losses resulting from leakage are also accommodated by the batch makeup process.

3.2.11 High Pressure Injection

The following actions occur on the receipt of an ESFAS signal from channels 1A and 1B (refer to Figure 3-1):

1. Letdown is isolated (V-3A, V-4A, V-5B).
2. The seal return penetration is isolated (V-283B).
3. Individual seal return isolation valves close (V-279A, -280A, -281A, 282A).
4. The makeup tank is isolated from the makeup pump suction header (V- 136A and V-137B).
5. The makeup pump recirculation isolation valves close. (V-198A and V-199B)
6. Normal makeup is isolated (V-208B).
7. The BWST suction supply valves open (V-144A and V-141B).
8. Makeup pumps start (standby pump).
9. High-pressure injection discharge cross-connect valve, V-380A, closes.
10. The high-pressure injection motor-operated valves open (V-179A, V- 174A, V-185B, and V-184B).

The high-pressure injection system is discussed in detail in Section 4.3 of this manual.

3.3 Component Description

3.3.1 Letdown Coolers

The letdown coolers are shell and tube heat exchangers with letdown flowing through the tubes and component cooling water flowing on the shell side. A maximum letdown flow of 200 gpm was calculated on the basis of the boron concentration changes required to compensate for the xenon reactivity associated with a power maneuver from 100% to 50% to 100%. This basis applies up to 90% of core life. Each cooler is designed to handle one-half of this flow. Both coolers are normally in service to minimize thermal stresses associated with placing a standby cooler in service. The coolers reduce the letdown temperature to less than 120°F, assuming a maximum component cooling water temperature of 105°F. Additional design data are given in Table 3-1.

3.3.2 Letdown Prefilter

Corrosion product activity is removed from the letdown stream by the letdown prefilter. This minimizes the crud loading of the demineralizers and extends the life of the demineralizer resins, which are normally changed based on the total contained activity. The prefilter is a cartridge type filter. Design data for the prefilter is given in Table 3-1.

3.3.3 Purification Ion Exchangers

Three ion exchanger units are installed to remove soluble ionic impurities from the reactor coolant system. Each unit is designed for one-half the maximum letdown flow. Flushable strainers on the outlet line of each ion exchanger are installed to collect resin fines. Design data for the purification ion exchangers are given in Table 3-1.

3.3.4 Purification Filters

The purification filters are installed to remove impurities that may have been added by the makeup tank addition valve effluent or the chemical addition system. Purification filter design data are listed in Table 3-1.

3.3.5 Makeup Tank

The makeup tank collects the reactor coolant system letdown and reactor coolant pump seal return flows and provides the normal suction source for the makeup pumps. The makeup tank inventory is maintained sufficiently high to accommodate surges that result from reactor coolant system transients and to provide 10 minutes of makeup at the small- break flow rate. The small break is defined as the loss of reactor coolant equivalent to the rupture of a 3/4 inch schedule 160 pipe. If the makeup tank is at the low-level alarm, 10 minutes of makeup are available. Additional design data are given in Table 3-1.

3.3.6 Makeup Pumps

Each makeup pump is an 11-stage, horizontal, centrifugal pump. The prime mover for the makeup pump is an 1800-rpm, 4160-vac, 1000-hp electric motor. The power supply for the motor is from vital distribution.

An auxiliary, electric-driven, lubricating pump provides lubrication for the pump inboard and outboard bearings and the gear box during pump startup. After startup, the makeup pump provides its own lubricating oil pressure, and the auxiliary pump may be stopped. Operating the auxiliary lubricating oil pump is required to build up sufficient oil pressure before starting the makeup pump; however, this interlock is bypassed when the pump is started by an ESFAS signal, channel 1. The design, normal, and emergency operating points are shown on the makeup pump characteristic curve, Figure 3-6.

3.3.7 Seal Injection Filters

The seal injection filters are installed to remove particulates that could damage the reactor coolant pump seal faces. Design data for the seal injection filters are listed in Table 3-1.

3.3.8 Seal Return Coolers

The seal return coolers are tube and shell heat exchangers. The seal return and makeup pump recirculation flows through the tubes, and component cooling water flows on the shell side. Each cooler is sized to cool all reactor coolant pump seal return and one makeup pump recirculation flow. Additional design data are given in Table 3-1.

3.3.9 Heat Tracing

Redundant heat tracing is installed on the equipment and piping that handle concentrated boric acid. The letdown line, downstream of the boric acid injection point, is not heat traced because of its temperature (~120°F) and because the boric acid is diluted by letdown flow.

3.4 Makeup and Purification System Operations

3.4.1 Reactor Coolant System Purification in Cold Shutdown

As shown in Figure 3-1, a cross connection from the decay heat removal system taps into the makeup and purification system downstream of the letdown flow control valve. A return cross connection is installed on the makeup tank inlet line. A manual valve on the inlet to the makeup tank is closed, and a portion of the decay heat pump discharge flow is routed through the prefilter, ion exchangers, and purification filters, and then back to the decay heat pump suction. This flowpath is used for purification, chemical addition, and boron concentration adjustments during cold shutdown.

3.4.2 Auxiliary Pressurizer Spray

In parallel with the normal makeup and seal injection headers is a cross connection to the auxiliary pressurizer spray header in the decay heat removal system. The makeup pumps can supply flow to the pressurizer spray line for pressurizer pressure control when the reactor coolant pumps are not operating and the reactor coolant system pressure exceeds the discharge pressure of the decay heat removal pumps.

