10.4 Other Features of Steam and Power Conversion System

This section provides discussions of each of the principal design features of the Steam and Power Conversion System.

10.4.1 Main Condenser

The main condenser is the steam cycle heat sink. During normal operation, it receives, condenses, deaerates and holds up for N-16 decay the main turbine exhaust steam, and turbine bypass steam whenever the turbine bypass system is operated. The main condenser is also a collection point for other steam cycle miscellaneous drains and vents.

The main condenser is utilized as a heat sink in the initial phase of reactor cooldown during a normal plant shutdown.

10.4.1.1 Design Bases

10.4.1.1.1 Safety Design Bases

The main condenser does not serve or support any safety function and has no safety design basis. It is, however, designed with necessary shielding and controlled access to protect plant personnel from radiation. In addition, the main condenser hotwell provides a hold-up volume for MSIV fission product leakage. The supports and anchors are designed to withstand a safe shutdown earthquake.

10.4.1.1.2 Power Generation Design Bases

Power Generation Design Basis One—The main condenser is designed to function as the steam cycle heat sink and miscellaneous drains and vents collection point.

Power Generation Design Basis Two—The main condenser is designed to accommodate at least 33% of the rated main steam flow, as it may be discharged directly to the condenser by the turbine bypass system, while maintaining the LP turbine exhaust conditions below the maximum allowable pressure and temperatures.

Power Generation Design Basis Three—The main condenser is designed to minimize air inleakage and provides for the separation of noncondensable gases from the condensing steam and their removal by the main condenser evacuation system (Subsection 10.4.2).

Power Generation Design Basis Four—During normal full load operation with nominal hotwell levels, the main condenser provides a four minute active condensate storage volume and has a two minute surge capacity. At minimum normal operating hotwell water level, and normal full load condensate flow rate, the condenser provides a two minute minimum condensate holdup time for N-16 decay.

Power Generation Design Basis Five—The main condenser provides for deaeration of the condensate, such that condensate dissolved oxygen content will not exceed 10 ppb during normal operation above 50% load.

Power Generation Design Basis Six—The condenser is designed in accordance with requirements of the Heat Exchange Institute "Standards for Steam Surface Condensers."

10.4.1.2 Description

10.4.1.2.1 General Description

The main condenser is a single pass, single pressure, three-shell, deaerating unit. Each shell is located beneath its respective low-pressure turbine.

The three condenser shells are cross-connected to equalize pressure. Each shell has at least two tube bundles. Circulating water flows in parallel through the three single-pass shells (Figure 10.4-3).

Each condenser shell hotwell is divided longitudinally by a vertical partition plate. The condensate pumps take suction from these hotwells (Figure 10.4-5).

The condenser shells are located in pits below the Turbine Building operating floor and are supported on the Turbine Building basemat. Failure of or leakage from a condenser hotwell during plant shutdown will only result in a minimum water level in the condenser pit. Expansion joints are provided between each turbine exhaust opening and the steam inlet connections of the condenser shell. Water seals are provided around the entire outside periphery of these expansion joints. Level indication provides detection of leakage through the expansion joint. The hotwells of the three shells are interconnected by steam-equalizing lines. Four low-pressure feedwater heaters are located in the steam dome of each shell. Piping is installed for hotwell level control and condensate sampling.

10.4.1.2.2 Component Description

Table 10.4-1 provides general condenser design data.

10.4.1.2.3 System Operation

During plant operation, steam expanding through the low-pressure turbine is directed downward into the condenser through the exhaust openings in the bottom of the turbine casings and is condensed. The condenser also serves as a heat sink for several other flows, such as cascading heater drains, and miscellaneous turbine cycle drains and vents.

Other flows occurring periodically or continuously originate from (1) the minimum recirculation flows of the reactor feed pumps, and condensate pumps, (2) feedwater line startup flushing, (3) turbine equipment clean drains, (4) low-point drains, (5) deaerating steam (6) makeup, etc.

During transient conditions, the condenser is designed to receive turbine bypass steam and feedwater heater and drain tank high-level dumps. These drain tanks include the moisture separator and reheater drain tanks. The condenser is also designed to receive relief valve discharges and any neccesary venting from moisture separator/reheater vessels, feedwater heater shells, the gland seal steam header, steam seal regulator, and various other steam supply lines. Spray pipes and baffles are designed to provide protection of the condenser tubes and components from high energy inputs to the condenser. At startup, steam is admitted to the condenser shell to assist in condensate deaeration. The condensate is pumped from the condenser hotwell by the condensate pumps described in Subsection 10.4.7.

Since the main condenser operates at a vacuum, any leakage is into the shell side of the main condenser. Provision is made for detection of circulating water leakage into the shell side of the main condenser. Water leakage is detected by measuring the conductivity of sample water extracted beneath the tube bundles. A leak will allow the circulating water to drain down the tube bundles and be collected for sampling. Sampling methods are described in Subsection 9.3.2. Radioactive leakage to the atmosphere cannot occur.

Air inleakage and noncondensable gases, including hydrogen and oxygen gases contained in the turbine exhaust steam due to dissociation of water in the reactor, are collected in the condenser from which they are removed by the main condenser evacuation system described in Subsection 10.4.2.

The condenser and water boxes are all welded carbon steel or low alloy ferritic steel. The tubes are stainless steel or titanium with compatible stainless steel or titanium carbon steel clad tube sheets depending on circulating water quality. The condenser is cooled by the circulating water system, as described in Subsection 10.4.5. Valves are provided in the circulating water system to permit any portion of the condenser to be isolated and removed from service.

In each condenser shell, the hotwell is divided by a system of baffles to ensure a normal retention of four minutes duration for all condensate from the time it enters the hotwell until it is removed by the condensate pumps. Condensate is retained in the main condenser for a minimum of two minutes to permit radioactive decay before the condensate enters the condensate system. Before leaving the condenser, the condensate is deaerated to reduce the level of dissolved oxygen to the required concentration.

Hotwell level controls provide automatic makeup or rejection of condensate to maintain a normal level in the condenser hotwells. On low hotwell water level, the makeup control valves open and admit condensate to the hotwell from the condensate storage tank. When the hotwell is brought to within normal operating range, the valves close. On high water level in the hotwell, the condensate reject control valve opens to divert condensate from the condensate pump discharge (downstream of the polishers and auxiliary condensers) to the condensate storage tank; rejection is stopped when the hotwell level falls to within normal operating range. The hotwell level signals and controller will be at least triply and dual redundant to assure the availability of the condensate pumps.

During the initial cooling period after plant shutdown, the main condenser removes residual heat from the reactor coolant system via the turbine bypass system. However, if the condenser is not available to receive steam via the turbine bypass system, the reactor coolant system can still be safely cooled down using only Nuclear Island systems.

10.4.1.3 Evaluation

During operation, radioactive steam, gases, and condensate are present in the shells of the main condenser. The anticipated inventory of radioactive contaminants during operation and shutdown is discussed in Sections 11.1 and 11.3.

Necessary shielding and controlled access for the main condenser are provided (Sections 12.1 and 12.3).

Hydrogen buildup during operation is not expected to occur due to provisions for continuous evacuation of the main condenser. During shutdown, significant hydrogen buildup in the main condenser will not occur, as the main condenser will then be isolated from potential sources of hydrogen.

Main condenser tubeside circulating water is treated to limit algae growth and prevent long-term corrosion of the tubes and other components. Corrosion of the outside of the condenser tubing is prevented by maintaining strict water quality using the condensate cleanup system described in Subsection 10.4.6. The construction materials used for the main condenser are selected such that the potential for corrosion by galvanic and other effects is minimized.

The potential flooding which would result from failure of the condenser is discussed in Section 3.4, which shows that failure of the condenser will not adversely affect any equipment required for safe shutdown of the reactor.

The loss of main condenser vacuum will cause a turbine trip and closure of the main steam isolation valves. The consequences of a turbine trip are discussed in Subsection 15.2.3. Should the turbine stop, control or bypass valves fail to close on loss of condenser vacuum, two rupture diaphragms on each turbine exhaust hood protect the condenser and turbine exhaust hoods against overpressure.

10.4.1.4 Tests and Inspections

Each condenser shell is to receive a field hydrostatic test before initial operation. This test will consist of filling the condenser shell with water and, at the resulting static head, inspecting all tube joints, accessible welds, and surfaces for visible leakage and/or excessive deflection. Each condenser water box is to receive a field hydrostatic test with all joints and external surfaces inspected for leakage.

10.4.1.5 Instrumentation Applications

10.4.1.5.1 Hotwell Water Level

The condenser hotwell water level is measured by at least three level transmitters. These transmitters provide signals to an indicator, annunciator trip units, the plant computer, and the hotwell level control system. Level is controlled by two sets of modulating control valves. Each set consists of a normal and an emergency valve.

One set of valves allows water to flow from the condensate storage tank to the condenser hotwell as the level drops below the setpoint. If the level increases above another setpoint, the second set of valves located on the discharge of the condensate pumps opens to allow condensate to be pumped back to the storage tank.

10.4.1.5.2 Pressure

Condenser pressure is measured by gauges, pressure switches, and electronic pressure transducers. These instruments provide signals to annunciators, trip units, the Turbine Control System, and the Steam Bypass and Pressure Control System. In addition, four independent and redundant safety-related pressure transmitters provide input signals to the Nuclear Steam Supply System.

As condenser pressure increases above normal levels, an annunciator is activated. A further increase in pressure results in a turbine trip. As pressure increases toward a complete loss of vacuum, the main steam isolation valves and the turbine bypass valves are closed to prevent overpressurization of the condenser shell.

The approximate setpoints for these functions are as follows:

(1) High condenser pressure turbine alarms at 0.081 MPa vacuum.

(2) High condenser pressure turbine trips at 0.074 MPa vacuum.

(3) Bypass valve closes at 0.041 MPa vacuum.

(4) Main steam isolation valve closes at 0.024 to 0.034 MPa vacuum.

In case of main condenser vacuum decreasing, the control room operator will reduce reactor power when required to avoid a turbine trip on high condenser pressure.

10.4.1.5.3 Temperature

Temperature is measured in each LP turbine exhaust hood by temperature controllers. The controllers modulate a control valve in the water spray line protecting the exhaust hoods from overheating.

Circulating water temperatures are monitored upstream and downstream of each condenser tube bundle and are fed to the plant computer and a main control room instrumentation for use during periodic condenser performance evaluations.

10.4.1.5.4 Leakage

Leakage of circulating water into the condenser shell is monitored by the online instrumentation and the process sampling system described in Subsection 9.3.2.

