

**General Electric Systems Technology Manual**

**Chapter 2.6**

**Condensate and Feedwater Systems**



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## 2.6 CONDENSATE AND FEEDWATER SYSTEMS

### Learning Objectives:

1. Recognize the purposes of the Condensate and Feedwater system.
2. Recognize the purpose, function and operation of the following Condensate and Feedwater system major components:
  - a. Condensate Storage Tank
  - b. Main Condenser
  - c. Main Condenser Hotwell
  - d. Condensate Pumps
  - e. Steam Jet Air Ejector Condenser
  - f. Steam Packing Exhauster
  - g. Condensate Demineralizers
  - h. Condensate Booster Pumps
  - i. Low Pressure Heaters
  - j. Feedwater Pumps
  - k. High Pressure Heaters
  - l. Feedwater Flow Detectors
3. Recognize the following flow paths of the Condensate and Feedwater system :
  - a. Normal full power operation
  - b. Hotwell Level Control
  - c. Startup level control
  - d. Long Cycle Cleanup
  - e. Short Cycle Cleanup
4. Recognize how the system will respond to Condensate Booster Pump Low Suction Pressure and Feedwater Pump Low Suction Pressure
5. Recognize how the Condensate and Feedwater system interfaces with the following systems:
  - a. Circulating Water System (Section 11.1)
  - b. Control Rod Drive System (Section 2.3)
  - c. Feedwater Control System (Section 3.3)
  - d. Reactor Water Cleanup System (Section 2.8)
  - e. High Pressure Coolant Injection System (Section 10.1)
  - f. Reactor Core Isolation Cooling System (Section 2.7)
  - g. Main Steam System (Section 2.5)
  - h. Offgas System (Section 8.1)

## 2.6.1 Introduction

The Condensate and Feedwater chapter includes information relating to the processing and preparing water for use in reactor systems, and the movement of water from the main condenser to the reactor vessel.

The purposes of the Condensate and Feedwater system are to:

- condense steam from the main and feed pump turbines and collect steam drains via the main condenser,
- remove non-condensable gases from the main condenser,
- purify and preheat water prior to injection into the reactor vessel,
- supply the driving head to pump water from the main condenser to the reactor vessel,
- provide injection path for High Pressure Coolant Injection system to the reactor vessel,
- provide injection path for Reactor Core Isolation Cooling system to the reactor vessel,
- provide a path for returning Reactor Water Cleanup system to the reactor vessel.

The Condensate and Demineralized Makeup Water System stores and distributes reactor quality water for the main steam cycle and for numerous auxiliary systems. It also maintains a minimum of 150,000 gallons for the Reactor Core Isolation Cooling and High Pressure Coolant Injection systems.

The functional classification of the Condensate and Feedwater System, and Condensate and Demineralized Makeup Water system is that of a power generation system.

## 2.6.2 System Description

The Condensate and Feedwater System shown in Figures 2.6-1 and 2.6-2, is an integral part of the reactor plant regenerative steam cycle. The steam exhausted from the low pressure turbines is condensed in the main condenser and collected in the main condenser hotwell. The main condenser also receives drainage from various system and equipment drains. The condensate that is collected in the hotwell is removed by the condensate pumps. The condensate pumps provide the driving force for the condensate flow through the steam jet air ejector (SJAE) condensers and steam packing exhauster. The SJAE condensers and the steam packing exhauster heat the condensate flow while cooling their respective process flows. Condensate flow is next directed to the condensate deep-bed demineralizers which purify the condensate water through ion exchange and filtration. Condensate booster pumps take suction from the demineralizers and maintain the driving force of the condensate flow through strings of low pressure feedwater heaters. The feedwater heaters take extraction steam and hot water from the main turbine and moisture separator reheaters to further raise the condensate temperature. The feedwater pumps take suction from the low pressure

feedwater heaters and develop system pressure high enough to inject into the reactor pressure vessel. The amount of feedwater flowing to the reactor pressure vessel during normal operations is controlled by varying the speed of the turbine driven reactor feed pumps. During very low power operations the feedwater flow rate is maintained by RFP Start-up Level Control throttle valves. The discharge of the feedwater pumps is directed to the two high pressure feedwater heaters. This final stage of feedwater heating is provided by extraction steam from the high pressure turbine. High temperature and pressure feedwater is directed to two feedwater lines that penetrate the primary containment. These feedwater lines further divide into a total of four reactor pressure vessel feedwater spargers. The feedwater spargers distribute feedwater within the reactor pressure vessel annulus where it is mixed with water rejected by the steam separators and steam dryers.

The Condensate and Demineralized Makeup Water system, (Figure 2.6-11) consists of a series of storage tanks, transfer pumps, and demineralizers providing reactor grade makeup water to a variety of balance of plant systems. Demineralized water is produced by a series of Demineralized Makeup Water Demineralizers and transfer pumps to maintain the Demineralized Water Storage Tank (DWST) full of water. Should the Condensate Storage Tank (CST) level drop below predetermined water levels demineralized water is automatically transferred from the DWST using the Demineralized Water Transfer pumps. The CST supplies water to the condensate transfer pumps, the Control Rod Drive Hydraulic System pumps, and the condenser makeup. A separate connection to the CST is used to supply water for the High Pressure Coolant Injection (HPCI) system, Reactor Core Isolation Cooling (RCIC) system, and Core Spray system pumps. The Core Spray system pump connection is primarily used for system testing.

### **2.6.3 Component Descriptions**

#### **2.6.3.1 Main Condenser**

The main condenser, shown in Figure 2.6-3, consist of two deaerating, single pass, single pressure, radial flow type surface condensers with divided water boxes. Each of the condensers is located beneath one of the two low pressure turbines with the condenser tubes running perpendicular to the turbine-generator axis. The main condenser receives cooling water from the Circulating Water System. Circulating water flows through the condenser tubes, condensing the low pressure turbine exhaust steam surrounding the tubes.

During normal operation, steam from the low pressure turbine is exhausted directly downward into the condenser shells through exhaust openings in the turbine casing.

As turbine exhaust flows downward the area increases, reducing the velocity of the exhaust steam. By lowering the exhaust steam velocity, the vibration and erosion experienced by the upper rows of tubes is minimized.

The condenser neck section of each condenser directs low pressure turbine exhaust steam to the condenser tube section. In addition to directing steam, the condenser neck houses two low pressure feedwater heaters, a drain cooler, and extraction steam piping. The low pressure feedwater heaters, drain cooler, and extraction steam piping that are located in the condenser neck are lagged with stainless steel insulating panels. The insulating panels minimize heat loss to the condenser.

A rubber belt type expansion joint is installed between the low pressure turbine and the condenser neck to permit differential expansion.

The condenser section internals establish circumfluent flow from the low pressure turbine exhaust to the condenser tube section. The remaining mixture of noncondensable gases and water vapor are then directed to the air cooler section.

The air cooler section consists of a vent duct and tube bundle enclosed by the air cooler baffle. The air cooler baffle is open at the bottom to direct all the remaining noncondensable gases and water vapor upward through the tube bundle. In passing through the tube bundle the mixture of noncondensable gases and water vapor is cooled, reducing its volume. The remaining mixture flows toward the colder end of the air cooler and the vent duct outlet.

The vent duct directs the steam mixture to the offgas penetrations where it will be further processed (Offgas System, Section 8.1).

The condenser units also serve as a heat sink for other systems, including:

- exhaust steam from the reactor feed pump turbines
- turbine bypass steam
- cascading low pressure heater drains
- air ejector condenser drains
- steam packing exhauster condenser drains
- feedwater heater shell operating vents
- moisture separator reheater (Figure 2.6-8).

Other systems periodically exhaust/drain to the main condenser sections, such as:

- startup vents of the condensate pumps, condensate booster pumps, reactor feed pumps
- return lines of the condensate pumps, condensate booster pumps, reactor feed pumps
- low pressure feedwater heater shell and minimum recirculation flow

Most of these return lines to the condenser contain steam or a mixture of steam and water vapor and exhaust to the main condenser below the tube bundle to prevent:

- Overheating the condenser tubes
- Disturbing the main turbine exhaust flow
- Overheating the turbine shell

Turbine bypass steam enters the condenser above the bundles due to the large steam flow which may be up to 25% of rated steam flow.

To ensure equal pressure between the condenser shells, cross-connect pipes are provided between the upper portions of the condenser tube nest.

### **2.6.3.2 Condenser Hotwell**

The condenser hotwells are incorporated in the bottom of each condenser shell and serve as collection points for all condensate. The hotwell for each shell is integral with, and a continuation of, the condenser shell side plates. The hotwells are tied together with 24 inch equalizing lines to ensure equal level in both hotwells.

Each hotwell is designed to store a sufficient quantity of condensate to provide a minimum of 2 minutes effective retention of all condensate entering the hotwell for radioactive decay of  $N^{16}$  ( $t_{1/2} = 7.11$  seconds). Retention time is ensured from normal water level to minimum operating level by use of a horizontal collector plate under the tube bundles. The plate directs the condensate to the end of the hotwell opposite the condensate pump suction pipe. Additional storage volume, over and above the specified storage capacity, is designed into the hotwell. With these provisions, the shortest possible path from the collector plate to the condensate outlet takes two minutes at a minimum operating level.

The hotwell level is regulated by a control circuit which maintains a constant level of water in the condenser hotwell. It consists of level indicating controllers which control a makeup supply from the CST and a reject back to the CST. When hotwell level is high, an air operated reject valve (LCV-04) on the outlet of the demineralizers opens. This removes water from the system, returning it to the CST, and lowers hotwell level. When hotwell level is low, makeup water is supplied from the CST through the air operated makeup valve (LCV-03). Makeup to the hotwell is supplemented by an addition air operated valve (LCV-02) in the event normal makeup flow is insufficient to maintain hotwell level. Figure 2.6-1 shows the flow path for condensate makeup and rejection flows.

### **2.6.3.3 Condensate Pumps**

Two condensate pumps (Figure 2.6-1) provide the motive force required to remove water from the condenser hotwell to the condensate booster pumps at sufficient pressure to ensure adequate net position suction head.

The condensate pumps are three stage pumps with a capacity of 12,153 gpm each at a discharge pressure of approximately 200 psig. Each of the condensate pumps take condensate from a common supply header via a manually operated valve and delivers it to a common discharge header.

#### **2.6.3.4 Steam Jet Air Ejector Condensers**

The steam jet air ejector (SJAE) condensers (Figure 2.6-1) are provided to condense the steam exhausted from the first stage SJAE and drain the resultant condensate back to the condenser hotwell. Additionally, the condensers provide for pre-heating condensate on its return path to the reactor. Condensate flow is normally aligned to both SJAE condensers though typically only one set is in service at a time. Operation of the SJAE can be found in the Offgas System, Section 8.1

#### **2.6.3.5 Steam Packing Exhauster**

The purpose of the Steam Packing Exhauster (Figure 2.6-1) condenses the leak-off steam from main turbine seals and reactor feed pump turbine seals. The steam packing exhauster is in the flow path with the SJAE condensers and requires constant 10,000 gpm flow through the Steam Packing Exhauster for optimum operation. As with the SJAE condensers the steam packing exhauster provides condensate pre-heating on its return path to the reactor. The Air Ejector and Steam Packing Exhauster Bypass Flow Control valve FCV-22 is closed anytime flow is below 10,000 gpm and opens to modulate flow through the exhauster for proper operation. Operation of the steam side can be found in the Main Steam System, Section 2.5.

