General Electric Systems Technology Manual

Chapter 2.8

Reactor Water Cleanup System

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2.8 REACTOR CLEANUP SYSTEM

Learning Objectives:

1. Recognize the purposes of the reactor water cleanup (RWCU) system.

2. Recognize the purpose, function and operation of the following reactor water cleanup system major components:
   a. RWCU inlet piping
   b. RWCU pumps
   c. regenerative heat exchangers
   d. non-regenerative heat exchangers
   e. filter demineralizer units
   f. RWCU outlet piping
   g. system bypass valve
   h. filter demineralizer bypass valve
   i. orifice bypass valve
   j. blowdown flow control valve
   k. Blowdown isolation valves
   l. reactor vessel discharge isolation (containment isolation) valves

3. Recognize the following flow paths of the reactor water cleanup system:
   a. normal operation
   b. blowdown operation

4. Recognize which plant parameters will cause an automatic closure of the RWCU Reactor Vessel Discharge Isolation (containment isolation) Valves and the reason for each isolation signal.

5. Recognize how the Reactor Water Cleanup system interfaces with the following systems:
   a. Recirculation System (Section 2.4)
   b. Reactor Vessel System (Section 2.1)
   c. Condensate and Feedwater System (Section 2.6)
   d. Reactor Building Closed Loop Cooling Water System (Section 11.3)
   e. Nuclear Steam Supply Shutoff System (Section 4.4)
   f. Control Rod Drive System (Section 2.3)
   g. Standby Liquid Control System (Section 7.4)
   h. Liquid Radwaste System (Section 8.2)

2.8.1 Introduction

The purposes of the Reactor Water Cleanup (RWCU) System are:

a) to maintain reactor water quality by filtration and ion exchange,
b) to provide a method of removing water from the reactor vessel during startups and shutdowns,
c) prevent excessive lost of water inventory from the reactor vessel, and
d) limits the release of radioactivity from containment.

Maintaining good reactor water quality minimizes corrosion of plant components, minimizes irradiation of corrosion products and subsequent radiation exposure problems, and prevents fouling of heat transfer surfaces.

The functional classification of the RWCU system is that of a power generation system. Portions of the RWCU system form part of the reactor coolant pressure boundary and perform safety-related isolation functions.

2.8.2 System Description

The RWCU system is a filtration and ion exchange system used to maintain and monitor reactor vessel water quality. The RWCU pumps remove water from both recirculation system loops and the reactor vessel bottom head and discharge into a common header. The common discharge header routes the water through three regenerative and two non-regenerative heat exchangers to reduce its temperature before entering the filter demineralizer units. The outlet of the filter demineralizers normally returns to the reactor vessel via the regenerative heat exchangers and both feedwater lines. Some or all the filter demineralizer outlet flow can be directed to the main condenser or the liquid radwaste system.

2.8.3 Component Description

The major components of the RWCU system are discussed in the following sections and are shown on Figures 2.8-1 and 2.8-2.

2.8.3.1 RWCU Inlet Piping

The RWCU system takes most of its flow from the suction piping of the A and B reactor recirculation pumps. An additional source of water is provided by a line from the reactor vessel bottom head drain. Water is removed from the bottom head to minimize thermal stratification and remove deposits from the bottom head region. A temperature element monitors the bottom head drain temperature.

Motor operated valves are provided in the RWCU inlet piping, both inside and outside of the primary containment for automatically isolating the system during potentially unsafe conditions.

2.8.3.2 RWCU Pumps

The RWCU pumps provide the needed motive force to overcome piping and equipment pressure drops and sends the treated water back to the reactor vessel via the feedwater system. The RWCU pumps are motor driven, horizontally mounted, centrifugal pumps with an externally supplied mechanical seal. One pump provides 100% system flow which corresponds to approximately 1% of rated feedwater flow.

Each pump is powered by a 50 HP motor which is supplied from a 480 VAC shutdown board. The design pump flow rate is 207 gpm at 545ºF with a developed head of approximately 565 ft. Pump bearing and seal cooling is provided by the Reactor Building Closed Loop Cooling Water (RBCLCW) system (Section 11.3). The control rod drive system (Section 2.3) provides seal water to the RWCU pumps.