Conductivity of the condensate is continuously monitored at selected locations in the condenser. Conductivity and sodium are continuously monitored at the discharge of the condensate pumps. High condensate conductivity and sodium content, which indicate a condenser tube leak, are individually alarmed in the main control room.

10.4.2 Main Condenser Evacuation System

Noncondensable gases are removed from the power cycle by the Main Condenser Evacuation System (MCES). The MCES removes the hydrogen and oxygen produced by radiolysis of water in the reactor, and other power cycle noncondensable gases, and exhausts them to the offgas system during plant power operation, and to the Turbine Building compartment exhaust system at the beginning of each startup.

10.4.2.1 Design Bases

10.4.2.1.1 Safety Design Bases

The MCES does not serve or support any safety function and has no safety design bases.

10.4.2.1.2 Power Generation Design Bases

Power Generation Design Basis One—The MCES is designed to remove air and other power cycle non-condensable gases from the condenser during plant startup, cooldown, and power operation and exhaust them to the offgas system or Turbine Building compartment exhaust system.

Power Generation Design Basis Two — The MCES establishes and maintains a vacuum in the condenser during power operation by the use of steam jet air ejectors, and by the mechanical vacuum pump during early startup.

10.4.2.2 Description

The MCES (Figure10.4-1) consists of two 100%-capacity, double stage, steam jet air ejector (SJAE) units (complete with intercondensers) for power plant operation, and two 100% mechanical vacuum pumps for use during startup. The last stage of the SJAE is a noncondensing stage. One SJAE unit is normally in operation and the other is on standby.

During the initial phase of startup, when the desired rate of air and gas removal exceeds the capacity of the steam jet air ejectors, and nuclear steam pressure is not adequate to operate the SJAE units, the mechanical vacuum pumps establish a vacuum in the main condenser and other parts of the power cycle. The discharge from the vacuum pumps is then routed to the plant vent stack, since there is then little or no effluent radioactivity present. Radiation detectors in the Offgas collecting duct and plant vent alarm in the main control room if abnormal radioactivity is detected (Section 7.6). Radiation monitors are provided on the main steamlines which trip the vacuum pump if abnormal radioactivity is detected in the steam being supplied to the condenser.

The SJAEs are placed in service to remove the gases from the main condenser after a pressure of about 7 kPa absolute or less is established in the main condenser by the mechanical vacuum pumps and when sufficient nuclear steam pressure is available.

During normal power operations, the SJAEs are driven by the main steam.

10.4.2.3 Evaluation

The offgas from the main condenser is one source of radioactive gas in the station. Normally, it includes the activation gases nitrogen-16, oxygen-19, and nitrogen-13, plus the radioactive noble-gas parents of strontium-89, strontium-90, and cesium-137. An inventory of radioactive contaminants in the effluent from the SJAEs is evaluated in Section 11.3.

Steam supply to the second-stage ejector is maintained at a minimum specified flow to ensure adequate dilution of hydrogen and prevent the offgas from reaching the flammable limit of hydrogen. In addition, maximum power limits will be placed on operation of the mechanical vacuum pumps to ensure the flammable limit of hydrogen will not be reached.

The MCES has no safety-related function (Section 3.2) and, thus, failure of the system will not compromise any safety-related system or component and will not prevent safe reactor shutdown.

Should the system fail completely, a gradual reduction in condenser vacuum would result from the buildup of noncondensable gases. This reduction in vacuum would first cause a lowering of turbine cycle efficiency due to the increase in turbine exhaust pressure. If the MCES remained inoperable, condenser pressure would then reach the turbine trip setpoint and a turbine trip would result. The loss of condenser vacuum incident is discussed in Subsection 15.2.5.

10.4.2.4 Tests and Inspections

Testing and inspection of the system is performed prior to plant operation in accordance with applicable codes and standards.

Components of the system are continuously monitored during operation to ensure satisfactory performance. Periodic inservice tests and inspections of the evacuation system are performed in conjunction with the scheduled maintenance outages.

10.4.2.5 Instrumentation Applications

Local and remote indicating devices for such parameters as pressure, temperature, and flow indicators are provided as required for monitoring the system operation. Dilution steam flow and vacuum pump and SJAE suction valve status is monitored in the main control room.

10.4.2.5.1 Steam Jet Air Ejectors

Steam pressure and flow is continuously monitored and controlled in the ejector steam supply lines. Redundant pressure controllers sense steam pressure at the second-stage inlet and modulate the steam supply control valves upstream of the air ejectors. The steam flow transmitters provide inputs to logic devices. These logic devices provide for isolating the offgas flow from the air ejector unit on a two-out-of-three logic, should the steam flow drop below acceptable limits for offgas steam dilution.

10.4.2.5.2 Mechanical Vacuum Pump

Pressure is measured on the suction line of the mechanical vacuum pumps. The pumps start with the seal water flow signal within the preset range. Seal pump discharge pressure is locally monitored. Seal water cooler discharge temperature is measured by a temperature indicating transmitter or switch. On high temperature, the switch activates an annuciator in the main control room. The vacuum pumps exhaust stream is discharged to the Offgas collecting duct, which provides for radiation monitoring of the system effluents prior to their release to the monitored vent stack and the atmosphere.

The vacuum pumps are tripped and their discharge valves are closed upon receiving a main steam high-high radiation signal.

10.4.3 Turbine Gland Sealing System

The Turbine Gland Sealing System (TGSS) prevents the escape of radioactive steam from the turbine shaft/casing penetrations and valve stems and prevents air inleakage through subatmospheric turbine glands.

10.4.3.1 Design Bases

10.4.3.1.1 Safety Design Bases

The TGSS does not serve or support any safety function and has no safety design bases.

10.4.3.1.2 Power Generation Design Bases

Power Generation Design Basis One—The TGSS is designed to prevent atmospheric air leakage into the turbine casings and to prevent radioactive steam leakage out of the casings of the turbine-generator.

Power Generation Design Basis Two—The TGSS returns the condensed steam to the condenser and exhausts the noncondensable gases, via the Turbine Building compartment exhaust system, to the plant vent.

Power Generation Design Basis Three—The TGSS has enough capacity to handle steam and air flows resulting from twice the normal packing clearances.

10.4.3.2 Description

10.4.3.2.1 General Description

The turbine gland seal system is illustrated in Figure10.4-2. The turbine gland seal system consists of a gland steam evaporator, sealing steam pressure regulator, sealing steam header, a gland steam condenser, with two full-capacity exhauster blowers, and the associated piping, valves and instrumentation.

10.4.3.2.2 System Operation

The annular space through which the turbine shaft penetrates the casing is sealed by steam supplied to the shaft seals. Where the gland seals operate against positive pressure, the sealing steam acts as a buffer and flows either inwards for collection at an intermediate leakoff point or, outwards and into the vent annulus. Where the gland seals operate against vacuum, the sealing steam either is drawn into the casing or leaks outward to a vent annulus. At all gland seals, the vent annulus is maintained at a slight vacuum and also receives air in-leakage from the outside. From each vent annulus, the air-steam mixture is drawn to the gland steam condenser.

The turbine is equipped with seals for a separate steam seal system. Both high and low pressure packings are fed with steam from a non-radioactive source, separate from the turbine at all loads. Non-radioactive steam is produced by the steam seal evaporator and fed to the sealing steam header through the sealing steam pressure regulator.

The steam seal evaporator is a shell-and-tube-type heat exchanger. The source of heating steam for the evaporator is the turbine auxiliary steam header (main steam) during low load operation and turbine extraction during normal operation. Heating steam is passed through the tube bundle, which is immersed in condensate to be evaporated. During startup and low load operation, heating steam is supplied from the main steam lines ahead of the turbine main stop valves. Shellside pressure is controlled by modulating position of control valves in the main steam source. As turbine load is increased, the heating steam source is switched to a turbine extraction when the extraction pressure becomes sufficiently high. Relief valves protect the tubeside and shellside from overpressure. Steam that is condensed in the tube bundle flows into a drain tank. It is then routed to a feedwater heater or to the main condenser by the drain tank level control system.

Condensate in the steam seal evaporator is controlled by the shellside level control system. Level controls on the evaporator maintain a set level by controlling the position of the evaporator water feed valve and hence the rate of condensate flow into the evaporator, according to the demand for sealing steam.

The seal steam header pressure is regulated automatically by the sealing steam pressure regulator. Pressure is controlled at approximately 27.6 kPaG. Relief valves protect the sealing steam header from overpressure. During startup, the seal steam is supplied from the auxiliary boiler. When reactor pressure exceeds a prescribed value during plant startup and up to rated power operation, sealing steam is normally provided by the gland steam evaporator. At all loads, gland sealing can be achieved using auxiliary steam so that plant power operation can be maintained without appreciable radioactivity releases even if highly abnormal levels of radioactive contaminants are present in the process steam, due to unanticipated fuel failure in the reactor.

The outer portion of all glands of the turbine and main steam valves is connected to the gland steam condenser, which is maintained at a slight vacuum by the exhauster blower. During plant operation, the gland steam condenser and one of the two installed 100% capacity motor-driven blowers are in operation. The exhauster blower to the Turbine Building compartment exhaust system effluent stream is continuously monitored prior to being discharged. The gland steam condenser is cooled by main condensate flow.

10.4.3.3 Evaluation

The TGSS is designed to prevent leakage of radioactive steam from the main turbine shaft glands and the valve stems. The high-pressure turbine shaft seals must accommodate a range of turbine shell pressure from full vacuum to approximately 1.77 MPaA. The low-pressure turbine shaft seals operate against a vacuum at all times. The gland seal outer portion steam/air mixture is exhausted to the gland steam condenser via the seal vent annulus (i.e., end glands), which is maintained at a slight vacuum. The radioactive content of the sealing steam, if any, which eventually exhausts to the plant vent and the atmosphere (Section 11.3), makes a negligible contribution to overall plant radiation release. During normal power operation, clean steam from the gland seal evaporator is used. In addition, the auxiliary steam system is designed to provide a 100% backup to the normal gland seal process steam supply. A full capacity gland steam condenser is provided and equipped with two 100% capacity blowers.

Relief valves on the seal steam header prevent excessive seal steam pressure. The valves discharge to the condenser shell.

10.4.3.4 Tests and Inspections

Testing and inspection of the TGSS will be performed prior to plant operation. Components of the system are continuously monitored during operation to ensure that they are functioning satisfactorily. Periodic tests and inspections may be performed in conjunction with maintenance outages.