#### **2.6.3.6 Condensate Demineralizers**

The function of the condensate demineralizers (Figures 2.6-14 & 2.6-15) is to remove dissolved and suspended impurities from the condensate. The condensate demineralizers, in conjunction with the Reactor Water Cleanup (RWCU) system, serve to purify the steam cycle water and maintain the reactor water quality limits under startup and normal operating conditions. The condensate demineralizers also may, depending on the magnitude of the contamination, allow an orderly shutdown of the reactor during abnormal conditions such as condenser tube leakage or contamination from other sources.

The condensate demineralizer system consist of eight demineralizer units and regeneration facilities to clean the mixed bed resins (mixed cation and anion resin), and ultrasonic resin cleaner, resin storage, and resin disposal equipment. The eight units are arranged in parallel, with a flow balancing circuit distributing flow equally across in-service filters. Seven of the units are needed for 100% power operation, one remains in standby. The demineralizers remove both dissolved and suspended solids from the

condensate. These solids may be corrosion products from the steam and condensate systems, foreign material from outages, or solids carried in by makeup water.

Condensate flow through the in service demineralizers is equally distributed such that flow through each demineralizer is between 1560 GPM to 3430 GPM.

Total pressure drop across the demineralizers is provided at the local control panel. When the total pressure drop across the demineralizers exceeds 50 psid an alarm occurs locally. Individual demineralizer differential pressure and conductivity is monitored. Demineralizer performance monitoring regulates when the spare demineralizer is placed in service. The demineralizers should be removed from service if temperature of the condensate entering the demineralizers exceeds 130°F. This administrative limit protects the resins from melting as temperatures approach 150° to 160° F.

A demineralizer is removed from service when its resin is depleted as indicated by high differential pressure (40 psig) or high effluent conductivity (0.1  $\mu$ mho/cm). If the resin is exhausted as indicated by high conductivity, it is replaced with new resin. If a high differential pressure occurs and conductivity is still within specification an ultrasonic cleaner can be used to mechanically clean the resin.

#### **2.6.3.7 Exhaust Hood Spray**

Exhaust hood spray (Figure 2.6.13) is required because at low turbine loads, the friction from the low velocity steam on the last stage blading causes temperature to increase, possibly leading to blade damage. Condensate water is sprayed into the low pressure turbine exhaust hoods to condense the steam, reduce backpressure, and increase turbine exhaust steam velocity to reduce the exhaust hood temperature. A temperature element located in the exhaust hood of each low pressure turbine controls the spray valve. If exhaust temperature increases above 130°F in either of the low pressure turbines, a spray valve opens, allowing water to be sprayed into the low pressure turbine exhaust hoods. Should temperature continue to rise to 175°F the operator will be alerted to the condition and if 225°F is reached a main turbine trip occurs.

#### **2.6.3.8 Exhaust Hood Spray Line Flow Paths**

The Exhaust Hood Spray Line (Figure 2.6-1) has multiple connections providing flow for the Low Pressure Turbine exhaust hood spray, suction to the control rod drive pumps, condensate reject to the CST and condensate clean-up return (short cycle) line to the main condenser is provided from the common line penetrating the common discharge pipe downstream of the condensate demineralizers.

The control rod drive pump suction is supplied from the condensate system (Figure 2.6-1 & 2.6-15) in order to obtain a clean source of water. This also helps reduce the wear on the control drive mechanism seals.

The condensate return to the CST is used for removing excess level from the condenser hotwell, recirculating water to the CST in order to maintain water quality in the CST, and if needed to keep the CST water warm during cold weather operations.

The condensate clean-up return (short cycle) line is normally used to circulate condenser hotwell water through the condensate demineralizers to obtain required water quality prior to startup following an outage.

### **2.6.3.9 Condensate Booster Pumps**

Two condensate booster pumps (Figure 2.6-1) take water from a common supply header downstream of the demineralizers and provide the required net positive suction head to the reactor feed pumps.

Each pump is a motor driven, horizontal, centrifugal pump with a capacity of 12,153 gpm at a discharge pressure of approximately 600 psig. The minimum flow requirement of the pump, 5200 gpm, is maintained, at low flows, by FCV-27A(B). Both booster pumps have a low suction pressure trip at 35 psig, the A pump is time delayed 20 seconds while the B pump is time delayed 45 seconds. This ensures that a complete loss of both booster pumps is limited to a complete loss of condensate pumps and not due to a single condensate pump loss.

### **2.6.3.10 Drain Coolers**

The drain coolers provide pre-heating to the condensate increasing plant efficiency while at the same time minimizing turbine blade damage from high moisture content steam. The process of heating the feedwater as extraction steam and drains cascade through the heaters is describe in the following section on Low Pressure Feedwater Heaters.

The drain coolers (Figure 2.6-1) are water to water heat exchangers used to remove the last amount of available heat energy from the heater drains prior to discharge to the condenser hotwell. At full power operation, feedwater enters the drain cooler at 103°F.

### **2.6.3.11 Low Pressure Feedwater Heaters**

Extraction steam provides the heat source for heating the feedwater heaters. Feedwater heater extraction steam provides for heating of the feedwater to improve plant efficiency. The extraction steam and heater arrangements are designed to supply sufficient heat to maintain feedwater at 300°F. High moisture content steam, extraction steam and low quality extraction steam from the low pressure turbine stages is piped to feedwater heaters where the steam condenses to form heater drain water.

The low pressure heaters (2, 3, 4, 5, and 6<sup>th</sup> point heaters) are arranged in two sets of parallel strings. Each low pressure heater is supplied with steam from its own extraction points located in one of the two low pressure turbines. The 6<sup>th</sup> point heaters are located in the exhaust trunk of the condenser. The 3<sup>rd</sup> point heaters also receive drain water from the moisture separator drain tank. The 4<sup>th</sup> point heaters also receive drain water from the steam seal evaporator drain tank and the radwaste steam generator drain tank. The heater drain coolers receive drain water from the 5<sup>th</sup> point heater as its heating medium.

The feedwater extraction steam system is illustrated in Figure 2.6-9. The B low pressure turbine is shown with the extraction steam lines to the low pressure heaters. The A low pressure feedwater heater strings are identical. Figure 2.6-9 also shows the feedwater heater extraction points.

The extraction lines to the no. 1, 2, 3, 4, and 5 point heaters are equipped with motor operated block valves which automatically close on a trip of the main turbine or on high water level in the heater. These extraction lines are also equipped with air operated Non-Return check Valves (NRV).

The low pressure feedwater heaters (Figure 2.6-4) are internally constructed to accommodate three flow paths: feedwater, extraction steam, and heater drains. Feedwater enters the heater at the water box and is directed to stainless steel u-tubes via a water box divider plate. Once inside the tubes the feedwater passes through an internal drain cooler section, except heater number 5, where it cools the heater drain water. After passing through the drain cooler section, the feedwater absorbs energy from the heater drain water located in the bottom of the heater. The feedwater makes a turn in the u-section of the tubes and enters the extraction steam section. The feedwater passes through the steam section where it absorbs heat energy prior to entering the water box and exiting the heater.

Extraction steam enters the feedwater heater via two penetrations in the upper section of the heater. Upon entering the heater, the steam is directed at right angles to the point of entry by impingement plates. The impingement plates along with internal baffling forces the steam to flow around the upper rows of feedwater heater tubes. When the extraction steam gives up its latent heat of vaporization to the feedwater, the steam condenses and falls to the bottom of the heater forming the heater drains.

The heater drains accumulate in the bottom of the heater where they flow around the feedwater heater tubes on the way to the drain cooler section. Once inside the drain cooler section, the drains follow a tortuous path via a baffle arrangement to transfer the last available energy to the feedwater. The drain cooler section is employed to limit the amount of heater drain water that flashes into steam when cascading to a lower pressure heater.

### **2.6.3.12 Heater String Isolation Valves**

The heater string isolation valves (Figure 2.6-1) are motor operated valves (MOV-33A(B) and MOV-34A(B)) with the capability of both automatic and manual closure. The heater string is also equipped with a bypass valve (MOV-30). Automatic closure of both the inlet and outlet valves and opening of the heater bypass valve is initiated upon detection of a heater high water level in that string. The automatic isolation of a heater string provides turbine protection from water intrusion caused by backing up of water from the heater into the extraction steam line. Manual operation of the isolation valves is provided for maintenance of the heaters.

### **2.6.3.13 Non-Return Check Valves**

The purpose of the Non-Return Check Valves (NRV) (Figure 2.6-12) is to prevent backflow of water or steam from entering the turbine and causing damage either by water induction or over speed resulting from reverse steam flow. The NRV's also close on a main turbine trip or high heater water level.

The NRV is a free swinging, gravity closing, check valve. The valve disc will open when the inlet pressure becomes slightly higher than the outlet pressure and will close when the inlet pressure becomes slightly less than the outlet pressure or a reversal of flow occurs. To ensure positive closing, a spring loaded air cylinder is installed on the outside of the valve body connected by means of a piston rod and suitable linkage to the shaft.

Under normal operating conditions, with air pressure established in the air cylinder, the piston is in its top position with the closing spring compressed. Upon receiving a high level in a feedwater heater, the solenoid valve will deenergize and vent the air pressure from below the piston. The closing spring forces the piston downward, which in turn acts through the piston and pulls down the closing lever on the shaft and rotates the disc to its seat. The valve will remain in this position until air pressure is again established in the cylinder and the piston moved upward or the extraction steam pressure overcomes the cylinder spring force. Upon receiving a turbine trip, the extraction relay dump valve which is part of the Electro Hydraulic Control System (Section 3.2) will trip and vent the air off the NRV's.

Because the 6th point heaters are located within the condenser, their extraction lines have no shutoff or check valves to isolate the heaters. The extraction steam piping to these heaters is protected from water induction by the automatic closing of the heater condensate inlet and outlet valves when high heater level is detected.

The 1st point through the 5<sup>th</sup> point feedwater heaters have air operated extraction steam line drain valves that are used to keep the extraction steam lines drained under various plant startup conditions. If closed, the drain valves automatically open upon a main

turbine load decrease to less than 15% (as determined by turbine first stage pressure), main turbine trip, or high heater water level.

In combination with the NRV's all low pressure feedwater heaters have flash containment baffles provided in the heater shells to reduce the possibility of turbine overspeed from flashing of shell drains.

#### **2.6.3.14 Reactor Feedwater Pumps**

Two Reactor Feedwater Pumps (RFPs) (Figure 2.6-2) take heated feedwater from the outlet of the low pressure feedwater heaters and provide the driving force necessary to supply water to the reactor vessel. Each RFP is a horizontal, centrifugal, single stage pump driven by a variable speed steam turbine with a designed flow rate of 14,000 gpm at a total discharge head of 1130 psig. Each pump is rated at 67% of system capacity.

Motive force is supplied by a six stage, single direction, dual admission condensing turbine. Steam turbine driven pumps are used to increase overall plant efficiency. The RFP Turbine (RFPT) is an impulse/reaction type turbine with a single thrust bearing. Each turbine is rated at 8,500 horsepower at 5500 rpm (rated speed), and is equipped with overspeed protection and bearing vibration detectors. Both pumps have a low suction pressure trip at 250 psig, the A pump is time delayed 8 seconds while the B pump is time delayed 25 seconds. As with the Condensate Booster pumps the reactor feedwater pumps use a sequenced suction trip to ensure a single condensate booster pump failure does not cause a complete loss of feed.