3.4.3 Plant Heatup

As reactor coolant temperature is increased by the heat added by the reactor coolant pumps, the reactor coolant expands. The expansion volume increases pressurizer level. To maintain pressurizer level in the desired range, the letdown flow is manually increased. Increasing letdown flow, in turn, increases makeup tank level. When the high-level alarm is reached, letdown flow is diverted to the bleed tanks by the manual repositioning of the ~~three-way~~ bleed diversion valve (V-81). The three-way bleed valve is returned to normal after the makeup tank level has been lowered to its normal range. The above evolution is repeated over and over during the plant heatup.

3.4.4 Plant Cooldown

Two requirements govern makeup and purification system operation during a plant cooldown: (1) the boron concentration in the reactor coolant system and (2) the required amount of boric acid that must be added to ensure a 1% ΔK/K shutdown margin. Fortunately, these requirements are not in opposition. Before the initiation of the plant cooldown, the boron concentration necessary for a 1% ΔK/K shutdown margin is calculated. The cooldown is initiated, and boric acid is added to compensate for the reactor coolant system contraction. After the required amount of boric acid has been added, demineralized water and boric acid are added to compensate for the contraction and to maintain the required boron concentration.

3.4.5 Power Operations

The control philosophy for the Babcock & Wilcox 205 fuel assembly plants is to use control rod movement to compensate for unit load changes, and boron control to compensate for fission product poison changes and fuel depletion. Therefore, the makeup and purification system provides a method of reactor coolant system boron concentration control. Boron is added or diluted to compensate for the following reactivity effects:

1. Reactivity deficit associated with a heatup from ambient to operating temperatures.
2. Buildup of xenon and samarium to equilibrium values.
3. Fuel burnup.
4. Transient xenon resulting from power level changes.
5. Reactivity addition associated with a cooldown from operating temperatures to cold shutdown.

3.5 Makeup and Purification System Summary

The makeup and purification system is a multipurpose system that is used to regulate reactor coolant system volume and boron concentration, to provide seal injection, to purify and control reactor coolant system chemistry, and to provide emergency core cooling if required. These functions, with the exception of high pressure injection, are accomplished by removing a small amount (~50 gpm) of reactor coolant from the reactor coolant system and routing it to the makeup and purification system. In the makeup and purification system, filters and ion exchangers remove reactor coolant system impurities. Boric acid concentration changes are performed by interfaces with the demineralized water system; the boric acid addition system, the deborating demineralizers, and the reactor coolant bleed tanks.

Boration/deboration permissive signals permits generated from rod position versus reactor power allow concurrent feed and bleed operations.

The coolant removed from the reactor coolant system is returned by the makeup pumps through the normal makeup path and the seal injection system.

High-pressure injection is supplied by the makeup pumps from the BWST during the injection phase of a LOCA or from the low-pressure injection pumps during the recirculation phase.

3.6 Component Cooling Water System (CCW) Introduction

The purpose of the component cooling water (CCW) system is to provide cooling water for components which may contain radioactive fluid and to transfer the absorbed heat to the nuclear service water (NSW) system. Some of the components cooled by the CCW system are listed below:

1. Letdown coolers
2. Reactor coolant pump seals and motors/oil coolers
3. Reactor coolant drain tank heat exchanger
4. Seal return coolers
5. Waste evaporators and waste gas system components
6. Spent fuel pool coolers
7. Miscellaneous sample coolers and air conditioning systems
8. Control rod drive cooling system heat exchangers

The CCW system is a closed-loop system which provides a barrier to the leakage of radioactivity to the environment via the NSW system. The barrier is provided by the low operating pressure of the CCW system. The pressure in the CCW system is lower than that of any component supplied by the system and CCW pressure is also lower than NSW pressure. Therefore, any leakage from cooled components or from the NSW system will be contained in the CCW system.

The control rod drive (CRD) cooling water system is a separate, smaller closed-loop cooling water subsystem that is contained within the CCW system. This subsystem is cooled by CCW and supplies cooling water to the CRD stators. Control rod drive cooling is required for normal operations, but it is not required to mitigate the consequences of any accident.

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Neither the CCW system nor the control rod drive cooling water system is required for safe shutdown of the plant. However, the availability of the CCW system during a loss of offsite power (LOOP) is ensured by separate LOOP CCW pumps that are sequenced onto the vital busses during these events. The LOOP CCW pumps ensure the ability to cool important components such as the RCPs and letdown heat exchangers. In addition, provisions exist to use the shutdown cooling water (SCW) system to cool the CCW system load during abnormal operating conditions. The SCW system is described in Chapter 4.0, ECCS.

3.7 CCW System Description

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The CCW system is shown in Figure 3-7.

The CCW system consists of two 50% capacity CCW pumps, three 50% capacity CCW heat exchangers, two 25% capacity loss-of-offsite power (LOOP) CCW pumps, one surge tank, a chemical addition standpipe, and associated piping, valves, instrumentation, and controls.

The discharge of the CCW pumps is divided into four headers. The first header supplies cooling water to the sample coolers, RCP seal return coolers, air conditioning coolers, control rod drive cooling water heat exchangers, and the containment building loads. The containment building loads are the letdown coolers, the RCP pump seal and motor/oil coolers, and the reactor coolant drain tank heat exchanger. The containment building loads are shown in Figure 3-8. The CCW flow to the containment building is isolated by a high-high containment building pressure ESFAS signal. During LOOP conditions, flow is maintained to the seal return coolers and the containment building loads. All the other components that are supplied from this header are automatically isolated, or the flow through the components is so small that the component heat load will not interfere with proper LOOP operation.