10.4.3.5 Instrumentation Application

10.4.3.5.1 Gland Steam Condenser Exhausters

10.4.3.5.1.1 Pressure

Gland steam condenser exhauster suction pressure is continuously monitored and reported to the main control room and plant computer. A low vacuum signal actuates a main control room annunciator.

10.4.3.5.1.2 Level

Water levels in the gland steam condenser drain leg are monitored and makeup is added as required to maintain loop seal integrity. Abnormal levels are annunciated in the main control room.

10.4.3.5.1.3 Effluent Monitoring

The TGSS effluents are first monitored by a system-dedicated continuous radiation monitor installed on the gland steam condenser exhauster blower discharge. High monitor readings are alarmed in the main control room. The system effluents are then discharged to the Turbine Building compartment exhaust system and the plant vent stack, where further effluent radiation monitoring is performed. (See Subsection 10.4.10.1 for COL license information pertaining to the radiological analysis of the TGSS effluents.)

10.4.3.5.2 Sealing Steam Header

Sealing steam header pressure is monitored and reported to the main control room and plant computer. Header steam temperature is also measured and recorded.

10.4.3.5.3 Steam Seal Evaporator

10.4.3.5.3.1 Pressure

The Plant Information and Control System continuously monitors steam seal evaporator tubeside and shellside pressures. Heating steam pressure is monitored to determine when it is high enough to switch over to the extraction source from the main steam source.

10.4.3.5.3.2 Level

Condensate level in the steam seal evaporator shell is continuously monitored as part of the function of controlling the rate of condensate flow for evaporation. High and low level alarms are provided in the main control room.

Condensate level in the tubeside drain tank is continuously monitored as part of the function of controlling the flow of condensed heating steam from the tubes. High and low level alarms are provided in the main control room.

10.4.4 Turbine Bypass System

The Turbine Bypass System (TBS) provides the capability to discharge main steam from the reactor directly to the condenser to minimize step load reduction transient effects on the Reactor Coolant System. The TBS is also used to discharge main steam during reactor hot standby and cooldown operations.

10.4.4.1 Design Bases

10.4.4.1.1 Safety Design Bases

The TBS does not serve or support any safety function and has no safety design bases. However, the TBS is analyzed to demonstrate structural integrity under safe shutdown earthquake (SSE) loading conditions.

10.4.4.1.2 Power Generation Design Bases

Power Generation Design Basis One—The TBS has the capacity to bypass at least 33% of the rated main steam flow to the main condenser.

Power Generation Design Basis Two—The TBS is designed to bypass steam to the main condenser during plant startup and to permit a normal manual cooldown of the Reactor Coolant System from a hot shutdown condition to a point consistent with initiation of Residual Heat Removal System operation.

Power Generation Design Basis Three—The TBS is designed, in conjunction with the reactor systems, to provide for a 33% electrical step-load reduction without reactor trip. The systems will also allow a turbine trip below 33% power without lifting the main steam safety valves.

10.4.4.2 Description

10.4.4.2.1 General Description

The TBS shown in Figure 10.3-1 (Main Steam System), consists of a three-valve chest that is connected to the main steamlines upstream of the turbine stop valves, and of three dump lines that separately connect each bypass valve outlet to one condenser shell. The system is designed to bypass at least 33% of the rated main steam flow directly to the condenser. The system and its components are shown in Figures 10.4-9 and 10.4-10.

The TBS, in combination with the reactor systems, provides the capability to shed 33% of the T-G rated load without reactor trip and without the operation of safety/relief valves. A load rejection in excess of 33% is expected to result in reactor trip with operation of steam safety valves at high power levels.

10.4.4.2.2 Component Description

One valve chest is provided and houses three individual bypass valves. Each bypass valve is an angle body type valve operated by hydraulic fluid pressure with spring action to close. The valve chest assembly includes hydraulic supply and drain piping, three hydraulic accumulators (one for each bypass valve), servo valves, fast acting solenoid valves, and valve position transmitters.

The turbine bypass valves are operated by the turbine hydraulic fluid power unit or they may be provided with a separate hydraulic fluid power unit. The unit includes high-pressure fluid pumps, filters, and heat exchangers. High-pressure hydraulic fluid is provided at the bottom valve actuator and drained back to the fluid reservoir. Sparger piping distributes the steam within the condenser.

10.4.4.2.3 System Operation

The turbine bypass valves are opened by redundant signals received from the Steam Bypass and Pressure Control System whenever the actual steam pressure exceeds the preset steam pressure by a small margin. This occurs when the amount of steam generated by the reactor cannot be entirely used by the turbine. This bypass demand signal causes fluid pressure to be applied to the operating cylinder, which opens the first of the individual valves. As the bypass demand increases, additional bypass valves are opened, dumping the steam to the condenser. The bypass valves are equipped with fast acting servo valves to allow rapid opening of bypass valves upon turbine trip or generator load rejection.

The bypass valves automatically trip closed whenever the vacuum in the main condenser falls below a preset value. The bypass valves are also closed on loss of electrical power or hydraulic system pressure. The bypass valve hydraulic accumulators have the capability to stroke the valves at least three times should the hydraulic power unit fail.

When the reactor is operating in the plant automation mode, load changes are coordinated by the Automatic Power Regulator (Subsection 7.7.1.7). These load changes are accomplished by change in reactor recirculation flow and/or rod control motion, without opening of the turbine bypass valves.

When the plant is at zero power, hot standby or initial cooldown, the system is operated manually by the control room operator or by the plant automation system. The measured reactor pressure is then compared against, and regulated to, the pressure set by the operator or automation system.

The turbine bypass control system can malfunction in either the open or closed mode. The effects of these potential failure modes on the NSSS and turbine system are addressed in Chapter 15. If the bypass valves fail open, additional heat load is placed on the condenser. If this load is great enough, the turbine is tripped on high-high condenser pressure. Ultimate overpressure protection for the condenser is provided by rupture discs. If the bypass valves fail closed, the relief valves permit controlled cooldown of the reactor.

The turbine bypass system valves and piping conform to the applicable codes as referenced in Chapter 3.

10.4.4.3 Evaluation

The TBS does not serve or support any safety function and has no safety design bases. There is no safety-related equipment in the vicinity of the TBS. All high energy lines of the TBS are located in the Turbine Building.

The effects of a malfunction of the turbine bypass system valves and the effects of such a failure on other systems and components are evaluated in Chapter 15.

10.4.4.4 Inspection and Testing Requirements

Before the TBS is placed in service, all turbine bypass valves are tested for operability. The steamlines are hydrostatically tested to confirm leaktightness. Pipe weld joints are inspected by radiography per ASME III, Class 2 requirements upstream and ANSI B31.1 downstream of the valve chest. The bypass valves may be tested while the unit is in operation. Periodic inspections are performed on a rotating basis within a preventive maintenance program in accordance with manufacturer’s recommendations.

10.4.4.5 Instrumentation Applications

Main steam pressure is redundantly measured in the reactor dome by six electronic pressure transmitters. Under normal conditions, a validated narrow range pressure signal will be used by the Steam Bypass and Pressure Control System (SB&PC). If one of the signals fails, an annunciator will be activated but the bypass control and/or reactor pressure regulation will be unaffected.

Input to the system also includes turbine steam flow demand and load reference signals from the turbine speed load control system. The SB&PC System uses these signals to position the turbine control valves and the bypass valves. A complete description of the control system is included in Chapter 7.

10.4.5 Circulating Water System

The Circulating Water System (CWS) provides cooling water for removal of the power cycle waste heat from the main condensers and transfers this heat to the power cycle heat sink.

10.4.5.1 Design Bases

10.4.5.1.1 Safety Design Bases

The CWS does not serve or support any safety function and has no safety design bases.

10.4.5.1.2 Power Generation Design Bases

Power Generation Design Basis One—The CWS supplies cooling water at a sufficient flow rate to condense the steam in the condenser, as required for optimum heat cycle efficiency.

Power Generation Design Basis Two—The CWS is automatically isolated by coincident logic in the event of gross leakage into the condenser pit to prevent flooding of the Turbine Building.

10.4.5.2 Description

10.4.5.2.1 General Description

The Circulating Water System (Figure 10.4-3) consists of the following components: (1) intake structure and intake screens, pumps, (2) condenser water boxes and piping and valves, (3) tube side of the main condenser, (4) water box fill and drain subsystem, and (5) related support facilities such as for system water treatment, inventory blowdown and general maintenance.

The power cycle heat sink is designed to maintain the temperature of the water entering the CWS within the range of 4.45°C to 37.78°C. The CWS is designed to deliver water to the main condenser within a temperature range of 4.45°C to 37.78°C. The 4.45°C minimum temperature is maintained, when needed, by warm water recirculation.

The cooling water is circulated by four 25% capacity induction motor-driven pumps.

The pumps are arranged in parallel and discharge into a common header. The discharge of each pump is fitted with a butterfly valve. This arrangement permits isolation and maintenance of any one pump while the others remain in operation.

The CWS and condenser are designed to permit isolation of each set of single pass tube bundles to permit repair of leaks and cleaning of water boxes while operating at reduced power.

The CWS includes water box vents to help fill the condenser water boxes during startup and removes accumulated air and other gases from the water boxes during normal operation.

A chemical additive subsystem is also provided to prevent the accumulation of biological growth and chemical deposits within the wetted surfaces of the system.

10.4.5.2.2 Component Description

Codes and standards applicable to the CWS are listed in Section 3.2. The system is designed and constructed in accordance with quality group D specifications. Table 10.4-3 provides design parameters for the major components of the Circulating Water System.

10.4.5.2.3 System Operation

The CWS operates continuously during power generation, including startup and shutdown. Pumps and condenser isolation valve actuation is controlled by locally mounted hand switches or by remote manual switches located in the main control room.

The circulating water pumps are tripped, the pump and condenser isolation valves are closed, and the siphon break valves are opened in the event of a system isolation signal from the condenser pit high-high level switches. These condenser pit high-high level switches are two-out-of-four logic. A condenser pit high level alarm is provided in the control room. The pit water level trip is set high enough to prevent inadvertent plant trips from unrelated failures, such as a sump overflow.

Draining of any set of condenser water boxes is initiated by closing the associated condenser isolation valves and opening the drain connection and water box vent valve. When the suction standpipe of the condenser drain pump is filled, the pump is manually started. A low level switch is provided in the standpipe, on the suction side of the drain pump. This switch will automatically stop the pump in the event of low water level in the standpipe to protect the pump from excessive cavitation.

Before pump startup, the Turbine Service Water pumps provide for filling of the CWS. The condenser water box vent system assists with removing air from the system.