Each turbine is equipped with two sets of stop and control valves (Figure 2.6-6). One set of valves regulates low pressure steam extracted from the cross-around piping downstream of the Moisture Separator/Reheaters (MSRs). This is the normal steam supply to the turbine. Steam from the cross-around piping flows through the LP steam block valves through the LP stop valves, and the five LP control valves, then the turbine. After the steam passes through the turbine it is exhausted to the main condenser. The high pressure stop valves and high pressure control valve are supplied steam from the main steam equalizing header through the HP steam block valves. The high pressure and low pressure stop valves provide for rapid isolation of the steam supply to the RFPT for turbine protection.

Control of the five low pressure control valves and the single high pressure control valve is from a linkage arrangement which sequentially opens the valves. The five low pressure control valves open in sequence, followed by the single high pressure control valve. The linkage is arranged so that the high pressure valve does not throttle open until the last low pressure valve is fully open. Thus, the turbine will use low pressure steam in preference to the high pressure steam whenever it is available.

The stop and control valves are hydraulically operated by control oil supplied from the RFPT oil system (Figure 2.6-7) and regulated by the Feedwater Control System (Section 3.3).

### **2.6.3.15 High Pressure Feedwater Heaters**

The high pressure feedwater heaters (Figures 2.6-2 & 2.6-5) represent the last stage of feedwater heating. High pressure feedwater heating consists of two identical parallel strings of heaters and valves (MOV-45A(B) & MOV-46A(B)). Each string consists of a vertically mounted feedwater heater and an inlet and outlet isolation valve. As with the low pressure heater string the high pressure heaters are equipped with a bypass valve (MOV-47A(B)). The high pressure heaters operate in the same manner as the low pressure heaters. The term high pressure originates from the location of the heaters in the condensate and feedwater system and the high pressure extraction steam used for heating. Both feedwater lines contain flow elements after the outlet isolation valve.

### **2.6.3.16 Feedwater Discharge Piping**

The feedwater piping downstream of the high pressure feedwater heaters consists of a common line which branches into two separate lines. Both feedwater lines contain an outboard isolation valve, a testable check valve, and an inboard manual isolation, and penetrations for certain safety related systems. Each feedwater line in turn then penetrates the primary containment and branches into two separate lines which are welded to the safe end nozzle penetrations on the reactor vessel.

In addition to performing a safety function, the feedwater lines provide a path for the Reactor Water Cleanup System (Section 2.8), the Reactor Core Isolation Cooling System (Section 2.7), and the High Pressure Coolant Injection System (Section 10.1) to return water to the reactor vessel.

### **2.6.3.17 Feedwater Heater Drains**

The feedwater heater drains are shown in Figure 2.6-10. As the extraction steam gives up its heat to the feedwater, it condenses and is collected in the bottom of the feedwater heaters as heater drains. The feedwater heaters utilize a cascading drain system with the drain flow from the highest pressure and temperature heaters flowing successively to the next lowest pressure heater.

Condensed extraction steam from the 1st point high pressure feedwater heaters is drained through normal drain valves to the 2<sup>nd</sup> point heater. An emergency drain line to the main condenser is provided to prevent heater flooding in the event of high heater level.

The remaining low pressure heaters are provided with a cascading drain system as described for the 1st point heater. The exception to this pattern is that the 5<sup>th</sup> point heater has a direct drain to a heater drain cooler. One heater drain cooler is provided for each heater string. Then the heater drain cooler drains to the main condenser. The 6th point heater also has a direct drain to the main condenser.

During a level transient, if the normal drain flow path and emergency drain flow path are unable to maintain the proper heater levels, the motor operated extraction block valves and NRV valves close for heaters 1, 2, 3, 4, or 5 and the condensate inlet and outlet valves close for heaters 1 through 5. High heater water level also opens the heater extraction steam bypass valves.

The moisture separator drain tank receives drains from the moisture separator section of the MSR, vents to the main section of the MSR, and drains to the 3<sup>rd</sup> point heater or the main condenser as shown in Figure 2.6-8. The first and second stage reheater drain tank receives drains from the first and second stage reheater section of the MSR, also vents to the main section of the MSR, and drains to the 1<sup>st</sup> point heater or the main condenser.

### **2.6.3.18 Condensate and Demineralized Makeup Water System**

#### **Condensate Storage Tank**

The condensate storage tank (CST) (Figure 2.6-11) is a carbon steel tank, 50 feet in diameter and 35 feet high. It has an effective capacity of 550,000 gallons and is vented to the atmosphere. It is located outdoors, inside a concrete dike, next to the turbine building. The dike has the capacity to retain all of the potentially contaminated condensate should the tank rupture or leak. All of the tank connections are located above the tank connection for the RCIC and HPCI header to ensure that there is 150,000 gallons of water for their operation. Core Spray pumps use the same piping connection as HPCI and RCIC when conducting core spray sparger testing. The CST provides the required static head for the suction of the condensate transfer pumps and the normal supply pump.

#### **Condensate Transfer Pumps**

The condensate transfer pumps (Figure 2.6-11) are used to supply makeup water to various auxiliary systems. The pumps are rated at 1000 gpm at 225 feet TDH. The pumps are normally off, and one will start automatically if the system flow reaches 330 gpm. If the demand on the system is in excess of the capacity of the running pump, the second pump starts to handle the required needs of the system. As system flow decreases, the second pump drops off the line.

#### **Makeup Water Storage Tank**

City water fills the Makeup Water Storage Tank (Figure 2.6-11). Untreated city water level is maintained within the tank by a level controller which operates a level control valve. The capacity of the Makeup Water Storage Tank is 10,000 gallons.

## **Demineralized Makeup Water Pumps**

The demineralized makeup water pump (Figure 2.6-11) operates continuously to maintain the demineralized water header filled and pressurized. The makeup pump is a centrifugal pump rated at 70 gpm. Normally one pump is running continuously; the other pump is in the standby condition. A minimum flow valve is provided to maintain flow through the operating pumps. If there is an excessive demand on the system, a flow switch will start the standby pump.

## **Makeup Demineralizers**

The makeup demineralizers (Figure 2.6-11) are comprised of two ion exchanger trains each with a cation ion exchanger and an anion ion exchanger. Both the anion and cation exchangers are layered, bead resin type, ion exchangers, with a capacity of approximately 200 ft<sup>3</sup> for each anion bed and approximately 150 ft<sup>3</sup> for each cation bed. Normally, both ion exchanger trains are in service except during periods when one of the trains is being replaced.

## **Demineralized Water Storage Tank**

The water discharged from the ion exchanger trains are piped into the demineralized water storage tank (Figure 2.6-11), which is a 75,000 gallon stainless steel structure located in the yard area adjacent to the water treatment building. Level indication is provided by a local level indicator. The level transmitter is also used for high/low level alarms as well as to regulate the flow of water through the demineralizers.

## **Demineralized Water Transfer Pumps**

The demineralized water transfer pumps (Figure 2.6-11) operate in response to a signal from a flow switch on the line to the distribution header. Normally, one transfer pump is in the automatic mode, the other is in the standby mode. If the header flow requirement approaches the capacity of the transfer pump then the standby transfer pump will start. As flow decreases, the standby pump, and then the automatic pump will automatically stop sequentially. A minimum flow line is provided from the common discharge header back to the demineralized water storage tank. Each transfer pump is rated at 165 gpm.

## **2.6.4 System Features and Interfaces**

### **2.6.4.1 Normal Operation**

The number of condensate pumps, condensate booster pumps, and reactor feed pumps in operation depends on the plant load (i.e., MWe output). Normally at 100% power both condensate pumps, both condensate booster pumps, both reactor feed pumps and all but one of the demineralizers are required for operation. At lower power levels,

various combinations of condensate and booster pumps and reactor feed pumps are used so that the pumps are operating near or at their design flow rate.

In general, the flow requirements are controlled by the Feedwater Control System (Section 3.3), with the Condensate and Feedwater System in operation and able to meet any expected flow transients by having reserve capacity on the line, or by starting additional pumps. The number of operating condensate pumps should always be equal to or greater than the number of operating condensate booster pumps.

#### **2.6.4.2 System Startup**

If the plant has been shutdown for maintenance for a long period of time, the condensate water quality may be low and require cleanup by the demineralizers.

The first step is to place the Condensate and Feedwater System in short or long cycle cleanup modes (Figure 2.6-1). For short cycle mode of operation one condensate pump is started and two demineralizers are placed in service. The condensate pump removes water from the condenser hotwell and provides the motive force for cleanup. The discharge of the condensate pump is directed through the auxiliary condensers, and demineralizers.

From the common discharge header of the demineralizers the water is recycled back to the condenser via the air operated, automatically controlled, condensate system minimum flow valve, FCV-23.

The long cycle cleanup mode of operation (Figure 2.6-2) is used when both the condensate and feedwater portions of the Condensate and Feedwater System require clean up. To accomplish long cycle cleanup; the system is aligned to allow flow through the low pressure feedwater heaters, around the reactor feed pumps via the startup bypass valve, and into the high pressure feedwater heater strings. From the high pressure feedwater heaters, flow is recycled back to the condenser hotwell via the water quality recirculation line located between downstream heater isolation valves (MOV-46A(B)) and the feed water flow elements. RFP Water Quality Recirc Control Valve, FCV-10 controls the long cycle cleanup flow back to the hotwell.

The startup bypass line also allows the condensate booster pumps to supply water to the reactor during startup operations when a feedwater pump is not required. During plant startup, feedwater is required to maintain water level in the reactor. The reactor startup bypass line level control valves are positioned to maintain the water level via the Feedwater Control System. At first a condensate, and condensate booster pump, will supply sufficient pressure and flow to maintain level. As pressure in the reactor increases, it becomes necessary to use another condensate booster and condensate pump to add water when required. When reactor pressure reaches approximately 350 psig, a reactor feed pump is started in preparation for feeding the reactor vessel. As the startup continues, equipment is placed in service as required.

### **2.6.4.3 Condensate and Demineralized Makeup Water System**

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

Makeup water is supplied to the CST by the demineralized water storage whenever CST level is abnormally low.

The makeup supply to the system is controlled in response to the water level in the makeup water storage tank. As level drops below operational limits supply valve opens allowing city water to fill the makeup water storage tank.

The operation of the demineralized water transfer pumps is controlled by the water level in the demineralized water storage tank. Both transfer pumps operate in response to large supply demands. Either pump may be selected for primary operation with the other in standby.

The demineralized water storage tank supplies water to the following systems or components:

- Condensate Storage Tanks
- Fuel Pool Cooling and Cleanup System
- Closed Cooling Water System
- Standby Liquid Control System
- Diesel Generators
- Condensate and Feedwater System
- Residual Heat Removal System
- Offgas System

### **2.6.4.4 System Interfaces**

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

#### **Circulating Water System (Section 11.1)**

The Circulating Water System provides the necessary cooling water flow for the main condensers. The cooling water provides the driving force to condense main turbine and reactor feed pump exhaust steam to condensate.

### **Control Rod Drive (CRD) System (Section 2.3)**

The normal supply to the CRD pumps is the Condensate Demineralizer effluent via the Hotwell reject line to the CST. The CST will also provides a gravity drain suction line to the CRD pumps when the Condensate Demineralizers are not in service. The CRD pump minimum flow and test lines are routed back to the CST.