The second CCW supply header supplies cooling water to the waste gas system components. The heat loads from this header are so small that the header is left in service during LOOP conditions.

The third supply header supplies cooling water to the waste evaporators. Since the operation of the waste evaporators is not critical to safe shutdown, this header is isolated during LOOP conditions.

The final CCW supply header supplies cooling water to the two spent fuel pool heat exchangers. To prevent overheating of the spent fuel during LOOP operations, this header is always supplied with cooling water.

The CCW from the four headers flows through the shell side of the CCW heat exchangers, where the heat load is rejected to the NSW system. During normal operations two of the three heat exchangers and both CCW pumps are in service. The heat exchangers and pumps can be cross-connected to provide maximum flexibility in the event of equipment malfunction. The CCW surge tank is connected to the pump suction header.

3.8 CCW Component Descriptions

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3.8.1 CCW Heat Exchangers

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The three CCW heat exchangers are horizontal tube and shell heat exchangers. The CCW flows through each heat exchanger shell and NSW flows through the heat exchanger tubes. The number one heat exchanger is supplied from the A NSW loop, and the number two heat exchanger is supplied from the B NSW loop. The number three heat exchanger may be supplied from either NSW loop. However, it is supplied from only one loop at any time.

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The heat exchangers are placed on the suction side of the CCW pumps to ensure that NSW pressure is greater than CCW pressure. Therefore, any leakage that occurs will be an NSW-to-CCW leak. This design helps to maintain the CCW system's barrier against radioactive leakage to the environment.

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3.8.2 CCW Surge Tank

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The CCW surge tank compensates for thermal expansion and contraction in the CCW system. The surge tank is a vertical cylindrical tank and has a capacity of 2300 gallons. Makeup to the surge tank is supplied by the plant demineralized water system. During normal operations, surge tank is pressurized with nitrogen. The tank is equipped with level detectors that will isolate selected components if a low level occurs. If a low level occurs, components such as the RCP motors/oil coolers, the reactor coolant drain tank heat exchanger and the control rod drive cooling water heat exchangers will be isolated.

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This isolation signal isolates most of the nonradioactive loads from the CCW system while the cooling water supply continues to those loads that have a significant impact on plant operations.

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3.8.3 CCW Pumps

Each of the two 50% capacity CCW pumps is a single-stage horizontal centrifugal pump with a capacity of 5900 gpm at a 230-ft. head (100 psi). The pumps are driven by 600-hp, 4160-Vac, 60-hertz induction motors. The motors are powered from non-class 1E busses.

3.8.4 CCW LOOP Pumps

Each of the two 25% capacity CCW LOOP pumps is a single-stage horizontal centrifugal pump with a capacity of 2820 gpm at a 230-ft. head (100 psi). The pumps are driven by 350-hp, 4160-Vac, 60-hertz induction motors. The motors are powered from class 1E busses. The motors are automatically started by either an LOOP signal or a low CCW pump discharge pressure. If maintenance is required on one of the CCW pumps, both LOOP pumps may be started to replace the inoperable pump.

3.9 CCW System Operations

3.9.1 CCW Normal Plant Operations

The normal operation of the CCW system has both CCW pumps and two of the three heat exchangers in service. The CCW system removes heat from the components that it serves and transfers this heat to the NSW system via the CCW heat exchangers. As previously stated, if one of the two pumps is removed from service for maintenance, both of the LOOP pumps are started to provide 100% CCW flow.

If a CCW heat exchanger requires maintenance, then the number three heat exchanger is placed in service. The NSW supply to the heat exchanger comes from the same NSW train that had been supplying the CCW heat exchanger removed from service.

3.9.2 CCW LOOP Operations

If a loss of offsite power occurs, then power is lost to the CCW pumps. In this event, the LOOP pumps start and provide cooling water to the following components:

1. RCP seal heat exchangers
2. Letdown coolers
3. Seal return coolers
4. Spent fuel pool heat exchangers

Continued cooling of the first three of these components allows for RCP seal integrity and RCS inventory control during LOOP situations. The fourth component in the list is supplied with cooling water to prevent the spent fuel pool from overheating.

3.9.3 CCW/SCW Operations

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Valves are installed to allow the shutdown cooling water system to supply a portion of the CCW loads if a total loss of CCW occurs. These valves are manually positioned by the operator. When the cross-connection valves are opened, the SCW system can supply cooling to the following loads:

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1. RCP seal heat exchangers
2. Letdown coolers
3. Seal return coolers
4. Spent fuel pool heat exchangers

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If the SCW/CCW cross-connect valves are open and an ESFAS signal is received, then the valves will close. This ensures sufficient SCW flow to cool the SCW safety-related loads.

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3.9.4 CCW ESFAS Operations

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If an ESFAS is received, the following realignments occur in the CCW system:

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1. The LOOP CCW pumps are stripped from the class 1E busses.
2. The CCW/SCW cross-connect valves receive a close signal.
3. The NSW supply to the CCW heat exchangers is isolated.
4. The CCW containment supply and return headers are isolated if the signal is a high-high containment pressure signal.

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Any CCW load that requires cooling during an accident may be cooled by starting the LOOP pumps or by opening the CCW/SCW cross-connects. Either of these actions must be performed manually. If the LOOP CCW pumps are used, then NSW flow to the CCW heat exchangers must be manually reestablished.