10.4.5.3 Evaluation

The CWS is not a safety-related system; however, a flooding analysis of the Turbine Building is performed on the CWS, postulating a complete rupture of a single expansion joint. The analysis assumes that the flow into the condenser pit comes from both the upstream and downstream side of the break and, for conservatism, it assumes that one system isolation valve does not fully close.

Based on the above conservative assumptions, the CWS and related facilities are designed such that the selected combination of plant physical arrangement and system protective features ensures that all credible potential circulating water spills inside the Turbine Building remain confined inside the Turbine Building. Further, plant safety is ensured in case of multiple CWS failures or other negligible probability CWS related events by plant safety-related general flooding protection provisions (Section 3.4).

10.4.5.4 Tests and Inspections

The CWS and related systems and facilities are tested and checked for leakage integrity prior to initial plant startup and, as may be appropriate, following major maintenance and inspection.

All active and selected passive components of the Circulating Water System are accessible for inspection and maintenance/testing during normal power station operation.

10.4.5.5 Instrumentation Applications

Temperature monitors are provided upstream and downstream of each condenser shell section.

Indication is provided in the control room to identify open and closed positions of motor-operated butterfly valves in the CWS piping.

All major CWS valves which control the flow path can be operated by local controls or by remote manual switches located on the main control board. The pump discharge isolation valves are interlocked with the circulating water pumps so that when a pump is started, its discharge valve will be opening while the pump is coming up to speed, thus assuring that there is water flow through the pump. When the pump is stopped, the discharge valve closes automatically to prevent or minimize backward rotation of the pump and motor.

To exclude air in the condenser water boxes during normal operation, water box vent valves are automatically opened by the water level high signal. Manual controls for the vent valves are also provided.

A circulating pump starts at approximately 25% of rated flow when the main condenser water box outlet valves are partially opened for water filling. Level switches or transmitters monitor water level in the condenser discharge water boxes and provide confirmation of water fill in the circulating water system during the operation of the circulating water pumps. These level switches ensure that the supply piping and the condenser water boxes are full of water prior to the circulating water pump achieving rated flow, thus preventing water pressure surges from damaging the supply piping or the condenser.

To satisfy the bearing lubricating water and shaft sealing water interlocks during startup, the circulating water pump bearing lubricating and shaft seal flow switches, located in the lubricating seal water supply lines, must sense a minimum flow to provide pump start permissive.

Monitoring the performance of the Circulating Water System is accomplished by differential pressure transducers across the condenser with remote differential pressure indicators located in the main control room. Temperature signals from the supply and discharge sides of the condenser are transmitted to the Plant Information and Control System for recording, display and condenser performance calculations.

To prevent icing and freeze-up when the ambient temperature of the power cycle heat sink falls below 0°C, warm water from the discharge side of the condenser is recirculated back to the intake structure. Temperature elements, located in each condenser supply line and monitored in the main control room, are utilized in throttling the warm water recirculation valve, which maintains the minimum inlet temperature of approximately 4.45°C.

10.4.5.6 Flood Protection

A circulating water system pipe, waterbox, or expansion joint failure, if not detected and isolated, would cause internal Turbine Building flooding up to slightly over grade level, with excess flood waters potentially spilling over on site. If a failure occurred within the condensate system (condenser shell side), the resulting flood level would be less than grade level due to the relatively small hotwell water inventory relative to the condenser pit capacity. In either event, the flooding of the Turbine Building would not affect the limited safety-related equipment in that building, since such equipment located inside the Turbine Building and all plant safety-related facilities are protected against site surface water intrusion.

10.4.5.7 Portions of the CWS Outside of Scope of ABWR Standard Plant

The portion outside the ABWR Standard Plant includes:

> intake structure and intake screens; pumps and pump discharge valves; and related support facilities such as makeup water, system water treatment, inventory blowdown, and general maintenance.

10.4.5.7.1 Safety Design Basis (Interface Requirements)

None

10.4.5.7.2 Power Generation Design Basis (Interface Requirements)

The COL applicant shall provide the following system design features and additional information which are site dependent;

(1) Compatible design as described in Subsection 10.4.5.2.

(2) Evaluation per Subsection 10.4.5.2.

(3) Tests and Inspections per Subsection 10.4.5.4.

(4) Instrument applications per Subsection 10.4.5.5.

(5) Flood protection per Subsection 10.4.5.6.

10.4.5.8 Power Cycle Heat Sink (Conceptual Design)

The power Cycle Heat Sink is outside the ABWR Standard Plant scope.

The conceptual design for the ABWR Power Cycle Heat Sink utilizes a cooling reservoir. Water circulation, water makeup, chemical control, and inventory blowdown are all part of the Circulating Water System.

10.4.5.8.1 Safety Design Basis (Interface Requirements)

None

10.4.5.8.2 Power Generation Design Basis (Interface Requirements)

The COL applicant shall provide the following system design features and additional information which are site dependent:

(1) Compatible design as described in Subsection 10.4.5.2.

(2) Evaluation per Subsection 10.4.5.3.

(3) Tests and inspections per Subsection 10.4.5.4.

(4) Instrument applications per Subsection 10.4.5.5.

(5) Flood protection per Subsection 10.4.5.6.

(6) The power cycle heat sink must provide for cooling of Turbine Service Water System while the plant is operating on the Combustion Turbine Generator in the absence of offsite power.

10.4.6 Condensate Purification System

The Condensate Purification System (CPS) purifies and treats the condensate as required to maintain reactor feedwater purity, using filtration to remove suspended solids, including corrosion products, ion exchange to remove dissolved solids from condenser leakage and other impurities, and water treatment additions to minimize corrosion/erosion product releases in the power cycle.

10.4.6.1 Design Bases

10.4.6.1.1 Safety Design Bases

The CPS does not serve or support any safety function and has no safety design bases.

10.4.6.1.2 Power Generation Design Bases

Power Generation Design Basis One—The CPS continuously removes dissolved and suspended solids from the condensate to maintain reactor feedwater quality.

Power Generation Design Basis Two—The CPS removes corrosion products from the condensate and from drains returned to the condenser hotwell so as to limit any accumulation of corrosion products in the cycle.

Power Generation Design Basis Three—The CPS removes impurities entering the power cycle due to condenser circulating water leaks as required to permit continued power operation within specified water quality limits as long as such condenser leaks are too small to be readily located and repaired.

Power Generation Design Basis Four—The CPS limits the entry of dissolved solids into the feedwater system in the event of large condenser leaks, such as a tube break, to permit a reasonable amount of time for orderly plant shutdown.

Power Generation Design Basis Five—The CPS injects in the condensate such water treatment additives as oxygen and hydrogen as required to minimize corrosion/erosion product releases in the power cycle.

Power Generation Design Basis Six—The CPS maintains the condensate storage tank water quality as required for condensate makeup and miscellaneous condensate supply services.

Power Generation Design Basis Seven—The CPS flow controllers and sequences will be at least dual redundant and the vessel flow signals and bypass arranged such that the condensate system flow will be uninterrupted even in the presence of a single failure.

10.4.6.2 System Description

10.4.6.2.1 General Description

The Condensate Purification System (Figure 10.4-4) consists of at least three high efficiency filters arranged in parallel and operated in conjunction with a normally closed filter bypass. The CPS also includes at least six bead resin, mixed bed ion exchange demineralizer vessels arranged in parallel with, normally at least five in operation and one in standby. A strainer is installed downstream of each demineralizer vessel to preclude gross resin leakage into the power cycle in case of vessel underdrain failure, and to catch resin fine leakage as much as possible. The design basis for the CPS system will be to achieve the water quality effluent conditions defined in the water quality specification. The CPS components are located in the Turbine Building.

Provisions are included to permit air scrub cleaning and replacement of the ion exchange resin. Each of the demineralizer vessels has fail-open inlet and outlet isolation valves which are remotely controlled from the local CPS control panel.

A demineralizer system bypass valve is also provided which is manually or automatically controlled from the main control room. Pressure downstream of the demineralizer or high demineralizer differential pressure is indicated and is alarmed in the main control room to alert the operator. The bypass is used only in emergency and for short periods of time until the CPS flow is returned to normal or the plant is brought to an orderly shutdown. To prevent unpolished condensate from leaking through the bypass, double isolation valves are provided with an orificed leak-off back to the condenser and, if an automatic bypass is used, the control scheme will be redundant.

10.4.6.2.2 Component Description

Codes and standards applicable to the CPS are listed in Section 3.2. The system is designed and constructed in accordance with quality group D requirements. Design data for major components of the CPS are listed in Table 10.4-4.

Condensate Filter—The CPS includes at least three backwashable high efficiency filters.

Condensate Demineralizers—There are at least six demineralizer vessels (one on standby) each constructed of carbon steel and lined with stainless steel. Normal operation full load steady-state design flowrate is 2.52L/s of bed. Maximum flowrates are 3.15 and 3.79L/s for steady state and transient operation, respectively. The nominal bed depth is 102 cm.

10.4.6.2.3 System Operation

The CPS is continuously operated to maintain feedwater purity levels.

Full condensate flow is passed through at least three filters and at least five of the six demineralizers, which are piped in parallel. The last demineralizer is on standby or is in the process of being cleaned, emptied or refilled. The service run of each demineralizer is terminated by either high differential pressure across the vessel or high effluent conductivity or sodium content. Alarms for each of these parameters are provided on the local control panel and the main control room.

The service run for each filter is terminated by high differential pressure across the filter. Alarms are provided on the local control panel.

The local control panel is equipped with the appropriate instruments and controls to allow the operators to perform the following operations:

(1) Remove a saturated filter from service, temporarily allowing some condensate filter bypass. Clean up the isolated filter by backwashing and place it back in operation.

(2) Remove an exhausted demineralizer from service and replace it with a standby unit.

(3) Transfer the resin inventory of the isolated demineralizer vessel into the resin receiver tank for mechanical cleaning or disposal.

(4) After cleaning, transfer the received resin bed from the receiver tank to the storage tank. Alternately, load the storage tank with fresh new resin.

(5) Transfer the resin storage tank resins to any isolated demineralizer vessel.

(6) Transfer exhausted resin from the receiver tank to the radwaste system.

On termination of a demineralizer service run, the exhausted vessel is taken out of service and isolated, and the standby unit is placed in service by remote manual operation from the local control panel. The resin from the exhausted vessel is transferred to the resin receiver tank and replaced by a clean resin bed that is transferred from the resin storage tank. A final rinse of the new bed is performed in the isolated vessel by condensate recycle before it is placed on standby or returned to service. The rinse is monitored by conductivity analyzers, and the process is terminated when the required minimum rinse has been completed and normal clean bed conductivity is obtained.