### **The Feedwater Control (FWC) System, (Section 3.3)**

The FWC system uses total feedwater flow as one it's controlling inputs in the three element system. The FWC system also controls the speed of the RFP turbines and the position of the startup level control valve.

### **Reactor Water Clean Up (RWCU) System, (Section 2.8)**

The RWCU System returns water to the reactor vessel via the feedwater lines. The Condensate and Demineralized Makeup Water System supplies the RWCU system with for water for filling, precoating, and backwashing of filter demineralizer resins.

### **High Pressure Coolant Injection (HPCI) System, (Section 10.1)**

The HPCI System supplies water to the reactor vessel via the feedwater lines. The HPCI pump gets its normal suction from the CST. This suction path is via a line shared with the Reactor Core Isolation Cooling System and is sized for simultaneous operation of these two systems. A HPCI pump test return line also taps into the CST.

### **Reactor Core Isolation Cooling (RCIC) System, (Section 2.7)**

The RCIC System supplies water to the reactor vessel via the feedwater lines. The RCIC pump gets its normal suction from the suction line shared with the HPCI pump. A RCIC pump test return line taps into the HPCI pump test return line to the CST.

### **Main Steam System, (Section 2.5)**

The Main Steam System supplies steam to the main turbine, reactor feedwater pumps and auxiliary steam loads

### **Offgas System, (Section 8.1)**

The Offgas System uses condensate flow as cooling water to the SJAE condensers and treats the noncondensable gases removed from the main condenser.

### **2.6.5 Summary**

The Condensate and Feedwater system provides for the collection of exhaust steam from the main turbine and the reactor feed pumps into the main condenser. Exhaust steam is condensed and returned to the reactor vessel for inventory control. The system provides for condensate storage, demineralized water production and the distribution throughout the nuclear facility. The Condensate and Feedwater system also supports off-normal level control through the common injection header connections with feedwater and the HPCI and RCIC systems.

The Condensate and Demineralized Makeup Water System is the primary means of distribution of condensate throughout the facility for normal and abnormal operations. The CST provides the volume for hotwell makeup and reject. The reject line and ultimately the CST volume are the primary source of water to the CRD system. The CST also has a dedicated supply of water for the HPCI and RCIC systems. Demineralized water is provided for makeup to the condensate system, stator water cooling, standby liquid control system, auxiliary boiler, and a variety of multipurpose stations and service boxes throughout the nuclear facility.

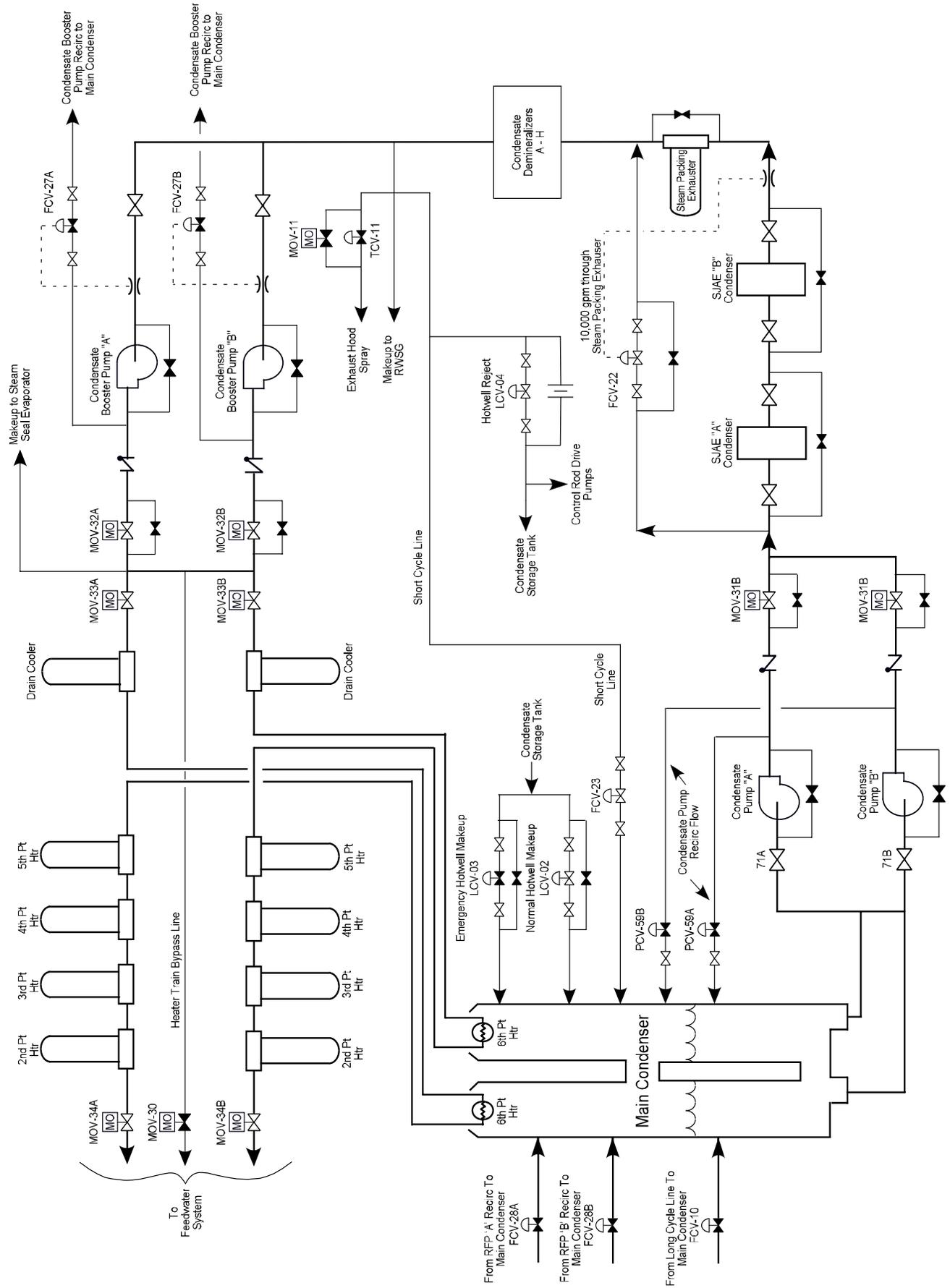


Figure 2.6-1 Condensate System

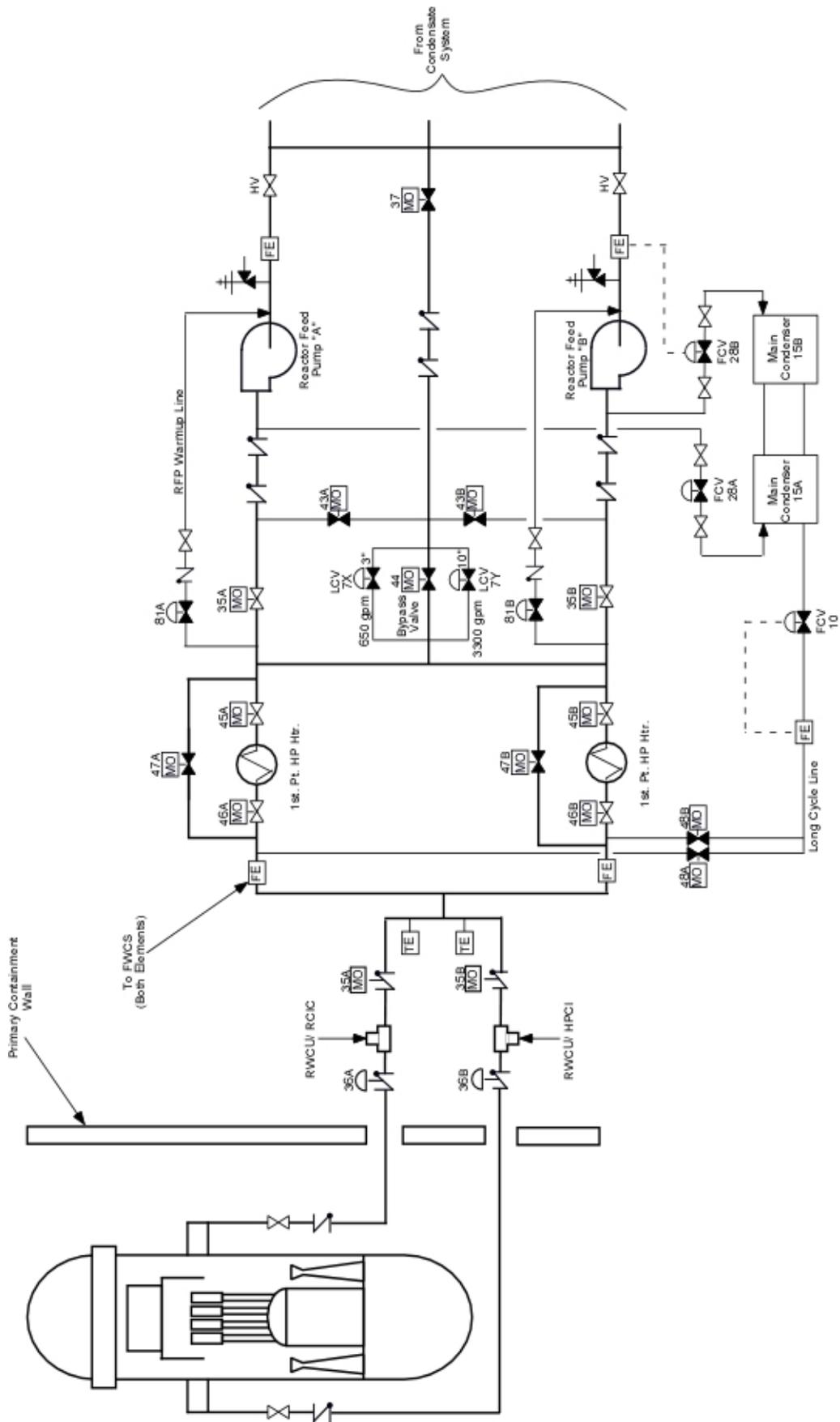
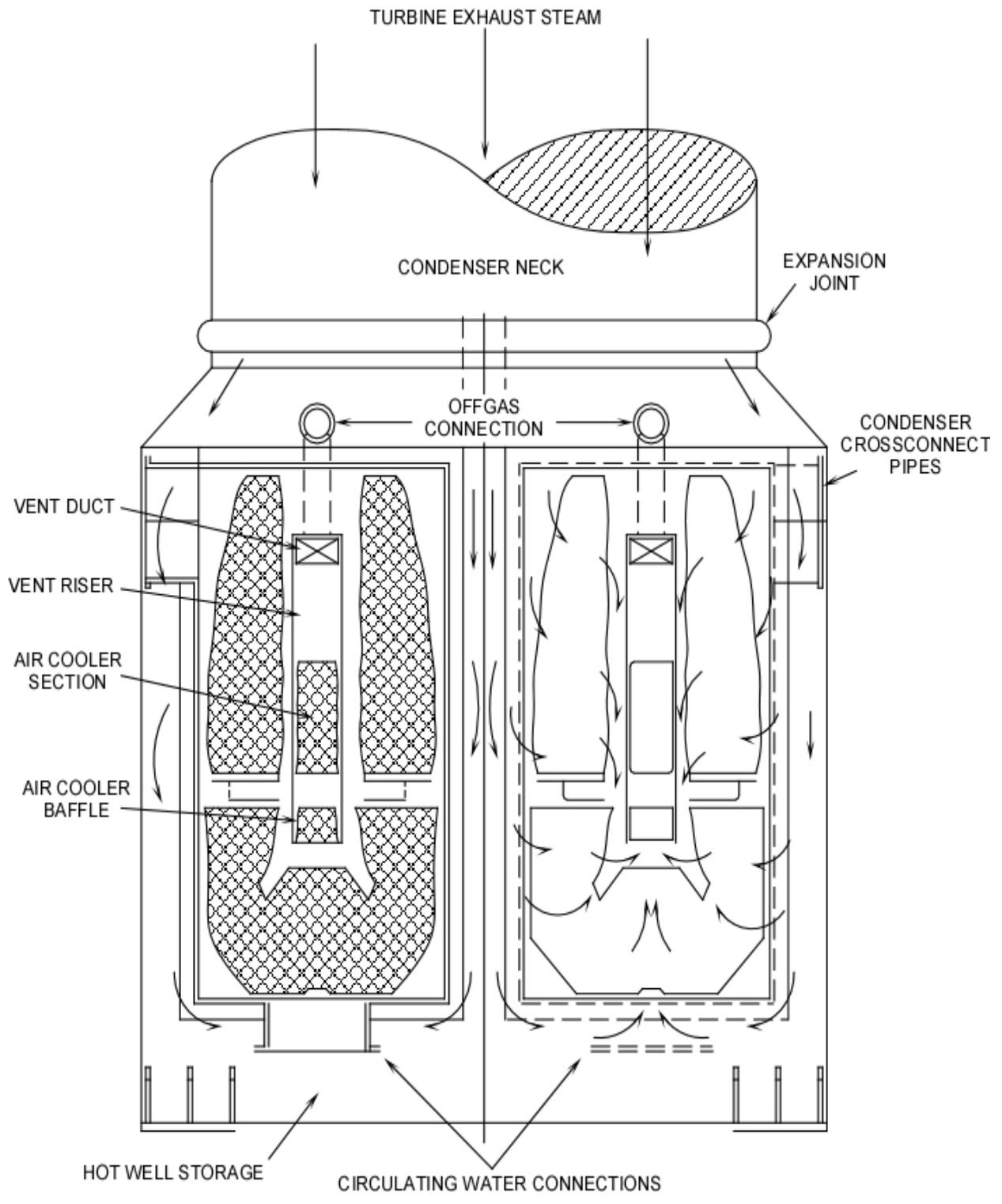