2.8.3.3 Regenerative Heat Exchangers

Three regenerative heat exchangers in series are provided to recover sensible heat in the reactor vessel water and to reduce the cycle heat loss while also limiting the heat load on the non-regenerative heat exchangers. The regenerative heat exchangers are tube and shell type heat exchangers with system influent water flowing through the tubes and system effluent water flowing around the tubes. The influent water is cooled from approximately 534ºF to 233ºF while heating the effluent water from approximately 120ºF to 430ºF. The processed cleanup water regains about 80% of the total heat lost, reducing the thermal stress as the effluent water enters the feedwater system piping.

2.8.3.4 Non-regenerative Heat Exchangers

Two non-regenerative heat exchangers in series provide the final reduction of water temperature prior to entering the filter demineralizers. The non-regenerative heat exchangers are tube and shell type heat exchangers with RWCU water flowing through the tube side and RBCLCW on the shell side. Unlike the regenerative heat exchangers, the heat removed from the RWCU water in the non-regenerative heat exchangers is lost to Long Island Sound via the reactor building closed loop cooling water (RBCLCW) system.

2.8.3.5 Filter Demineralizer Units

Two RWCU filter/demineralizer (F/D) units in parallel remove soluble and insoluble impurities from the reactor water. This process is accomplished by forcing the F/D influent water through finely ground ion exchange resins.

The two F/D units are of a pressure precoat type in which the vessel filter tubes are coated with a filter aid and powdered ion exchange resin. These materials serve as the filter media and/or ion exchange agent and are held on to the screen type tubes by the differential pressure generated by the water flowing through each unit. Flow through the system is automatically controlled by flow control valves located at the outlet of each filter/demineralizer.

Each F/D unit consists of a pressure vessel which contains the filter tubes, a holding pump, instrumentation, controls, valves, and piping. Air operated inlet and outlet isolation valves and the flow control valve are furnished for each filter demineralizer unit to permit individual operation and servicing. A strainer in the discharge piping for each F/D unit minimizes the material entering the reactor vessel in the event a filter precoat fails. Auxiliary components required for precoating, backwashing, and disposal of the resin are shared by both F/D units.

If flow is lost through a F/D unit, the precoat will fall off the filter tubes. A holding pump for each filter demineralizer holds the resin on the filter tubes by recycling flow through the units during standby periods. The holding pump starts automatically when flow through a filter demineralizer falls below 60 gpm.

2.8.3.6 RWCU Outlet Piping

During normal system operation, flow from the F/D units is routed through the shell side of the regenerative heat exchangers, through a motor operated isolation valve (MOV-041) and into feedwater lines ‘A’ and ‘B.’ The RWCU flow returning to the 'A' feedwater line enters the reactor core isolation cooling system piping which connects to the 'A' feedwater line. The RWCU returning to the 'B' feedwater line enters the high pressure coolant injection piping which connects to the 'B' feedwater line. Each RWCU system connection contains two check valves in series which provide the isolation function for the containment penetrations. The motor operated containment isolation valve (MOV-041) can be remotely closed from the control room to provide long term isolation for the containment penetration.

During blowdown operation, flow from the F/D units is routed to either the main condenser or to the liquid radwaste system. Blowdown flow is directed through a common header which is controlled by a flow control valve (HCV-04) and a restricting orifice. The blowdown flow is directed to the main condenser or the liquid radwaste system via appropriate motor operated valve (MOV-038 or MOV-039 respectively). The drain line to the liquid radwaste system is provided with a pressure relief valve (setpoint 150 psig) to protect the low pressure piping from over-pressurization. The relief valve opens a path to the RWCU blowdown piping to the main condenser.

2.8.3.7 System Bypass Valve (MOV-035)

A bypass line containing a normally closed isolation valve (MOV-35) connects the RWCU pump discharge header with the RWCU piping returning to the feedwater lines. This flow path bypasses the heat exchangers and filter demineralizers and is used primarily to prevent temperature stratification of the water inside the reactor vessel during startups, shutdowns, and outages.