A filter with high differential pressure is removed from service and the filter system bypass valve is opened to maintain condensate flow. The filter is backwashed, refilled and returned to service. The filter system bypass valve is then closed.

Through normal condensate makeup and reject, the condensate storage tank water inventory is processed through the CPS, and tank water quality is maintained as required for condensate makeup to the cycle and miscellaneous condensate supply services.

The condensate purification and related support system wastes are processed by the radwaste system, as described in Chapter 11.

10.4.6.3 Evaluation

The CPS does not serve or support any safety function and has no safety design bases.

The Condensate Purification System removes condensate system corrosion products, and impurities from condenser leakage in addition to some radioactive material, activated corrosion products and fission products that are carried-over from the reactor. While these radioactive sources do not affect the capacity of the resin, the concentration of such radioactive material requires shielding (Chapter 12). Wastes from the condensate cleanup system are collected in controlled areas and sent to the radwaste system for treatment and/or disposal. Chapter 11 describes the activity level and removal of radioactive material from the condensate system.

The Condensate Purification System complies with Regulatory Guide 1.56.

The Condensate Purification System and related support facilities are located in non-safety-related buildings. As a result, potential equipment or piping failures cannot affect plant safety.

10.4.6.4 Tests and Inspections

Preoperational tests are performed on the Condensate Purification System to ensure operability, reliability, and integrity of the system. Each filter vessel, polisher vessel and system support equipment can be isolated during normal plant operation to permit testing and maintenance.

10.4.6.5 Instrumentation Applications

Conductivity elements are provided for the system influent and for each demineralizer vessel effluent and monitored in the main control room. System influent conductivity detects condenser leakage; whereas, demineralizer effluent conductivities provide indication of resin exhaustion. The demineralizer effluent conductivity elements also monitor the quality of the condensate that is recycled through a standby vessel before it is returned to service. Differential pressure is monitored across each filter demineralizer vessel and each vessel discharge resin strainer to detect blockage of flow. The flow through each demineralizer is monitored and used as control input to assure even distribution of condensate flow through all operating vessels and by correlation with the vessel pressure drop, to permit evaluation of the vessel throughput capacity. Individual demineralizer vessel effluent conductivity, differential pressure, and flow measurements are recorded at the system local control panel. Individual filter vessel pressure drop and flow data are provided at the system local control panel. A multipoint annunciator is included in the local panel to alarm abnormal conditions within the system. The local panel is connected to the main control room where local alarms are annunciated by a global system alarm but can also be displayed individually if requested by the operators.

Other system instrumentation includes other water quality measurements as necessary for proper operation of the filters, demineralizer, and miscellaneous support services, and programmable controllers for automatic supervision of the resin transfer and cleaning cycles. The control system prevents the initiation of any operation or sequence of operations which would conflict with any operation or sequence already in progress whether such operation is under automatic or manual control.

10.4.7 Condensate and Feedwater System

The function of the Condensate and Feedwater System (CFS) is to receive condensate from the condenser hotwells, supply condensate to the cleanup system, and deliver high purity feedwater to the reactor, at the required flow rate, pressure and temperature.

10.4.7.1 Design Bases

10.4.7.1.1 Safety Design Bases

The condensate-feedwater system does not serve or support any safety function and has no safety design bases.

10.4.7.1.2 Power Generation Design Bases

Power Generation Design Basis One—The CFS is designed to provide a continuous and dependable feedwater supply to the reactor at the required flow rate, pressure, and temperature under all anticipated steady-state and transient conditions.

Power Generation Design Basis Two—The CFS is designed to supply up to 115% of the rated feedwater flow demand during steady-state power operation and for at least 10 seconds after generator step load reduction or turbine trip, and up to 75% of the rated flow demand thereafter.

Power Generation Design Basis Three—The CFS is designed to permit continuous long-term full power plant operation with the following equipment out of service: one feedwater pump, one condensate pump or one heater drain pump, or one high pressure heater string with a slightly reduced final feedwater temperature.

Power Generation Design Basis Four—The CFS is designed to permit continuous long-term operation with one LP heater string out of service at the maximum load permitted by the turbine manufacturer (approximately 85%). This value is set by steam flow limitation on the affected LP turbine.

Power Generation Design Basis Five—The CFS is designed to heat up the reactor feedwater to 215.55°C during full load operation and to lower temperatures during part load operation.

Power Generation Design Basis Six—The CFS is designed to minimize the ingress or release of impurities to the reactor feedwater.

Power Generation Design Basis Seven—All CFS functions needed to support power operation will use at least dual redundant controllers and triply redundant signals; a single control system failure will not cause an inadvertent pump trip or valve operation.

10.4.7.2 Description

10.4.7.2.1 General Description

The Condensate and Feedwater System (Figures 10.4-5 and 10.4-6) consists of the piping, valves, pumps, heat exchangers, controls and instrumentation, and the associated equipment and subsystems which supply the reactor with heated feedwater in a closed steam cycle utilizing regenerative feedwater heating. The system described in this subsection extends from the main condenser outlet to (but not including) the seismic interface restraint outside of containment. The remainder of the system, extending from the restraint to the reactor, is described in Chapter 5. Turbine cycle steam is utilized for a total of six stages of closed feedwater heating. The drains from each stage of the low-pressure feedwater heaters are cascaded through successively lower pressure feedwater heaters except the lowest and second lowest pressure feedwater heaters which drain to the low pressure heater drain tanks for each string. The drains from each low pressure heater drain tank flow into the external drain coolers of each lowest pressure feedwater heater and finally to the main condenser. The high-pressure heater drains are pumped backward to the reactor feedwater pumps suction. The cycle extraction steam, drains and vents systems are illustrated in Figures 10.4-7 and 10.4-8.

The CFS consists of four 33% capacity condensate pumps (three normally operating and one on automatic standby), four 33% capacity condensate booster pumps (three normally operating and one on automatic standby), four 33% capacity reactor feedwater pumps (three normally operating and one on automatic standby), four stages of low-pressure feedwater heaters, and two stages of high-pressure feedwater heaters, piping, valves, and instrumentation. The condensate pumps take suction from the condenser hotwell and discharge the deaerated condensate into one common header which feeds the condensate filter/demineralizers. Downstream of the condensate demineralizers, the condensate is taken by a single header and flows through the auxiliary condenser/coolers (one gland steam exhauster condenser and two sets of SJAE condensers). The condensate then branches into three parallel strings of low pressure feedwater heaters. Each string contains four stages of low-pressure feedwater heaters. The strings join together at a common header which is routed to the suction of the reactor feedwater pumps.

Another input to the feedwater flow consists of the drains which are pumped backward and injected into the feedwater stream at a point between the fourth stage low-pressure feedwater heaters and the suction side of the reactor feed pumps. These drains, which originate from the crossaround steam moisture separators and from the two sets of high-pressure feedwater heaters, are directed to the heater drain tank. The high pressure heater drains are deaerated in the heater drain tank so that, after mixing with condensate, the drains are compatible with the reactor feedwater quality requirements for oxygen content during normal power operations. The heater drain pump takes suction from the heater drain tank and injects the deaerated drains into the feedwater stream at the suction side of the reactor feed pumps.

The reactor feedwater pumps discharge the feedwater into two parallel high-pressure feedwater heater strings, each with two stages of high-pressure feedwater heaters. Downstream of the high-pressure feedwater heaters, the two strings are then joined into a common header, which divides into two feedwater lines that connect to the reactor.

A bypass is provided around the reactor feedwater pumps to permit supplying feedwater to the reactor during early startup without operating the feedwater pumps, using only the condensate pump and/or condensate booster pump head.

Another bypass is provided around the high-pressure heaters to maintain full feedwater flow capability when a high-pressure heater string must be isolated for maintenance.

During startup, the flow control valve is used to regulate the flow of feedwater supplied by either the condensate pumps or the reactor feed pumps operating at their minimum fixed speed.

During power operation, the condensate is well deaerated in the condenser and continuous oxygen injection is used to maintain the level of oxygen content in the final feedwater as shown on Figure 10.4-5.

To minimize corrosion product input to the reactor during startup, recirculation lines to the condenser are provided from the condensate booster pump suction and discharge headers and from the high-pressure feedwater heater outlet header.

Prior to plant startup, cleanup is accomplished by allowing the system to recirculate through the condensate polishers for treatment prior to feeding any water to the reactor during startup.

10.4.7.2.2 Component Description

All components of the condensate and feedwater system that contain the system pressure are designed and constructed in accordance with applicable codes as referenced in Section 3.2.

Condensate Pumps—The four condensate pumps are identical, fixed speed motor-driven pumps, three are normally operated, and the fourth is on automatic standby. Valving is provided to allow individual pumps to be removed from service.

A minimum flow recirculation line is provided downstream of the auxiliary condensers for condensate pump protection and for auxiliary condenser minimum flow requirements.

Condensate Booster Pumps—Four identical and independent, 33% capacity, fixed speed motor-driven condensate booster pumps are provided between the condensate purification system and the low pressure feedwater heaters. Three pumps normally operate manually in parallel, with the fourth pump in standby. The condensate booster pumps, in combination with the main condensate pumps, provide the required NPSH for the main feedwater pumps and achieve the design pressure for the condensate purification system.

Low-pressure Feedwater Heaters—Three parallel and independent strings of four closed feedwater heaters are provided, and one string is installed in each condenser neck. The heaters have integral drain coolers except for the lowest pressure heaters which have separate drain coolers, and their drains are cascaded to the next lower stage heaters of the same string except for the lowest and second lowest pressure heaters which drain to the low pressure drain tanks, drain coolers of the lowest pressure heaters and finally to the main condensers, successively. The heater shells are either carbon steel or low alloy ferritic steel, and the tubes are stainless steel. Each low pressure feedwater heater string has an upstream and downstream isolation valve which closes on detection of high level in any one of the low pressure heaters in the string.

High-pressure Feedwater Heaters—Two parallel and independent strings of two high-pressure feedwater heaters are located in the high-pressure end of the Turbine Building. The No. 6 heaters, which have integral drain coolers, are drained to the No. 5 heaters. The No. 5 heaters, which are condensing only, drain to the heater drain tank. The heater shells are carbon steel, and the tubes are stainless steel.