Figure 2.6-2 Feedwater System



**Figure 2.6-3 Condenser Flow Paths**

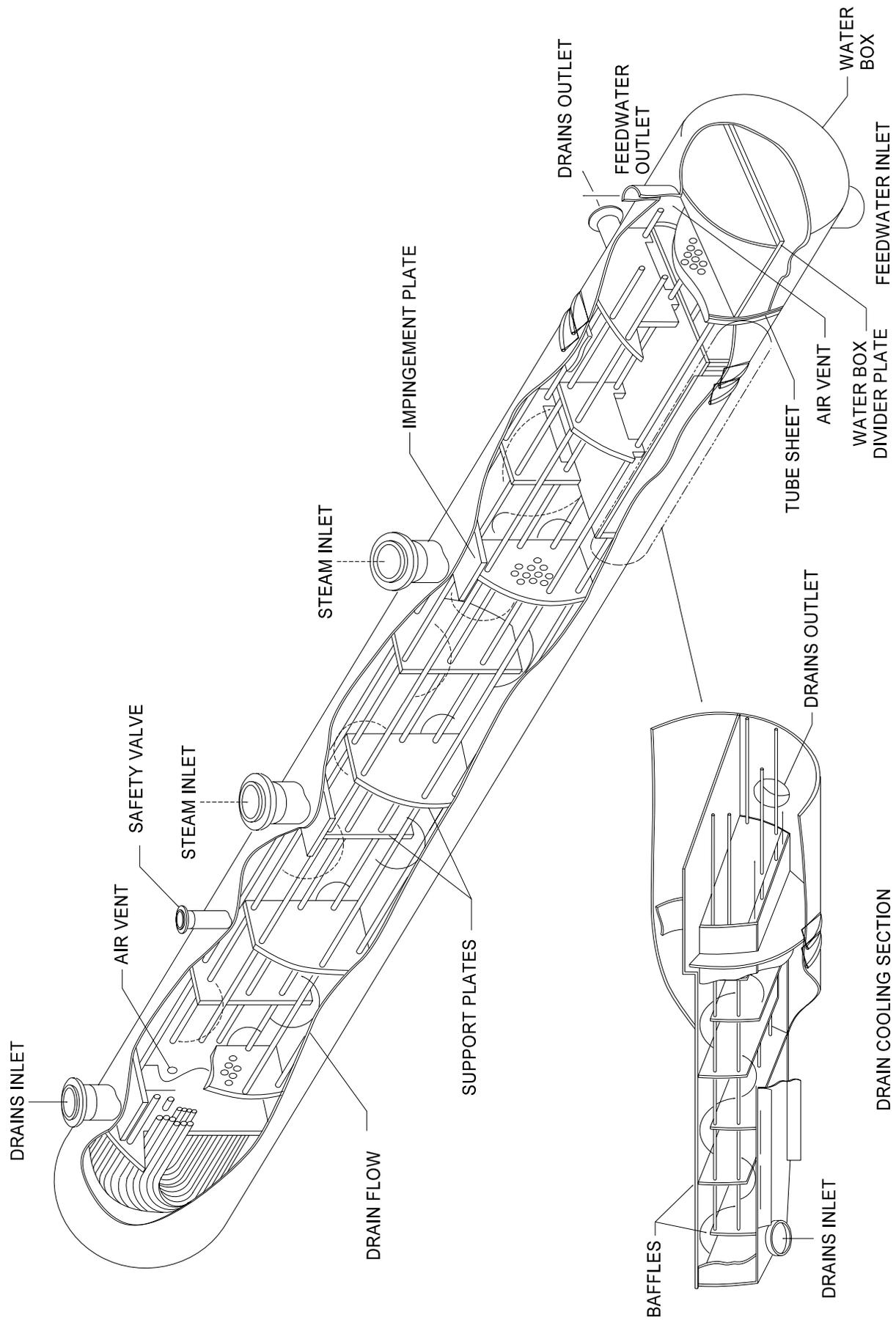


Figure 2.6-4 Typical Horizontal Feedwater Heater

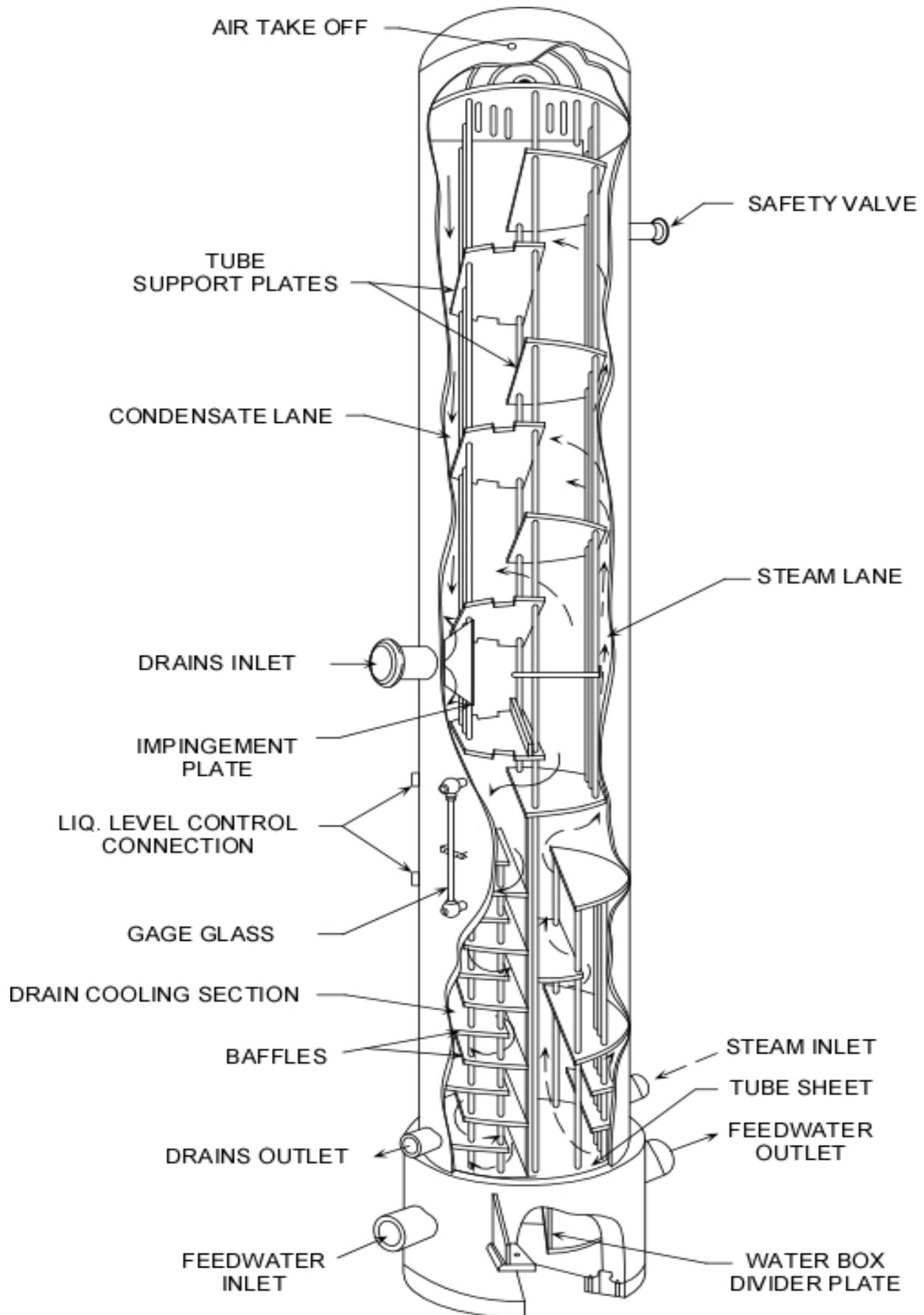


Figure 2.6-5 Typical Vertical Feedwater Heater