2.8.3.8 Filter Demineralizer Bypass Valve (MOV-036)

A bypass line containing a normally closed motor operated valve (MOV-036) is provided for bypassing flow around the filter demineralizers. The filter demineralizers may be bypassed during low power and shutdown conditions to support reactor vessel level control and/or for reactor vessel pressure control. Reactor vessel level control can be supported by rejecting water via the RWCU blowdown line. Reactor vessel pressure control can be supported by removing heat via the RWCU non-regenerative heat exchangers and returning the cooled water to the reactor vessel.

2.8.3.9 Orifice Bypass Valve (MOV-037)

A bypass line around the restricting orifice with a motor operated valve (MOV-037) can be used during low reactor pressure conditions (<60 psig) to obtain a higher blowdown flow rate.

2.8.3.10 Blowdown Control Valve (HCV-04)

As discussed below in section 2.8.4.2.2, the RWCU system can be used to remove water from the reactor vessel by diverting some or all of the return flow to either the liquid radwaste system or the main condenser. The blowdown control valve (HCV-04) is opened from the main control room to regulate the amount of blowdown flow.

Because the liquid radwaste system and main condenser are designed for low pressure (<150 psig) and the RWCU system is connected to the reactor vessel and can experience high operating pressure, the blowdown control valve will automatically close on high pressure in the downstream piping. This automatic action protects the low pressure piping and components from overpressure damage.

The blowdown control valve automatically closes on low pressure in the upstream piping. This automatic action prevents the RWCU system piping from being drained by siphoning to the main condenser or liquid radwaste system.

2.8.4 System Features and Interfaces

The features and interfaces this system has with other plant systems are discussed in the following sections.

2.8.4.1 System Monitoring

The principal parameters monitored are shown in Figures 2.8-1 and 2.8-2. They include system temperatures, system pressures, F/D unit differential pressures, conductivity, and system flows.

In addition to this process flow monitoring, the spaces housing the RWCU heat exchangers and filter demineralizers have temperature monitors that will isolate the system on high temperature (indicative of a piping or component leak) as discussed in Section 2.8.4.4 below.

2.8.4.2 System Operation

Impurities transported by water into the reactor vessel tend to collect there because they are unlikely to be carried away with the steam flow. The reactor water quality depends on several factors which include: corrosion of primary system materials; input of impurities and corrosion products via the feedwater piping and/or condenser tube leaks; and removal of impurities by the filter/demineralizers.

Impurities in the reactor water are of two forms – soluble and insoluble. The soluble materials are suspended in the water until collected or plated onto some surface. The F/D units remove soluble materials via powdered ion exchange resins. The insoluble materials are removed by filtration.

The RWCU system seeks to maintain the reactor water conductivity less than 0.1 micro-mho/cm and undissolved solids less than 0.01 ppm. Reactor water cleanup system operation is necessary to maintain reactor water purity. Reactor operation without the reactor cleanup system is limited to relatively short periods of time.

2.8.4.2.1 Normal Operation

The system is normally operated continuously during all phases of reactor operation including refueling. Blowdown is normally used only to remove excess or impure water from the reactor pressure vessel at low steaming rates and when the reactor is shutdown.

During normal operation, about 200 gpm of reactor vessel water flows through the RWCU system. Of this total flow, approximately 90 gpm is taken from each recirculation system loop to decrease the amount of impurities before flow enters the reactor core region. The remaining 20 gpm is taken from the reactor vessel bottom head area which tends to be the primary collection point for solids in the reactor since it is the low point of the vessel, and flow in this region is restricted by bottom head internal components (CRD housings and incore detector housings). At this flow rate, one RWCU system pump and both filter demineralizer units are typically in service. This flow rate is determined to be sufficient to maintain sufficient reactor vessel water quality by continually removing the impurities before a large buildup occurs in the reactor vessel as a result of concentration. The reactor water quality is maintained to: (1) minimize the corrosion of materials used in the plant; (2) minimize the levels of radioactivity in the coolant; and (3) prevent fouling of heat transfer surfaces.