Heater string isolation and bypass valves are provided to allow each string of high-pressure heaters to be removed from service, thus slightly reducing final feedwater temperature but requiring no reduction in reactor power. The heater string isolation and bypass valves are actuated on detection of high level in either of the two high-pressure heaters in the string.

The startup and operating vent from the steam side of each feedwater heater is piped to the main condenser. Discharges from shell relief valves for the feedwater heaters are piped to the main condenser.

High Pressure Heater Drain Tank—A high pressure heater drain tank is provided. Drain tank level is maintained by the heater drain pump control valves in the drain pump discharge and recirculation lines.

The heater drain tank is provided with an alternate drain line to the main condenser for automatic dumping upon detection of high level. The alternate drain line is also used during startup and shutdown when it is desirable to dump the drains for feedwater quality purposes.

The drain tank and tank drain lines are designed to maintain the drain pumps net positive suction head (NPSH) in excess of the pump required minimum under all anticipated operating conditions including, particularly, load reduction transients. This is achieved mainly by providing a large elevation difference between tanks and pumps (approximately 14m) and optimizing the drain lines which would affect the drain system transient response, particularly the drain pump suction line.

Low Pressure Heater Drain Tanks—Three low pressure drain tanks are provided which receive the drains from the No.1 and No. 2 feedwater heaters of each string, and drain to separate drain coolers of each lowest pressure heater. The drain tanks are installed at lower level than the No.1 and No.2 heaters to provide gravity-assisted drains.

Heater Drain Pumps—Four 33% motor-driven heater drain pumps are provided. Three pumps normally operate in parallel, each taking suction from the heater drain tank and discharging into the suction side of the reactor feedwater pumps.

Controlled drain recirculation is provided from the discharge side of the heater drain pump to the associated heater drain tank. This ensures that the minimum safe flow through each heater drain pump is maintained during operation.

Reactor Feedwater Pumps—Four identical and independent 33% capacity reactor feedwater pumps (RFP) are provided. Three pumps normally operate in parallel and discharge to the high-pressure feedwater heaters. The pumps take suction downstream of the last stage low-pressure feedwater heaters and discharge through the high-pressure feedwater heaters. Each pump is driven by an adjustable speed drive.

Isolation valves are provided which allow each reactor feed pump to be individually removed from service for maintenance, while the plant continues operation at full power on the three remaining pumps.

Controlled feedwater recirculation is provided from the discharge side of each reactor feed pump to the main condenser. This provision ensures that the minimum safe flow through each reactor feed pump is maintained during operation.

10.4.7.2.3 System Operation

Normal Operation—Under normal operating conditions, system operation is automatic. Automatic and redundant level control systems control the levels in all feedwater heaters, MS/RH drain tanks, the heater drain tanks, and the condenser hotwells. Feedwater heater levels are controlled by modulating drain valves. Control valves in the discharge and recirculation lines of the heater drain pumps control the level in the heater drain tank. Valves in the makeup line to the condenser from the condensate storage tank and in the return line to the condensate storage tank control the level in the condenser hotwells.

During power operation, feedwater flow is automatically controlled by the reactor feedwater pump speed that is set by the feed pump speed control system. The control system utilizes measurements of steam flow, feedwater flow, and reactor level to regulate the feedwater pump speed. During startup, feedwater flow is automatically regulated by the flow control valve.

Ten-percent step load and 5%/min ramp changes can be accommodated without a major effect on the CFS. The system is capable of accepting a full generator load rejection without reducing feedwater flow rate.

10.4.7.3 Evaluation

The Condensate and Feedwater System does not serve or support any safety function. Systems analyses show that failure of this system cannot compromise any safety-related system or prevent safe shutdown.

During operation, radioactive steam and condensate are present in the feedwater heating portion of the system, which includes the extraction steam piping, feedwater heater shells, heater drain piping, and heater vent piping. Shielding and access control are provided as necessary (Chapter 12). The CFS is designed to minimize leakage with welded construction utilized where practicable. Relief discharges and operating vents are channeled through closed systems.

If it is necessary to remove a component from service such as a feedwater heater, pump, or control valve, continued operation of the system is possible by use of the multistring arrangement and the provisions for isolating and bypassing equipment and sections of the system.

The majority of the condensate and feedwater piping considered in this section is located within the non-safety-related Turbine Building. The portion which connects to the seismic interface restraint outside the containment is located in the steam tunnel between the Turbine and Reactor Buildings. This portion of the piping is analyzed for dynamic effects from postulated seismic events. The feedwater control system is designed to ensure that there will not be large sudden changes in feedwater flow that could induce water hammer.

The CSFS trip logic and control schemes will respectively use coincident logic and redundant controllers and input signals to assure that plant availability goals are achieved and spurious trips are avoided. This specifically includes all FW heater and drain tank level controllers, all CFS flow and minimum flow controllers, and pump suction pressure trips, FW heater string isolation/high level trips and CFS bypass system(s) operation.

10.4.7.4 Tests and Inspections

10.4.7.4.1 Preservice Testing

Each feedwater heater and condensate pump receives a shop hydrostatic test which is performed in accordance with applicable codes. All tube joints of feedwater heaters are shop leak tested. Prior to initial operation, the completed CFS receives a field hydrostatic and performance test and inspection in accordance with the applicable code. Periodic tests and inspections of the system are performed in conjunction with scheduled maintenance outages.

10.4.7.4.2 Inservice Inspections

The performance status, leaktightness, and structural leaktight integrity of all system components are demonstrated by continuous operation.

10.4.7.5 Instrumentation Applications

Feedwater flow-control instrumentation measures the feedwater discharge flow rate from each reactor feed pump. The feedwater system flow measurements are used by the Feedwater Control System (Subsection 7.7.1.4) to regulate the feedwater flow to the reactor to meet system demands.

Pump flow is measured on the pump inlet line, and flow controls provide automatic pump recirculation flow for each reactor feedwater pump. Automatic and redundant controls also regulate the condensate flow through the auxiliary condensers (gland steam condenser and SJAE condensers) and maintains condensate pump minimum flow. Measurements of pump suction and discharge pressures are provided for all pumps in the system. Main feedpump suction pressure, discharge pressure and flow are indicated in the main control room.

The high-pressure feedwater heater isolation valves are interlocked such that, if a string of heaters were to be removed from service, the extraction non-return valves and isolation valves for those heaters would automatically close and the heater string bypass valve open. The low pressure feedwater heater isolation valves are interlocked such that, if a string of heaters were removed from service, the extractions to the affected heaters which are equipped with nonreturn valves would automatically close.

Sampling means are provided for monitoring the quality of the condensate and final feedwater, as described in Subsection 9.3.2. Temperature measurements are provided for each stage of feedwater heating. Steam pressure measurements are provided at each feedwater heater. Redundant level instrumentation and controls are provided for automatically regulating the heater drain flow rate to maintain the proper level in each feedwater heater shell or heater drain tank. High-level control valves provide automatic dump-to-condenser of heater drains on detection of high level in the heater shell.

The total water volume in the CFS is maintained through automatic makeup and rejection of condensate to the condensate storage tank. The system makeup and rejection are controlled by the redundant condenser hotwell level controllers.

10.4.8 Steam Generator Blowdown System (PWR)

Not applicable to the ABWR.

10.4.9 Auxiliary Feedwater System (PWR)

Not applicable to the ABWR.

10.4.10 COL License Information

10.4.10.1 Radiological Analysis of the TGSS Effluents

The COL applicant shall perform a radiological analysis of the TGSS effluents based on conservative site-specific parameters. From this analysis, the applicant shall determine the various actions to be taken if and when the TGSS effluent radiation monitor detects preset levels of effluent contaminations, including the level at which the TGSS steam supply will be switched over to auxiliary steam (Subsection 10.4.3.5.1.3).

Table 10.4-1 Condenser Design Data

Item	
Condenser Type	Single Pressure, 3 shells, Deaerating
Design duty, kW-total 3 shells	251.50×10^4
Shell pressures w/32.2°C Circ. water, kPaA	8.90
Circulating water flow rate, m^3/h	272,550
Tubeside temp. rise-total 3 shells, °C	7.99
Shell design pressure range, MPaA	0 to 0.207*
Hotwell storage capacity-total 3 shells, L	355,780
Channel design pressure, MPaA	0.70
Surface Area, cm^2	1077.97×10^6
Number of tube passes per shell	1
Applicable codes and standards	ANSI Standards, HEI Standards for Steam Surface Condensers

* The value 207 kPaA is applied for the head of hydrostatic test

Table 10.4-2 Main Condenser Evacuation System

Steam Jet Air Ejector (SJAE) System		
	Number of ejector stages	2
	Number of intercondenser	2
	Number of ejector sets and capacity	2 x 100%
	Required supply steam pressure, MPaA	1.47
	Normal steam supply source	Main Steam
Start-up Vacuum Pump System		
	Number of pumps and capacity	2 x 100%

Table 10.4-3 Circulating Water System

Circulating Water Pumps	
Number of pumps	4
Pump type	Vertical, concrete volute
Unit flow capacity, m^3/h	~ 68,140
Driver Type	Induction motor
Other System Features	
Pump discharge valve & actuator	Butterfly, motor
Condenser isolation valve & actuator	Butterfly, motor
Number of water box drain pump	1

Table 10.4-4 Condensate Purification System

Condensate Filters	
Filter type	High efficiency (hollow fiber or equivalent)
Number of vessels	3*
Design flow rate per vessel, m^3/h	2300
Design pressure, MPaG	~ 4.81
Condensate Polishers	
Polisher type	Bead resin, mixed bed
Number of vessels	6 (5 operat., 1 standby)*
Design flow rate per vessel, m^3/h	~ 1380
Specific flow rate, L/s/m^2	Normal: 0.234 (Max: 0.352)
Design pressure, MPaG	~ 4.81
Other System Features	
Filter backwash tank	1
Resin receiver tank	1
Resin storage tank	1

* The number of demineralizers and filter vessels are dependent on the final Turbine Building design and are quoted here for reference purposes only.