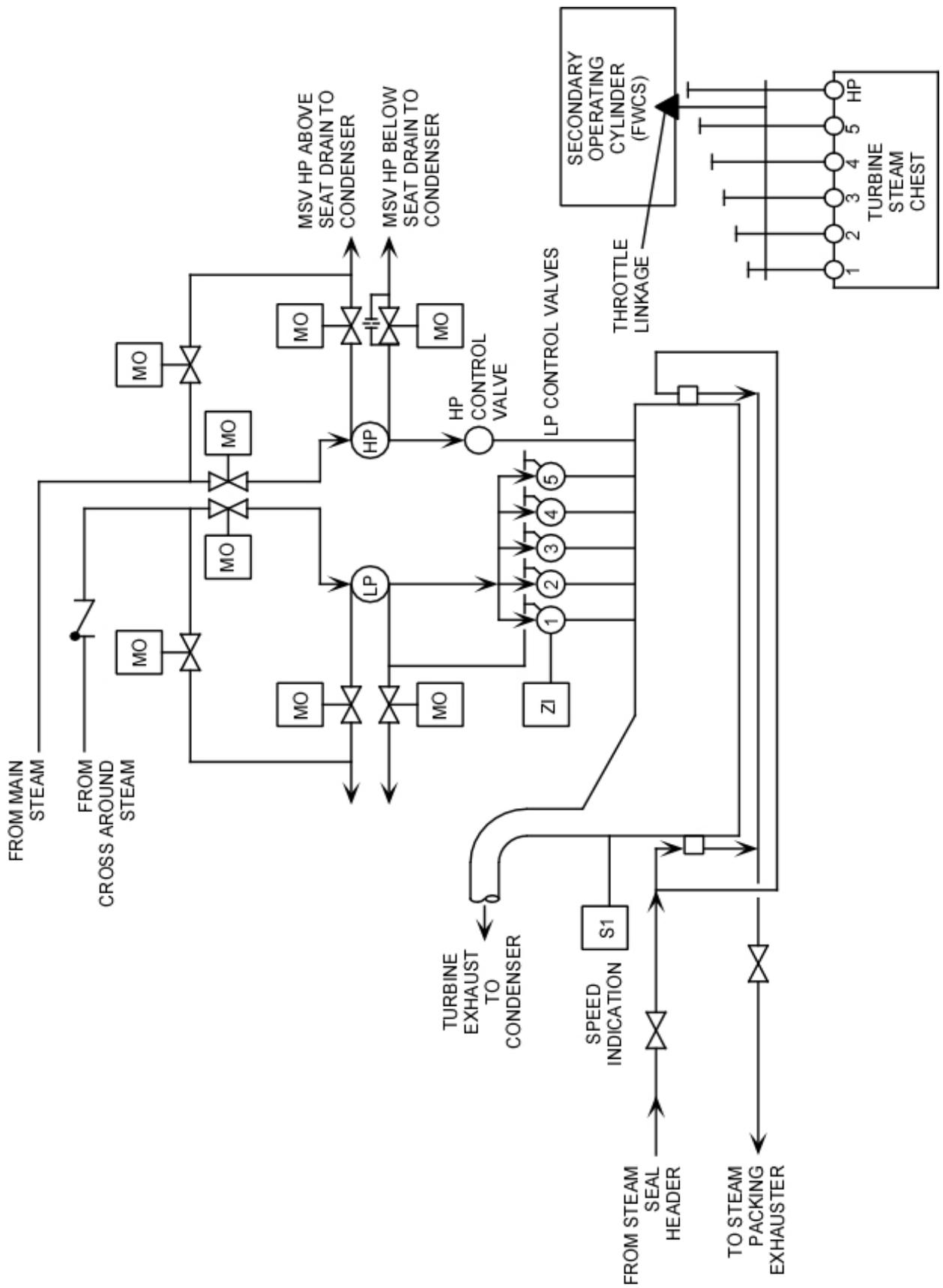


Figure 2.6-6 Reactor Feed Pump Turbine



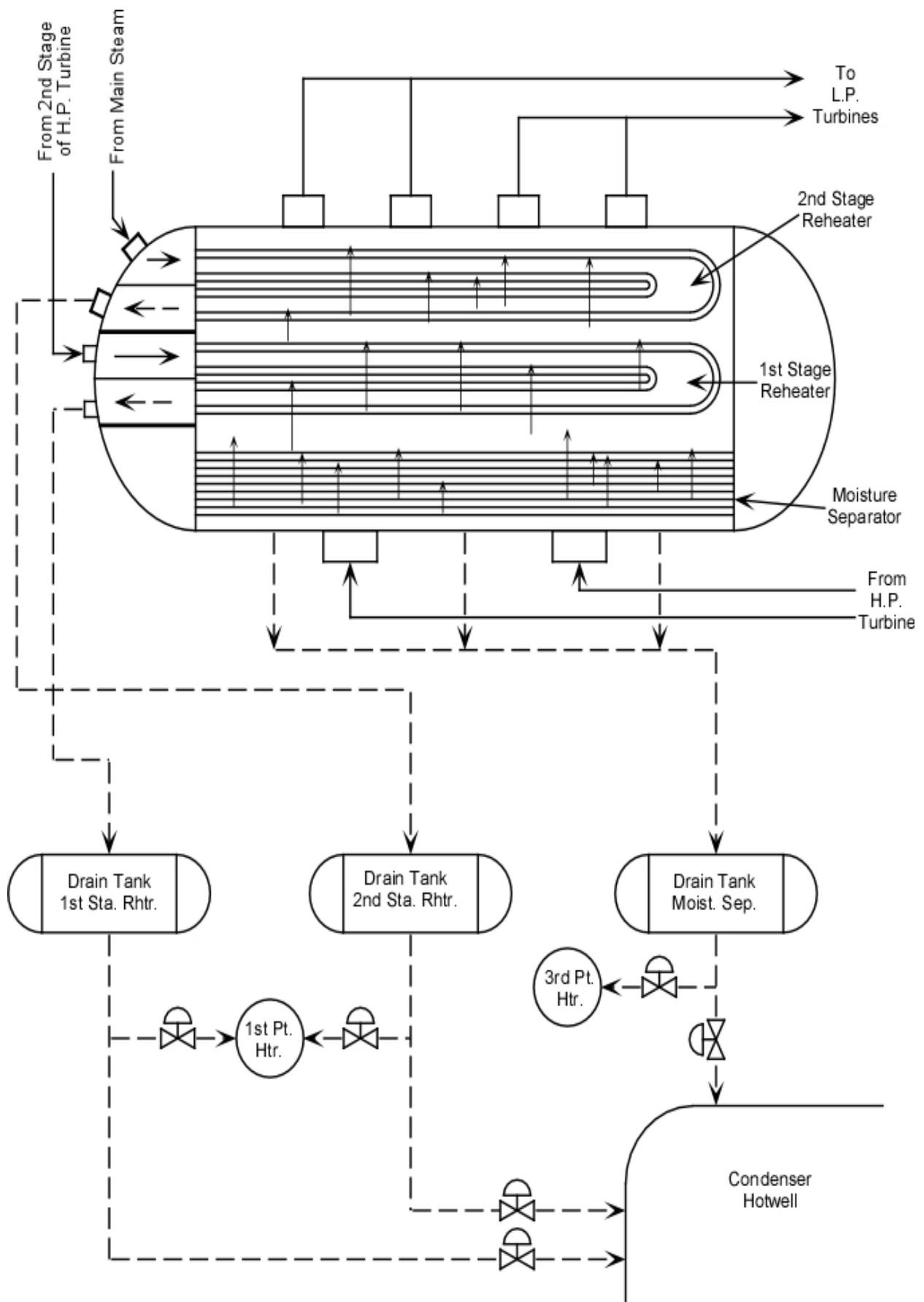


Figure 2.6-8 Moisture Separator Reheater

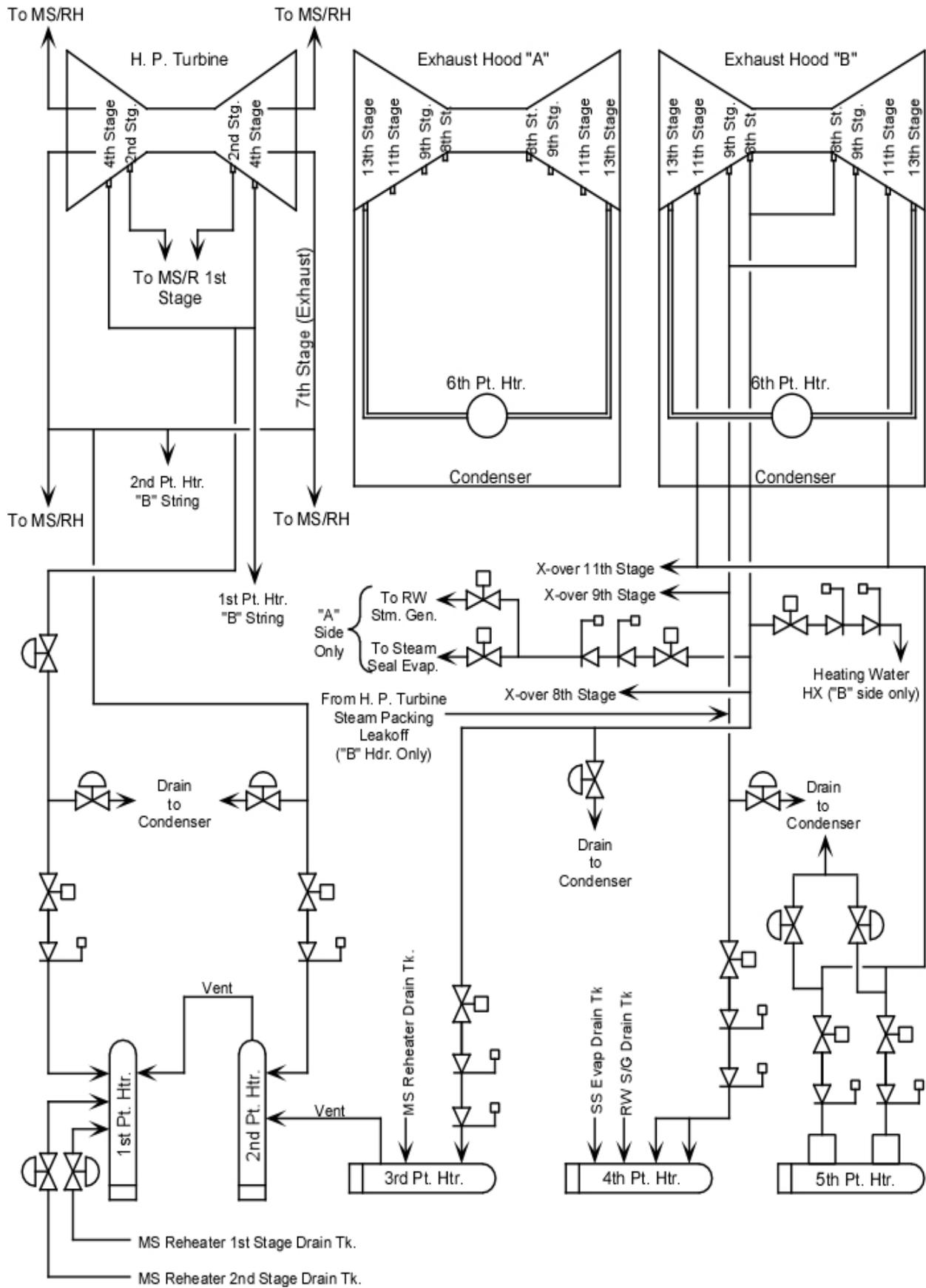


Figure 2.6-9 Extraction Steam