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3.10 CCW System Summary

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The CCW system is a closed-loop, low-pressure system designed to transfer heat from radioactive systems to the environment and to act as a barrier between those systems and the environment. The CCW system is operated at a lower pressure than the other systems it interfaces with; therefore, it will collect leakage. During normal operations two CCW pumps and heat exchangers are in service providing cooling water to the CCW supplied components. If a loss of offsite power occurs, the LOOP pumps will automatically start and supply selected CCW loads. Provisions are made for cross-connecting the SCW and CCW systems in the event of a total loss of CCW. Since CCW is not a safety-related system, it is isolated in the event of an accident.

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TABLE 3-1
MAKEUP AND PURIFICATION SYSTEM COMPONENT DATA

Item	Data
Letdown Coolers	
Cooler inlet/outlet temperatures, °F	570/95
Heat transferred, Btu/hr	2.39×10^7
Letdown flow, lb/hr	4.98×10^4
Component cooling water system flow, lb/hr	3.05×10^5
Design pressure, shell/tube, psig	200/2500
Letdown Prefilter	
Design flow, gpm	200
Design pressure, psig	150
Design temperature, °F	200
Filter size, microns	5
Purification Ion Exchangers	
Resin capacity, ft^3	50
Design flow, gpm	100
Design pressure, psig	150
Purification Filters	
Design flow, gpm	100
Design pressure, psig	150
Design temperature, °F	200
Filter size, micron.	5
Makeup Tank	
Volume, ft^3	1200
Nominal water volume, ft^3	800
Design pressure, psig	100
Design temperature, °F	200
Normal pressure range, psig	15 - 35
Seal Injection Filters	
Design flow, gpm	60
Design pressure, psig	3200
Design temperature, °F	200
Filter size, microns	5
Seal Return Coolers	
Cooler inlet/outlet, °F	145/120
Heat transferred, Btu/hr	1.42×10^6
Tube flow, lb/hr	5.58×10^4
Shell flow, lb/hr	1.58×10^5
Design pressure, shell/tube, psig	200/150

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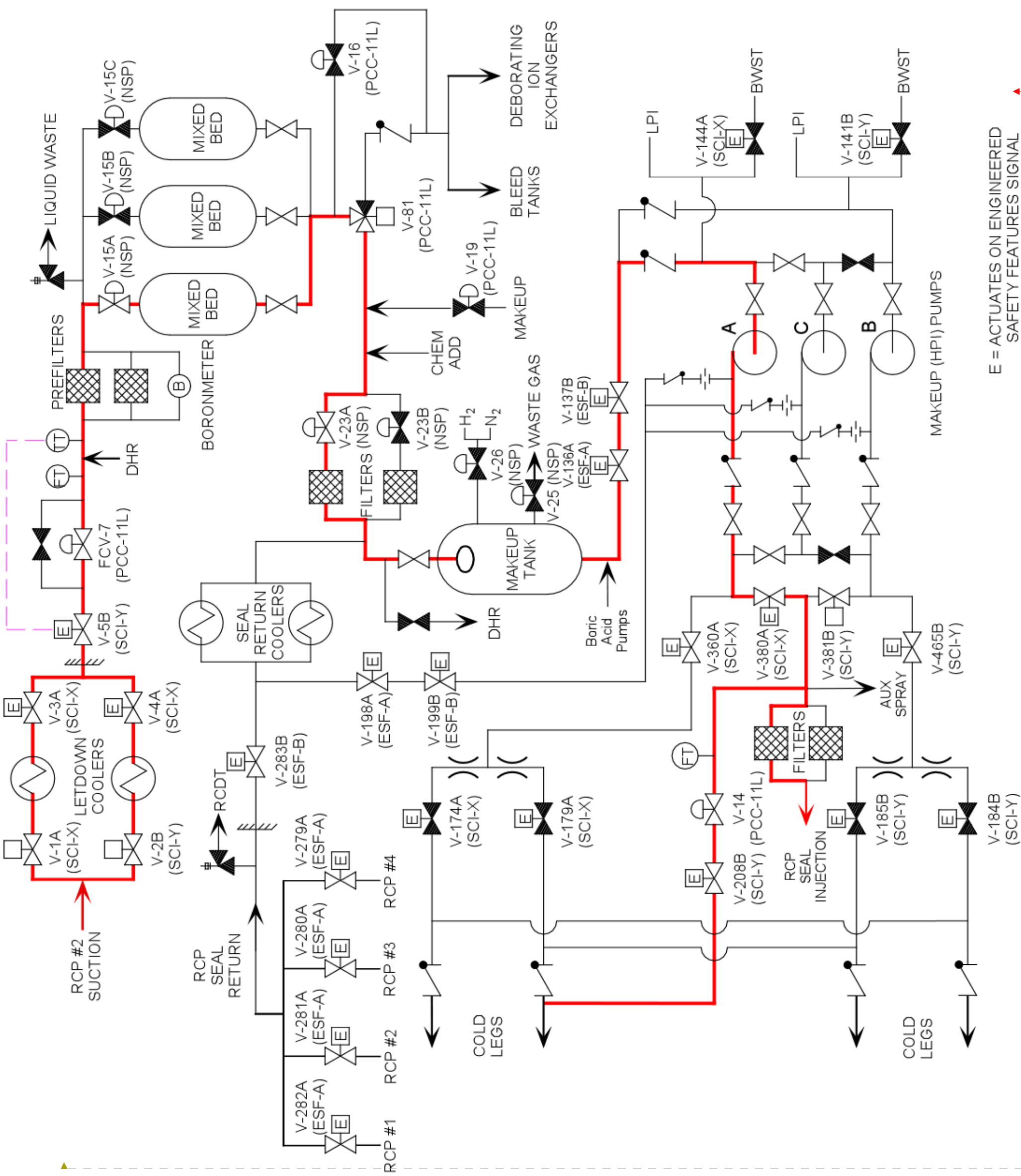