2.8.4.2.2 Blowdown Operation

During a plant startup, shutdown, or low steaming rates, it is necessary to drain water from the vessel in order to maintain a proper vessel level. This is done with the blowdown portion of the RWCU system. Water from the outlet of the F/D units can be rejected to the main condenser or to the liquid radwaste system rather than being returned to the vessel. In this way, water is removed from the reactor vessel. The blowdown flow rate is established from the control room via a manually operated controller. The appropriate motor operated valve is opened to direct flow to either the main condenser or radwaste (MOV-038 or MOV-039 respectively). Following blowdown alignment, the blowdown control valve (HCV-04) is adjusted to drain the desired amount of water from the reactor vessel. The main condenser is the preferred blowdown path in order to limit the burden on the liquid waste processing facilities.

Blowdown is necessary during a plant startup from a cold shut down condition to control water level inside the reactor vessel by compensating for the water inventory being added by the control rod drive system and the water inventory swell occurring due to heatup. Prior to achieving higher steaming rates, RWCU blowdown balances the factors acting to increase the reactor vessel water level.

The blowdown flow rate may be limited by the inlet temperature to the F/D units. The heat load on the non-regenerative heat exchangers is affected because some or all of the return RWCU flow to the shell side of the regenerative heat exchangers is now bypassing them via the blowdown line. If the temperature of the water leaving the non-regenerative heat exchangers going to the F/D units exceeds 140°F, the RWCU system will isolate to protect the F/D unit resin from breakdown due to excessive temperature.

Blowdown to the main condenser is not allowed if the condensate demineralizers are not in operation, the RWCU filter demineralizer effluent conductivity is > 0.1 μmho, or the activity of the water is greater than the minimum detectable activity when the filter demineralizers are bypassed.

2.8.4.3 Filter Demineralizer Operations

Two filter demineralizer operations are discussed in the following sections using components shown on Figure 2.8-2.

2.8.4.3.1 Backwashing

When the differential pressure across a filter demineralizer unit approaches 20 psid, the outlet conductivity reaches 0.1 micro-mhos, or the outlet to inlet conductivity approaches 1.0, the filter demineralizer is removed from service for backwashing and precoating. These parameters are indicative of the filter media becoming saturated with insoluble materials and/or the resin capability becoming exhausted.

Backwashing consists of removing the spent resins from the filter demineralizer elements. This is accomplished by the use of an air blast injected into the filter demineralizer to dislodge the precoat. Condensate is then pumped into the filter demineralizer through the outlet line. The drain line is then opened, and the mixture of water and spent resins is pumped to the cleanup phase separator tank of the radwaste facilities.

2.8.4.3.2 Precoating

After the filter demineralizer is backwashed, it is now ready for a new application of resins. The filter demineralizer is precoated by circulating a slurry of the resin from the resin feed tank onto the stainless steel resin holding elements. The slurry deposits evenly on the elements while the water returns to the resin feed tank. Precoat recirculation continues until the return water is clear. At this time, a holding pump is automatically started to maintain the precoat in place on the holding elements. The filter demineralizer is then returned to service, and the holding pump flow stops as system flow increases.

2.8.4.4 System Isolation

The RWCU system supply isolation valves MOV-033 and MOV-034 automatically close on any of the following signals.

1. Low low reactor vessel water level -38" (Level 2)
2. RWCU system high differential flow (44 gallons for >45 seconds)
3. Main steam tunnel penetration area temperature high (175ºF)
4. RWCU heat exchanger/pump/filter demineralizer unit area high temperature (155°F)

These signals are suggestive that piping or component integrity has been breached with the potential for loss of water inventory from the reactor vessel and the release of radioactivity. The automatic closure of MOV-033 and MOV-034 coupled with the dual check valves in each RWCU return line effectively isolate the RWCU system from the reactor coolant pressure boundary to prevent the system from being a continuing cause of inventory loss and radioactivity releases. For long term leakage control, the MOV-041 may be closed to backup the check valves.

The RWCU system high differential flow uses flow measurements at three distinct points: (1) the common header at the pump discharge, (2) the blowdown line, and (3) the common header returning to the feedwater lines. The sum of the latter two is subtracted from the first flow value to obtain the differential. Isolation logic requires a sustained high differential signal to avoid isolations during transients, such as those caused by starting a pump or placing a F/D unit in service.