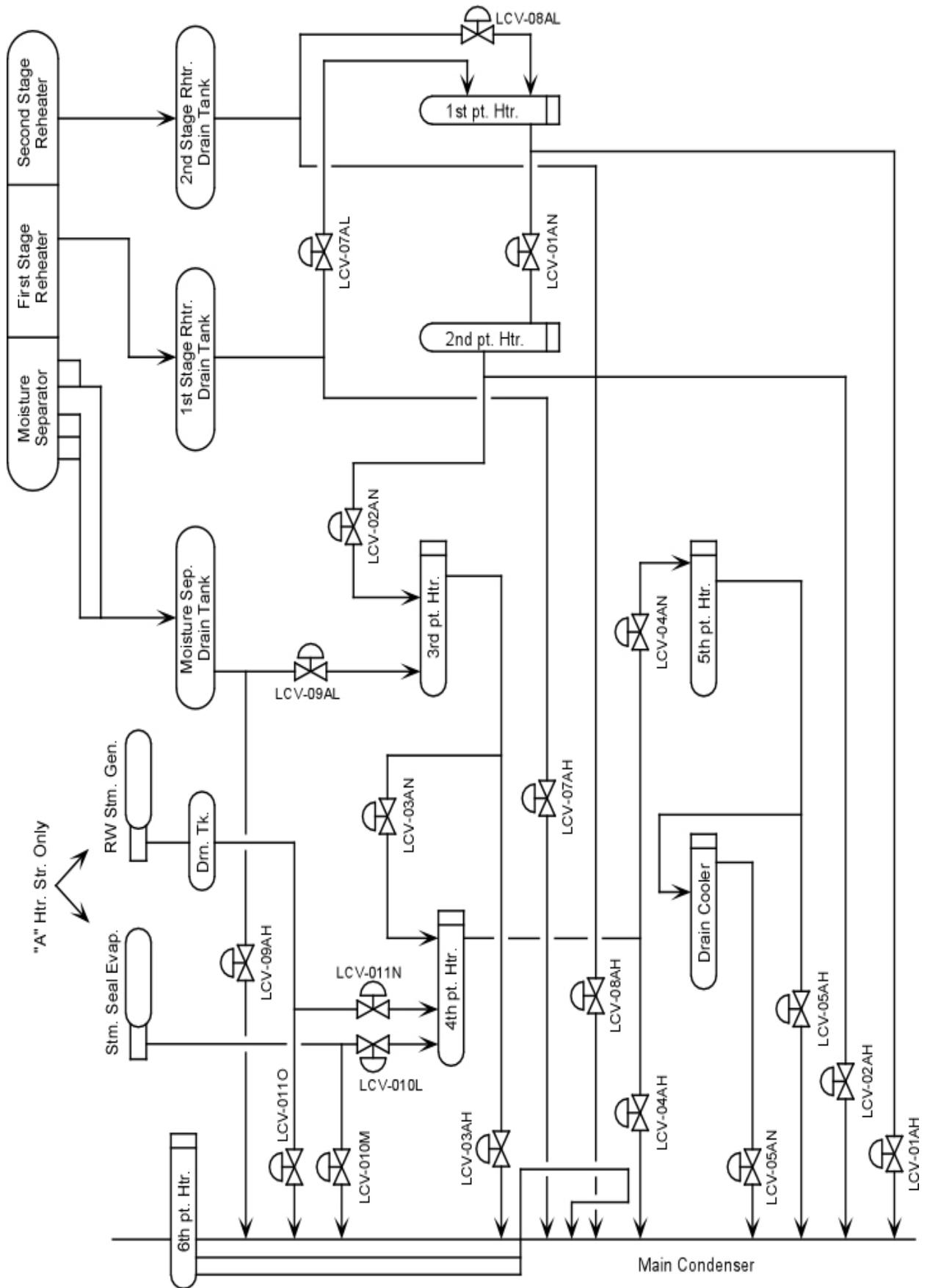


Figure 2.6-10 Heater Drains Flow

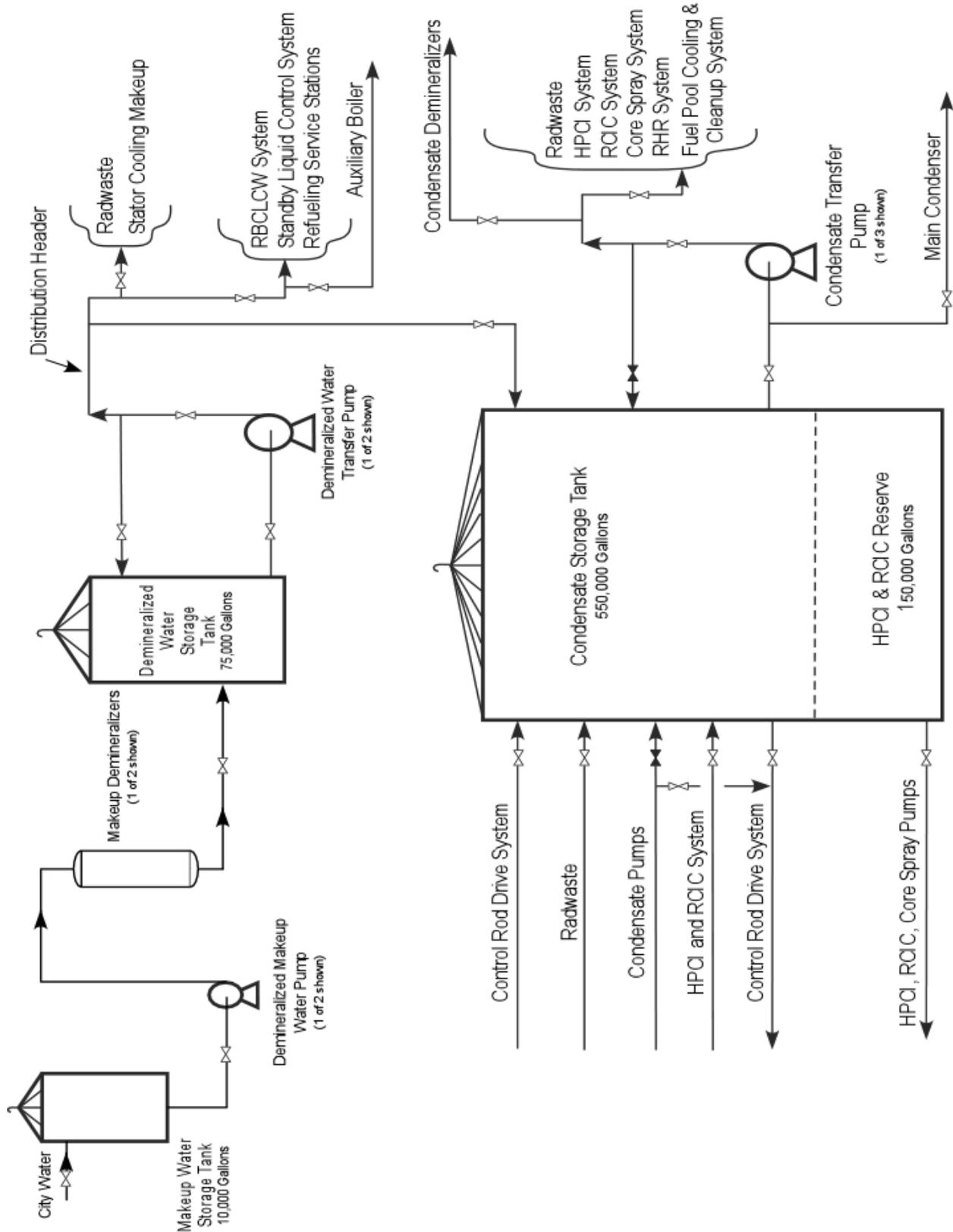


Figure 2.6-11 Condensate and Demineralized Makeup Water System

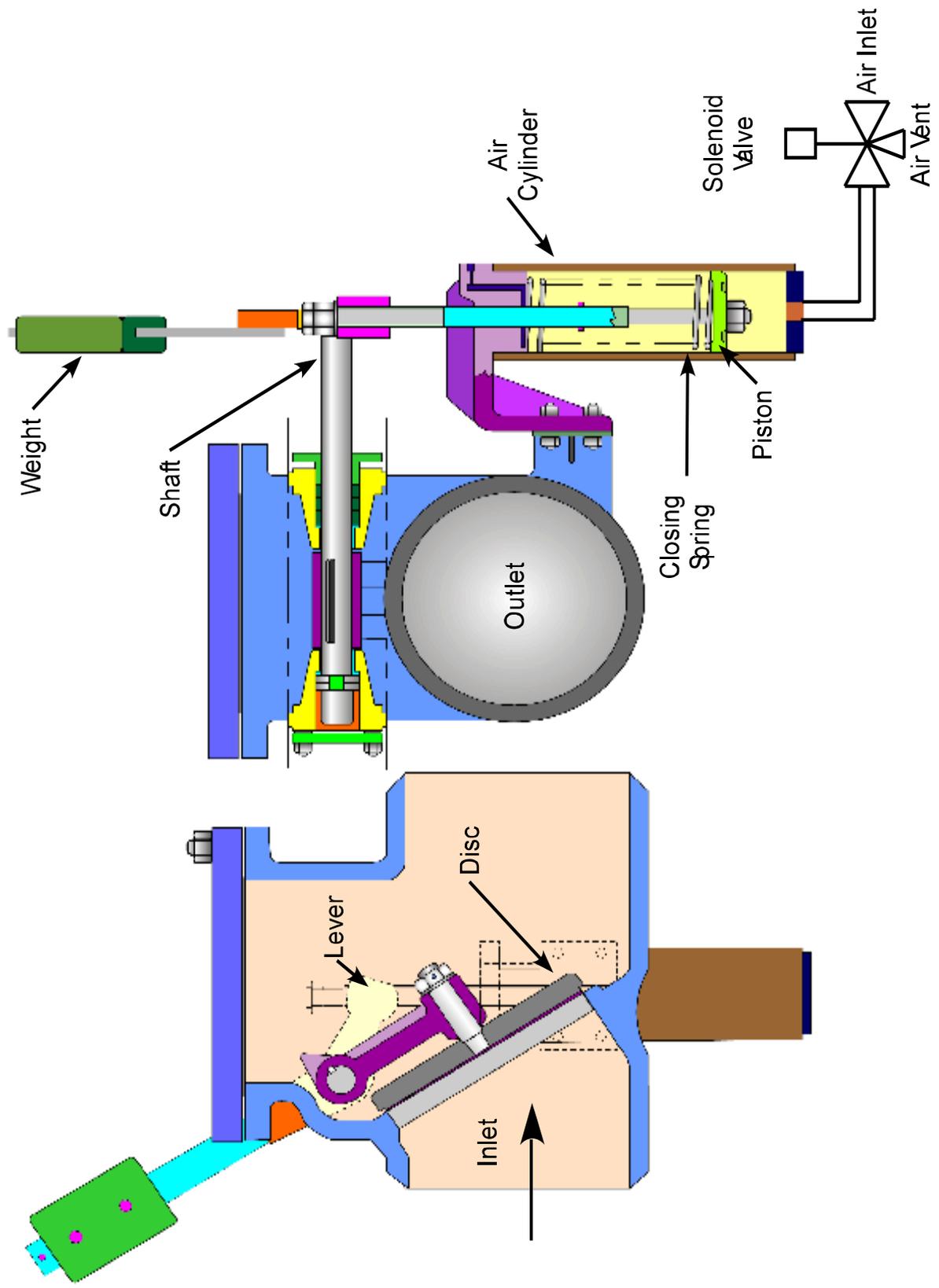


Figure 2.6-12 Non-Return Check Valve