Figure 3-1 Makeup and Purification System

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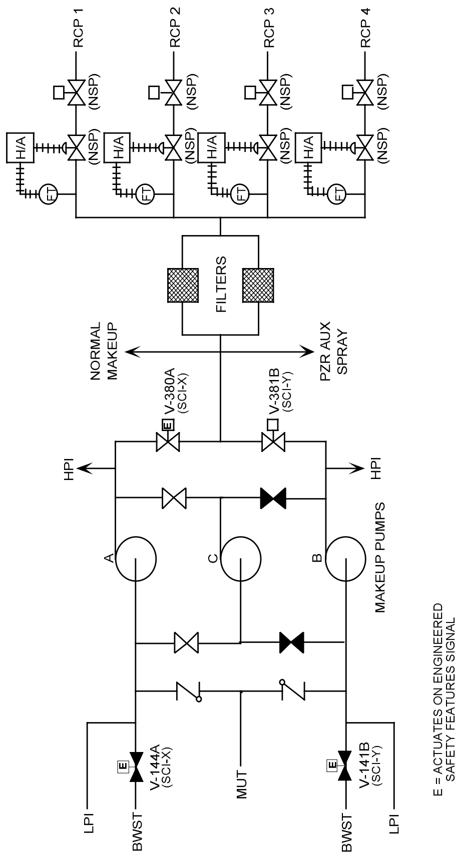

Figure 3-2 Seal Injection System

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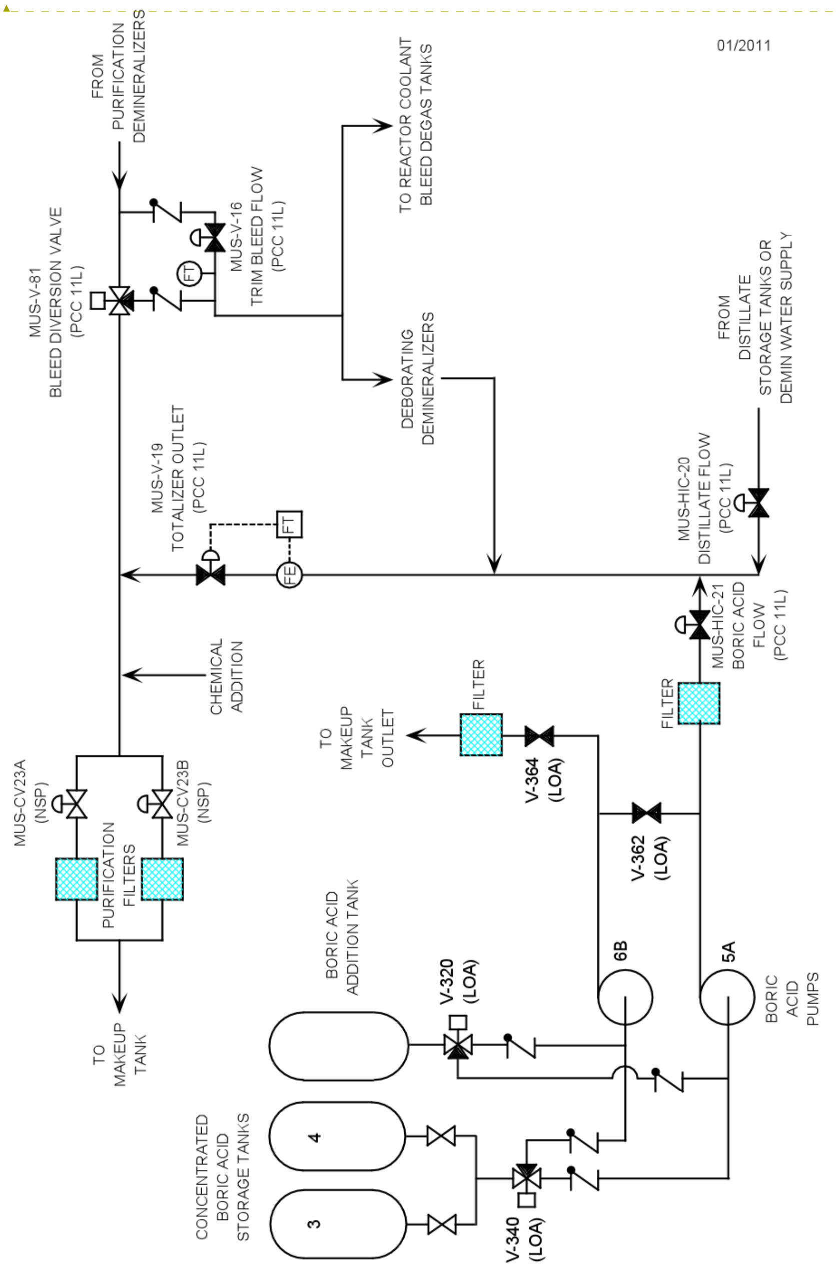