The RWCU heat exchanger/pump/filter demineralizer unit area high temperature signals come from six temperature detectors, two in each of the three areas. Half of the detectors provide an output to the nuclear steam supply shutoff system which isolates the RWCU system by automatically closing the inboard containment isolation valve (MOV-033). The remaining detectors also provide an output to the NSSSS which isolates the RWCU system by automatically closing the outboard containment isolation valve (MOV-034). Thus, each of these three RWCU areas are monitored by two temperature detectors with the trip of one detector causing the inboard containment isolation valve to close and trip of the other detector closing the outboard containment isolation valve.

In addition, the outboard containment isolation valve (MOV-34) will also automatically close on the either of the following two signals:

1. Standby liquid control system actuation
2. Non-regenerative heat exchanger outlet high temperature (140ºF)

The automatic closure of MOV-034 on SLC system actuation prevents the RWCU system from impairing reactivity control by either removal of soluble boron by the F/D units or dilution in the large water inventory within the system.

The automatic closure of MOV-034 on high temperature at the outlet of the non-regenerative heat exchangers protects the resin in the F/D units from degradation caused by excessive temperature.

2.8.4.5 Component Trips and Interlocks

The RWCU pumps will automatically trip on any one of the following conditions: (1) the pump's cooling water outlet temperature exceeds 195°F, (2) the inboard containment isolation valve MOV-033 is not fully open, (3) the outboard containment isolation valve MOV-034 is not fully open, or (4) pump flow of less than 70 gpm. The low pump flow trip is bypassed for 30 seconds after the pump's control switch is placed in START to allow the pump to come up to speed.

On an accident signal (high drywell pressure or low-low-low reactor water level, Level 1), the load shed logic will automatically de-energize RWCU pumps A and B.

The RWCU F/D unit holding pumps will automatically start and air operated valves will realign to place a F/D unit into hold on any one of the following conditions: (1) RWCU system flow less than 60 gpm, (2) differential pressure across the effluent strainer greater than 10 psid, or (3) differential pressure across a F/D unit greater than 30 psid.

The blowdown flow controller (HCV-004) will automatically close on any of the following conditions: (1) pressure greater than 140 psig downstream, and (2) pressure less than 5 psig upstream.

2.8.4.6 System Interfaces

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

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

The reactor building closed loop cooling water system provides cooling water to the RWCU system pump bearings and seals and to the non-regenerative heat exchangers.

Recirculation System, (Section 2.4)

The 'A' and 'B' recirculation system loops supply water from the suction side of the recirculation pumps to the RWCU system.

Reactor Vessel System, (Section 2.1)

The reactor vessel provides water to the RWCU system via the bottom head drain line.

Condensate and Feedwater System, (Section 2.6)

The condensate and feedwater system provides a return path to the reactor vessel for the water processed by the RWCU system. The main condenser can collect water from RWCU system during blowdown.

Liquid and Solid Radwaste Systems, (Sections 8.2 and 8.3)

The radwaste facilities are used to collect water from RWCU blowdown and spent resins from the filter demineralizers.

Nuclear Steam Supply Shutoff System, (Section 4.4)

The nuclear steam supply shutoff system provides automatic closure signals to the containment isolation valves MOV-033 and MOV-034 of the RWCU system upon sensing certain conditions.

Standby Liquid Control System, (Section 7.4)

The standby liquid control system provides an isolation signal to the RWCU system upon initiation.

Control Rod Drive System, (Section 2.3)

The control rod drive system provides seal water to the RWCU pumps.

2.8.5 Summary

<u>Classification</u>**:** Power generation system

<u>Purposes</u>**:** To maintain reactor water quality by filtration and ion exchange, provide a path for removal of water from the reactor vessel, prevent excessive loss of water inventory from the reactor vessel, and limit the release of radioactive material from containment..

<u>Components</u>: Inlet piping, two 100% capacity pumps, three regenerative heat exchangers, two non-regenerative heat exchangers, two 50% capacity filter demineralizer units, outlet piping, and containment isolation valves.