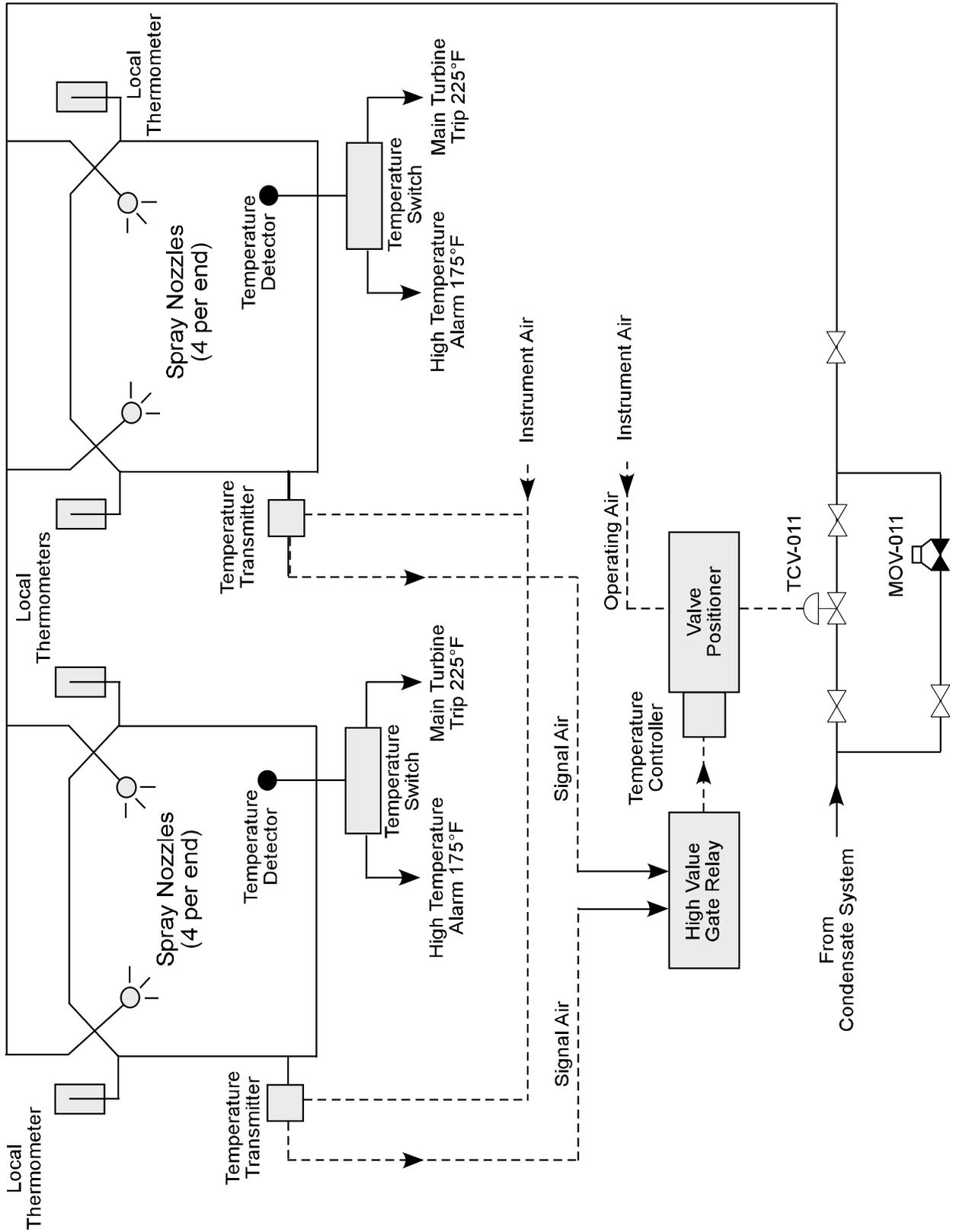


Figure 2.6-13 Exhaust Hood Spray

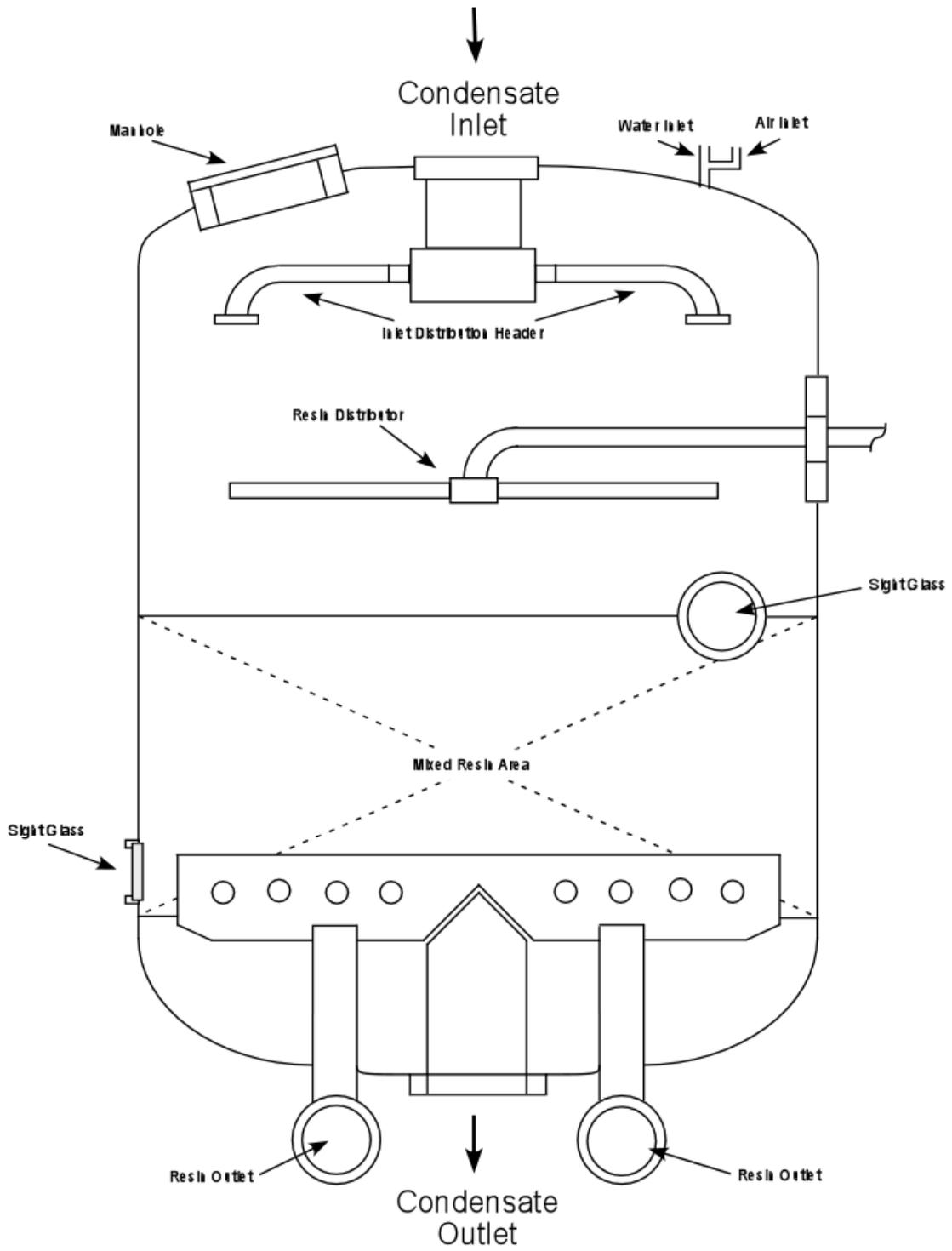


Figure 2.6-14 Condensate Demineralizer

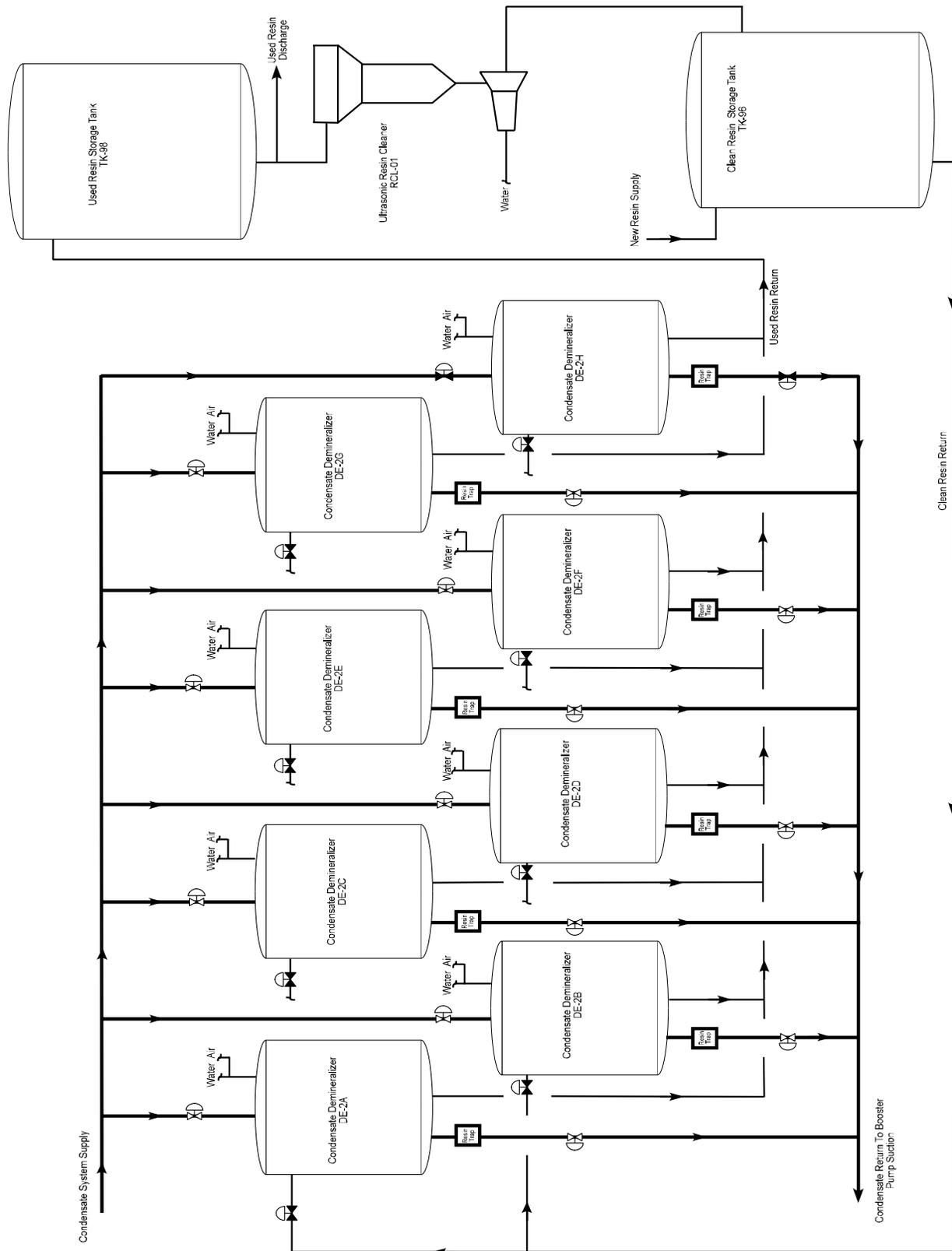


Figure 2.6-15 Condensate Demineralizer Process Flow