Figure 3-3 Soluble Poison Control

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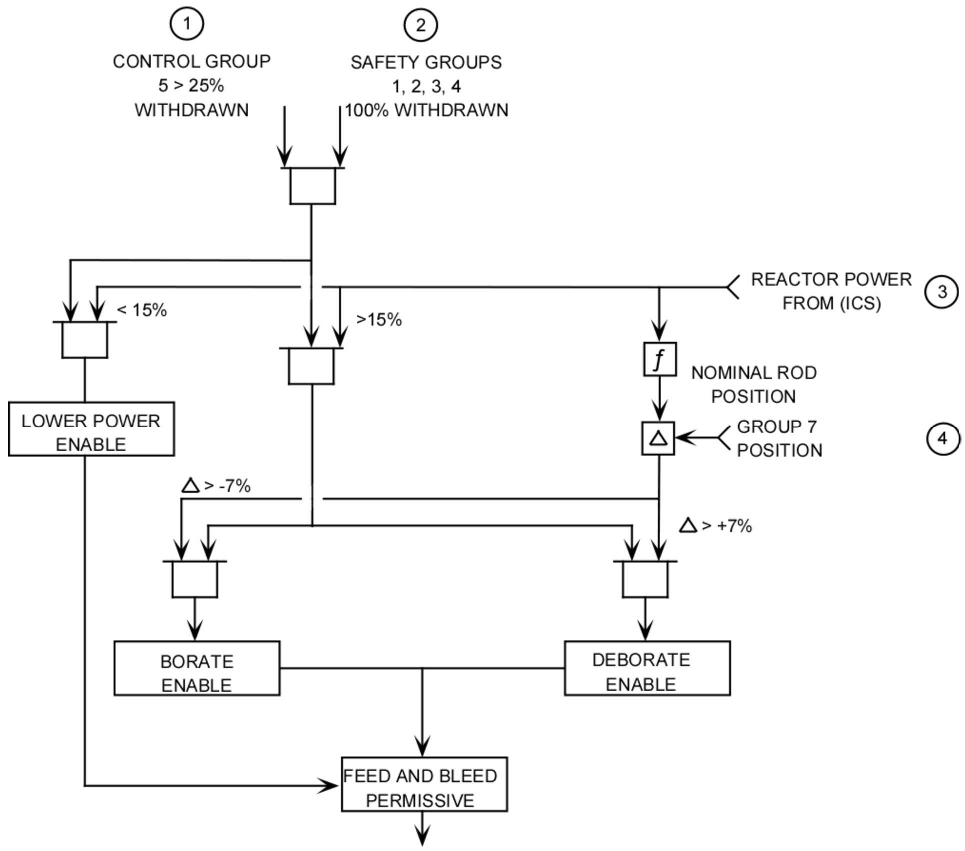

Figure 3-4 Boron Feed and Bleed Logic

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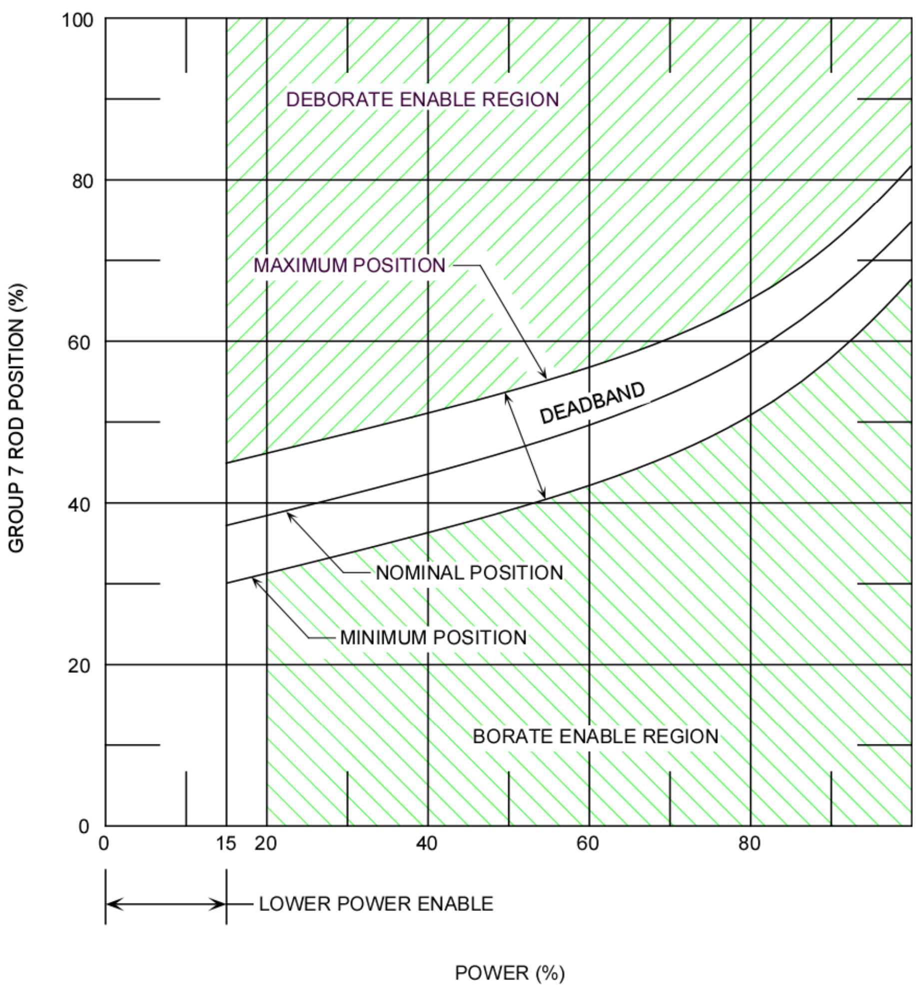