Table 10.4-5 Condensate and Feedwater System Design Data

Condensate Piping (Reactor Feedwater Pump Inlet Condition)	
Normal flowrate, kg/h	~7,629,000
Number of lines	4
Nominal pipe size	550A
Fluid velocity, m/s	~3.7
Fluid temperature, °C	158.5
Design code	ANSI B31.1
Seismic design	Analyzed for SSE design loads
Main Feedwater Piping (No.6 Feedwater Heater Outlet Condition)	
Design (VWO) flowrate, kg/h	~7.986,000
Number of lines	2
Nominal pipe size	650A
Fluid velocity, m/s	~4.7
Fluid temperature, °C	217.7
Design code	ANSI B31.1
Seismic design	Analyzed for SSE design loads

Table 10.4-6 Condensate and Feedwater System Component Failure Analysis

Component	Failure Effect On Train	Failure Effect on System	Failure Effect on RCS
Condensate pump	None. Condenser hotwells and condensate pumps are interconnected.	Operation continues at full capacity, using parallel pumps and auto start of standby pump.	None
Condensate booster pump	None. Suction line and condensate booster pumps are interconnected.	Operation continues at full capacity, using parallel pumps and auto start of the standby condensate booster pump.	None
No.1, 2, 3 or 4 feedwater heater	One train of No. 1, 2, 3 and 4 feedwater heaters is shut down. Remaining trains continue to operate.	Operation continues at re-duced capacity, using parallel feedwater heaters. Load must not exceed turbine vendor's requirements to protect the LP turbines from excessive steam flow.	Reactor control system reduces reactor power to a level compatible to the safe LP turbine operation.
Heater drain tank	Drains from affected heater drain subsystem are dumped to condenser.	High pressure drains are dumped to condenser.	Reactor control system reduces reactor power to a level compatible with the condensate and feedwater capacity.
Heater drain pump	None	Operation continues at full capacity with auto start of standby pump.	None.
Reactor feedwater pump	None. Feedwater pumps are interconnected.	Operations continue at full capacity with auto start of standby pump.	None
No. 5 or 6 feedwater heater	One train is shut down.	CFS operation continues at capacity, using parallel train and bypass line.	Reactor control system adjusts the reactor to permit continued operation with the reduced feedwater temperature.