<u>System Interfaces</u>**:** reactor building closed loop cooling water system; recirculation system; reactor vessel system; condensate and feedwater system; liquid and solid radwaste systems; nuclear steam supply shutoff system; standby liquid control system; and control rod drive system.

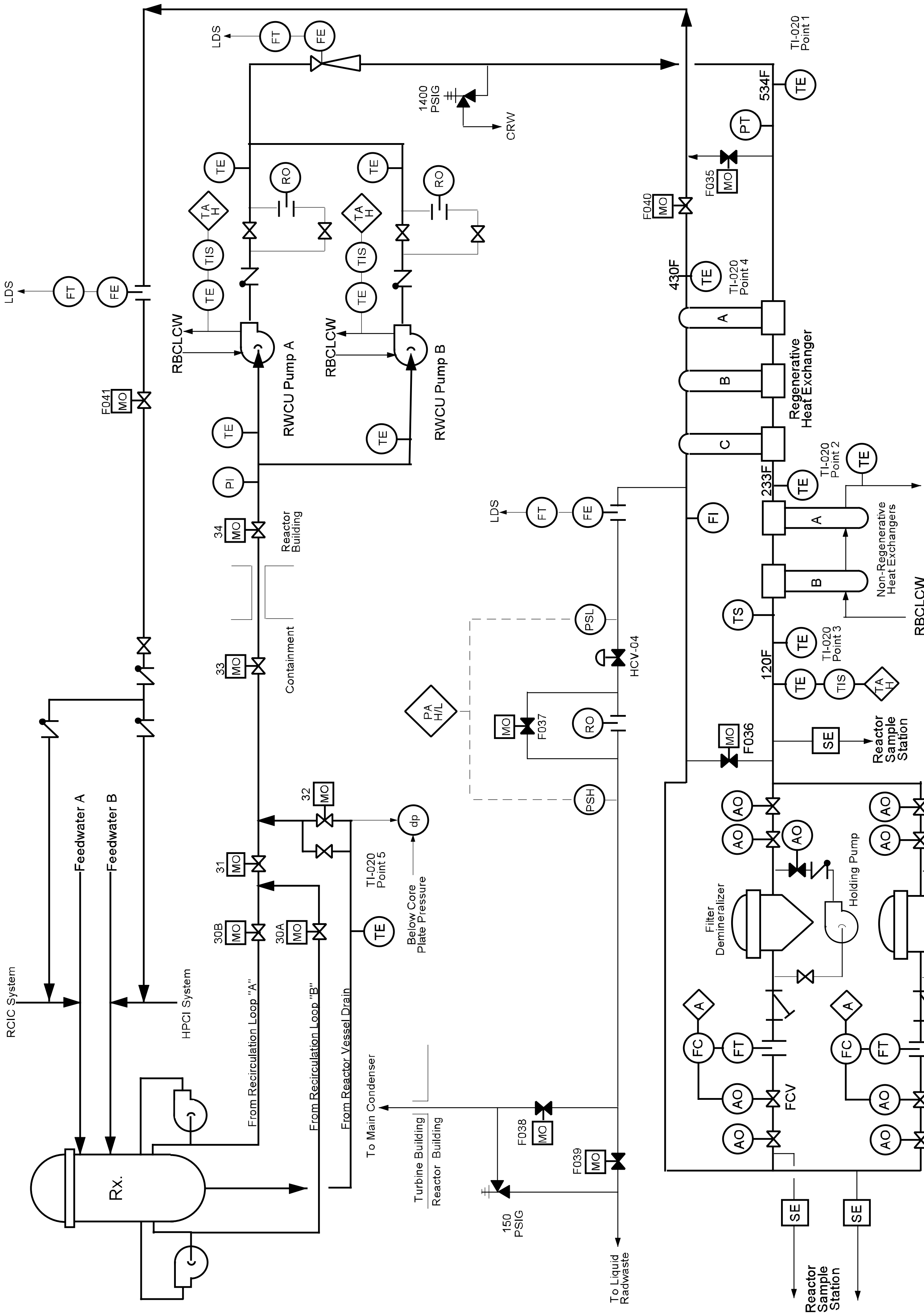

Figure 2.8-1 Reactor Water Cleanup System

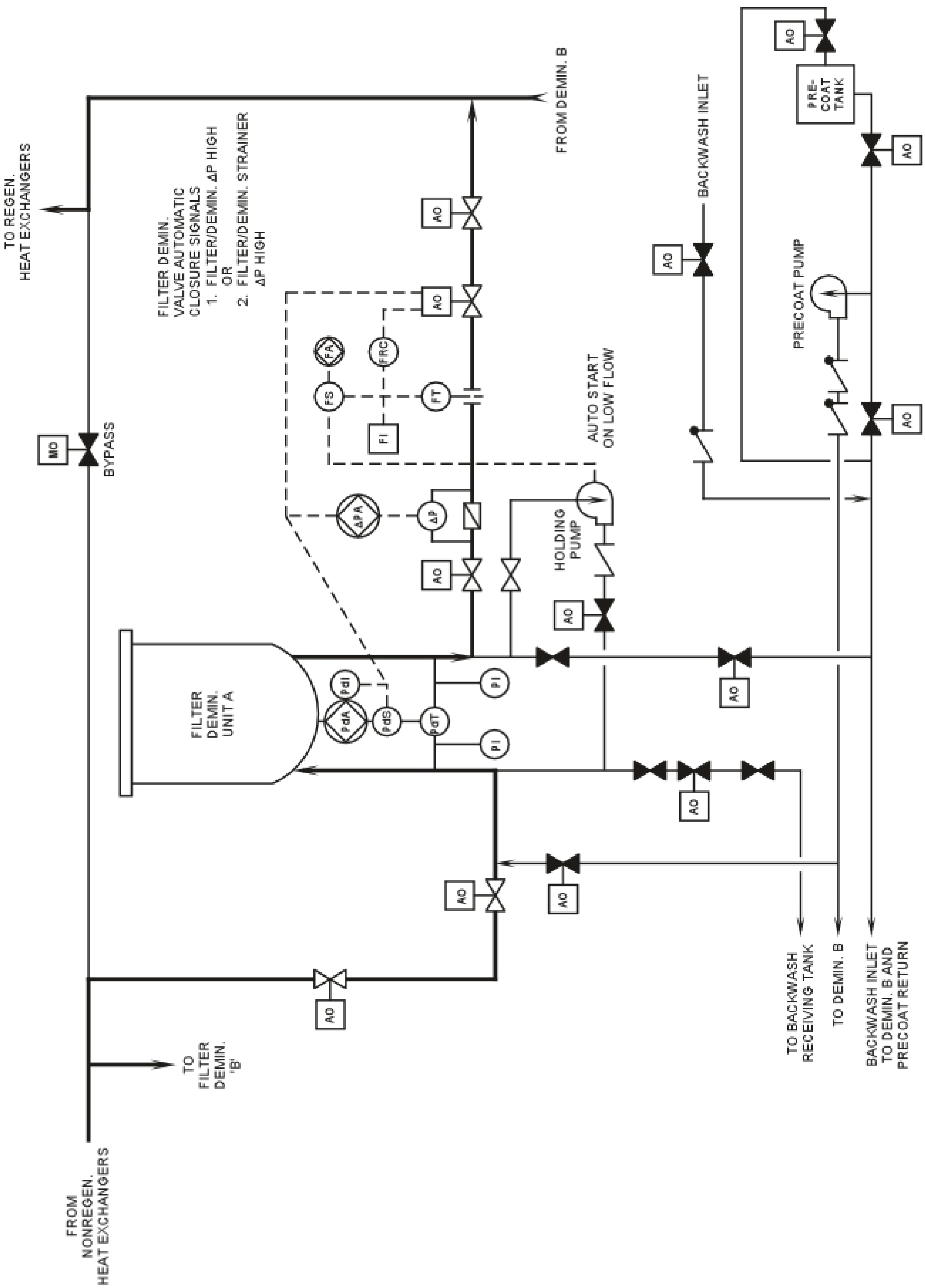

Figure 2.8-2 RWCU Filter/Demineralizer