Figure 3-5 Nominal Control Rod Position vs. Reactor Power

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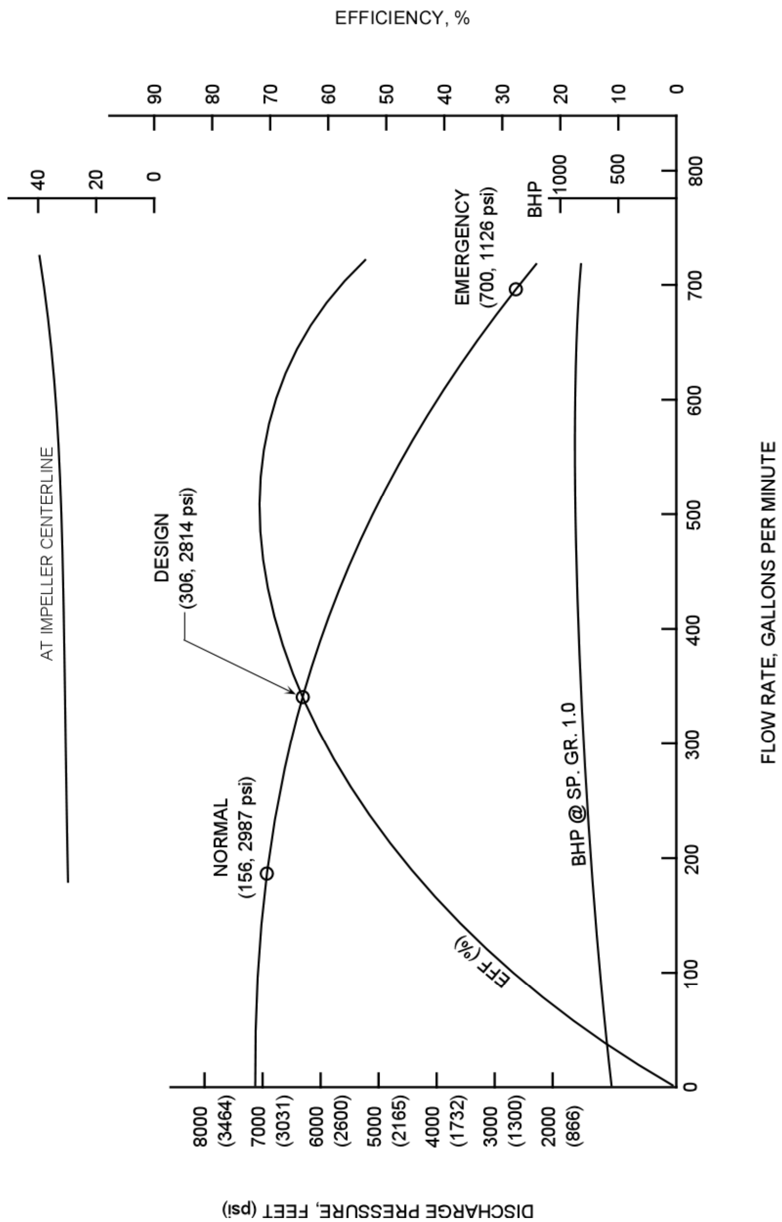

Figure 3-6 Makeup Pump Characteristic Curve

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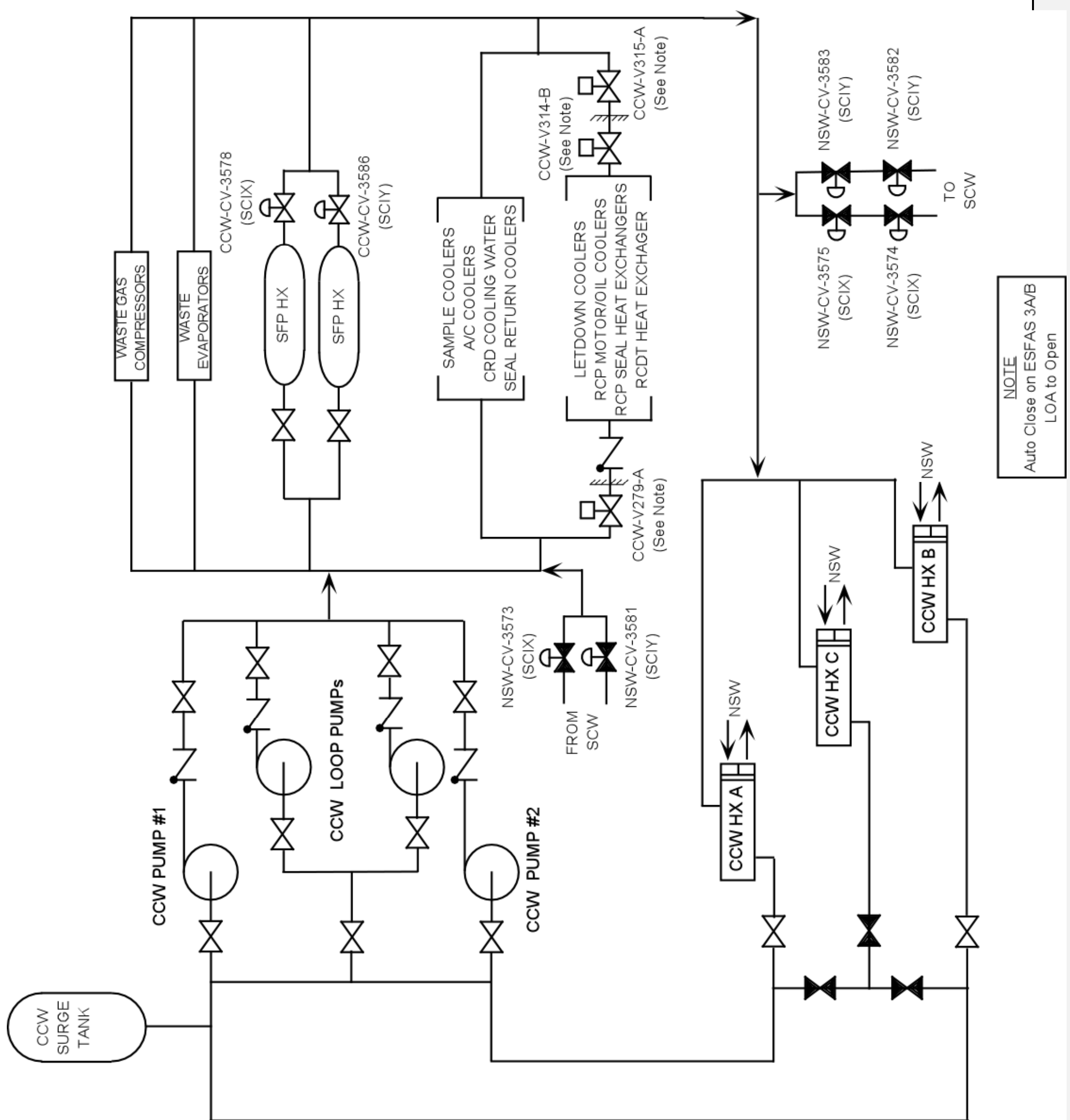

Figure 3-7 Component Cooling Water System

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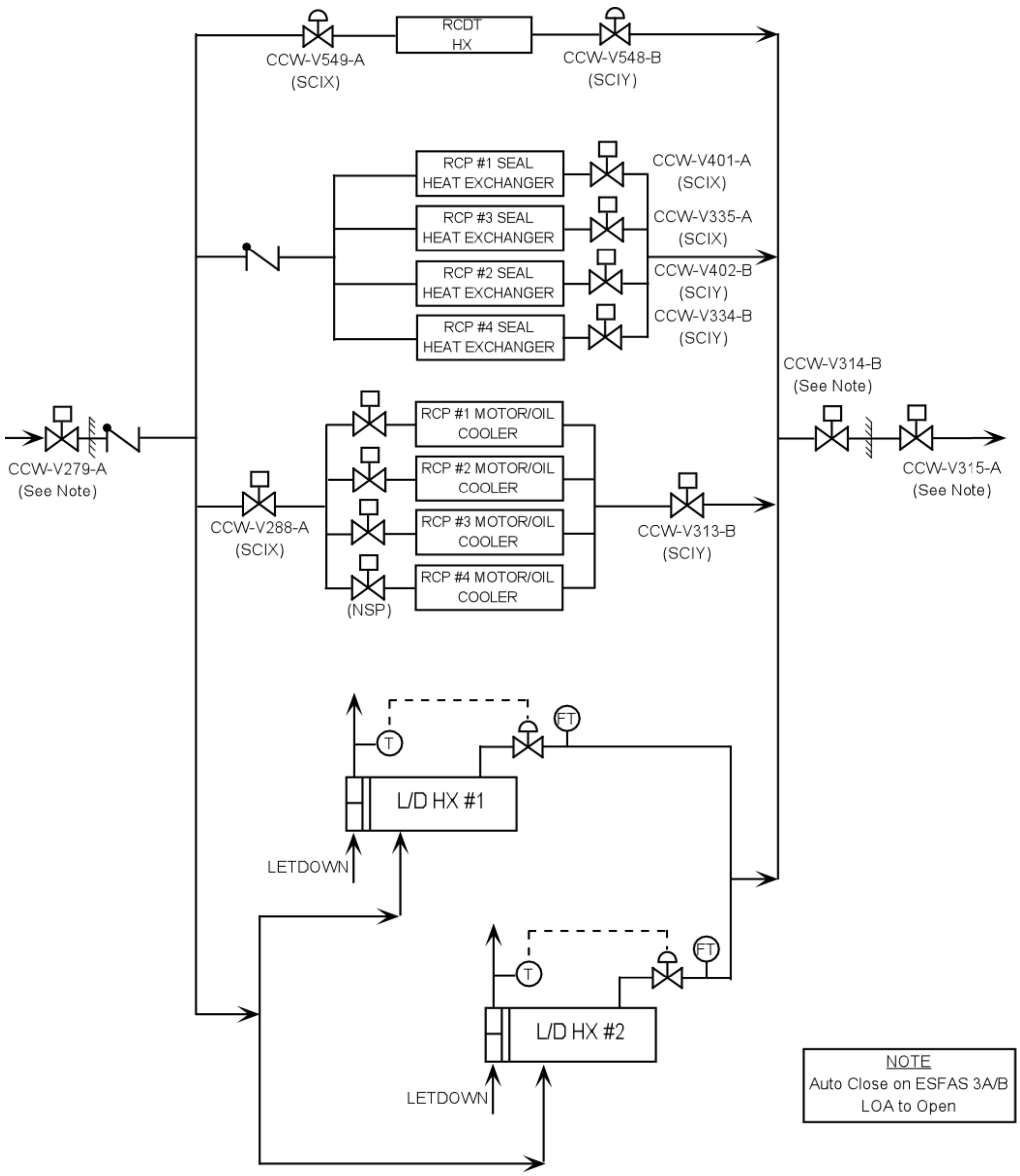

Figure 3-8 CCW in Containment

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