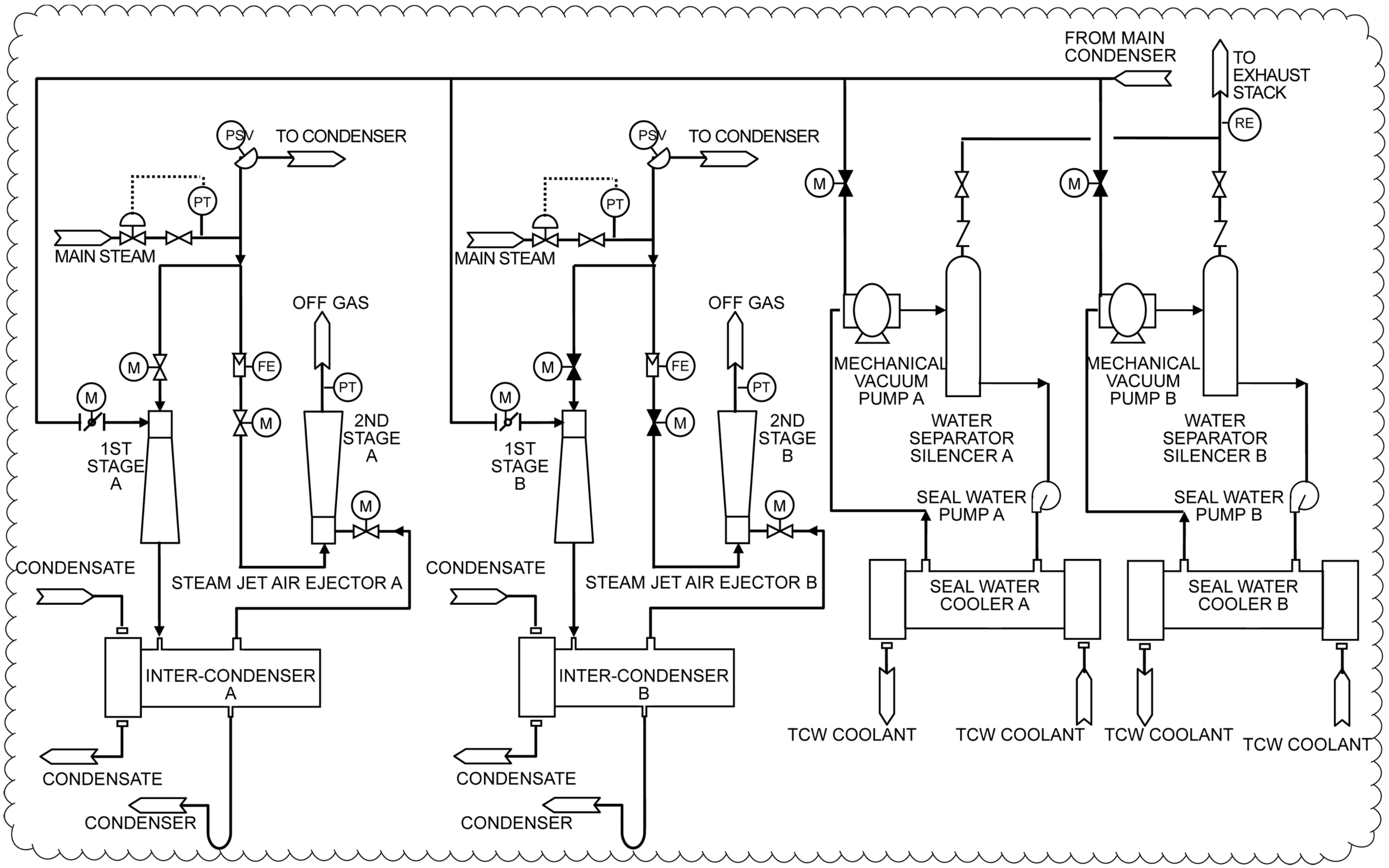

Figure 10.4-1 Main Condenser Evacuation System

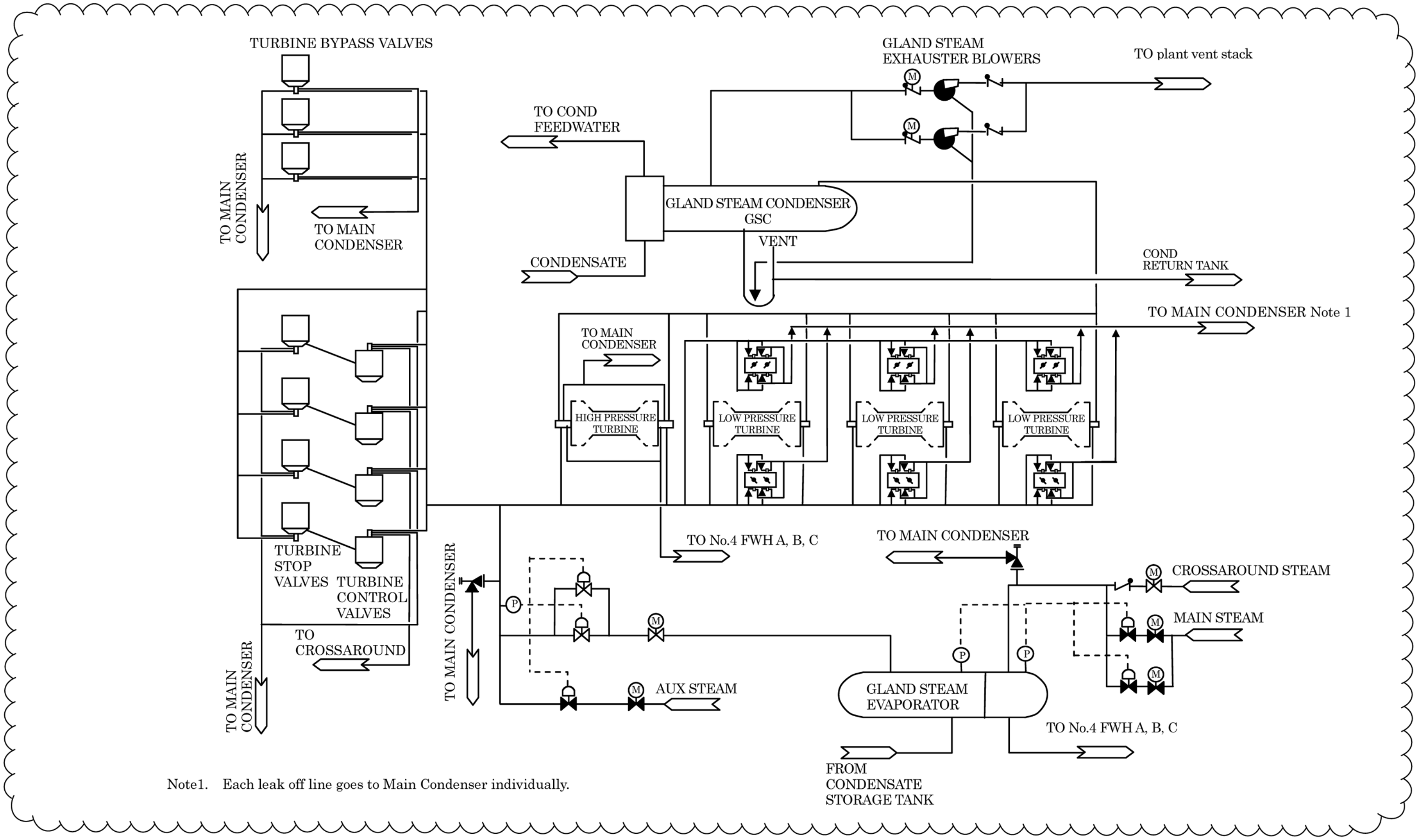

Figure 10.4-2 Turbine Gland Seal System

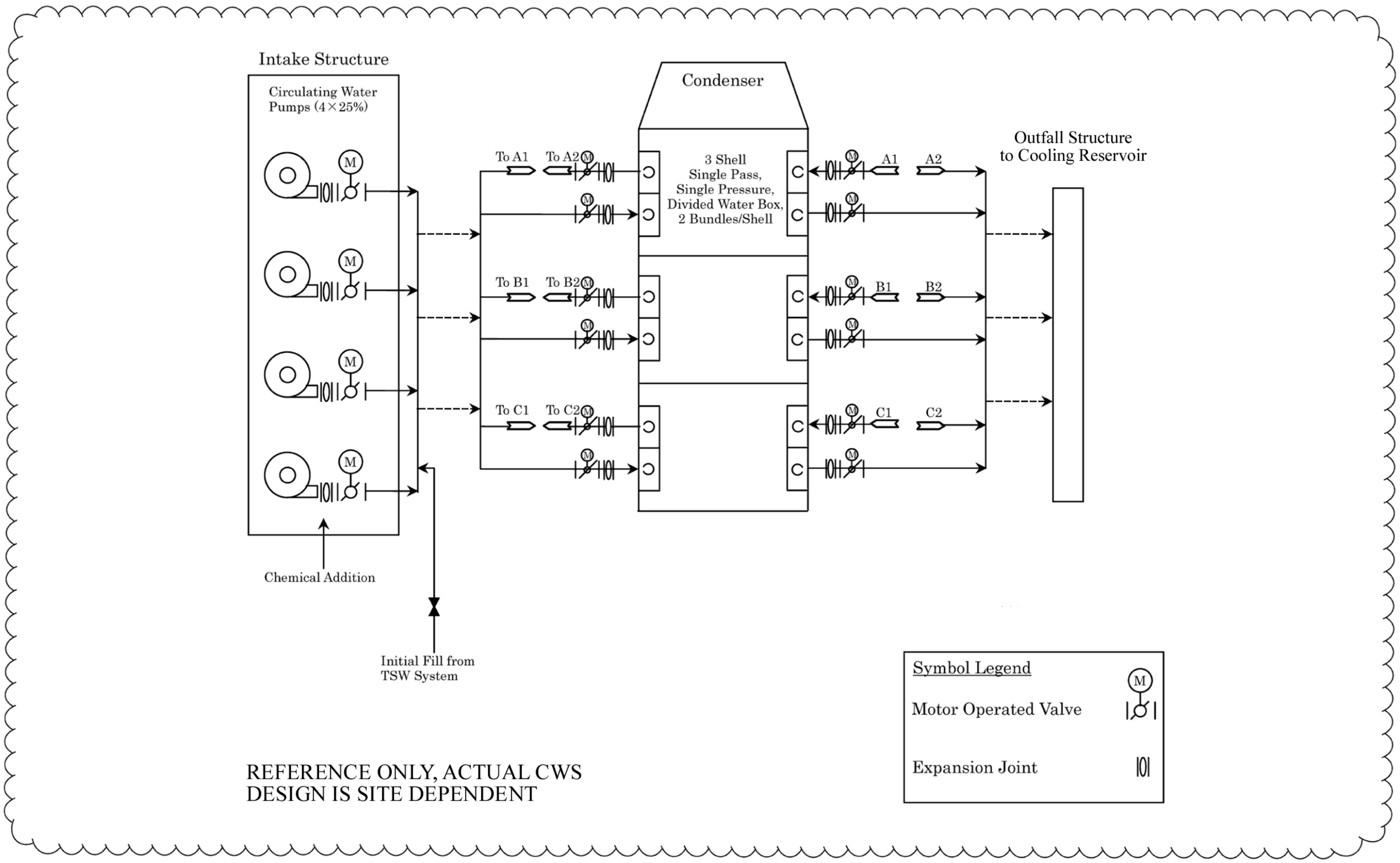

Figure 10.4-3 Circulating Water System

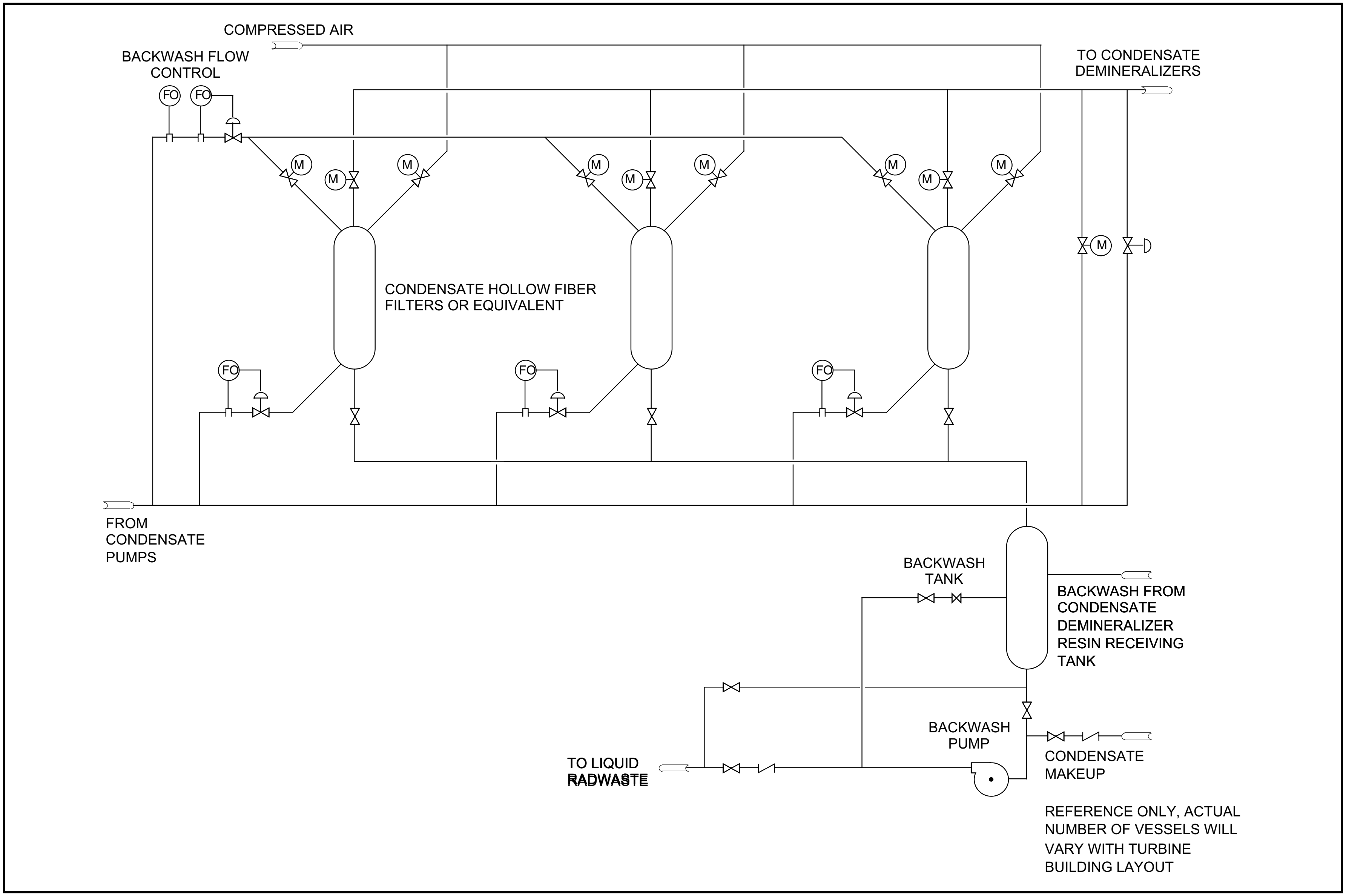

Figure 10.4-4 Condensate Purification System

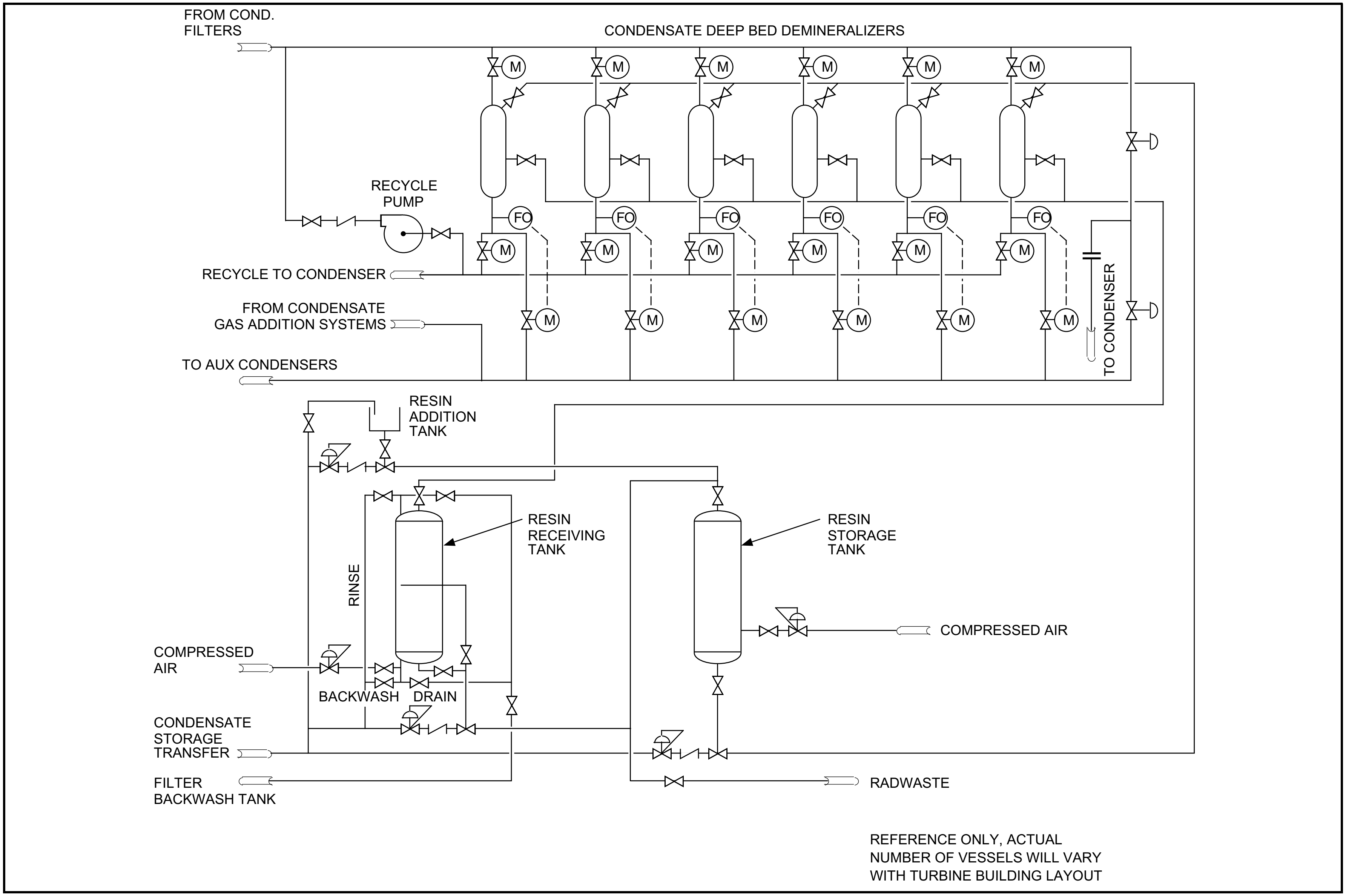

Figure 10.4-4 Condensate Purification System (Continued)

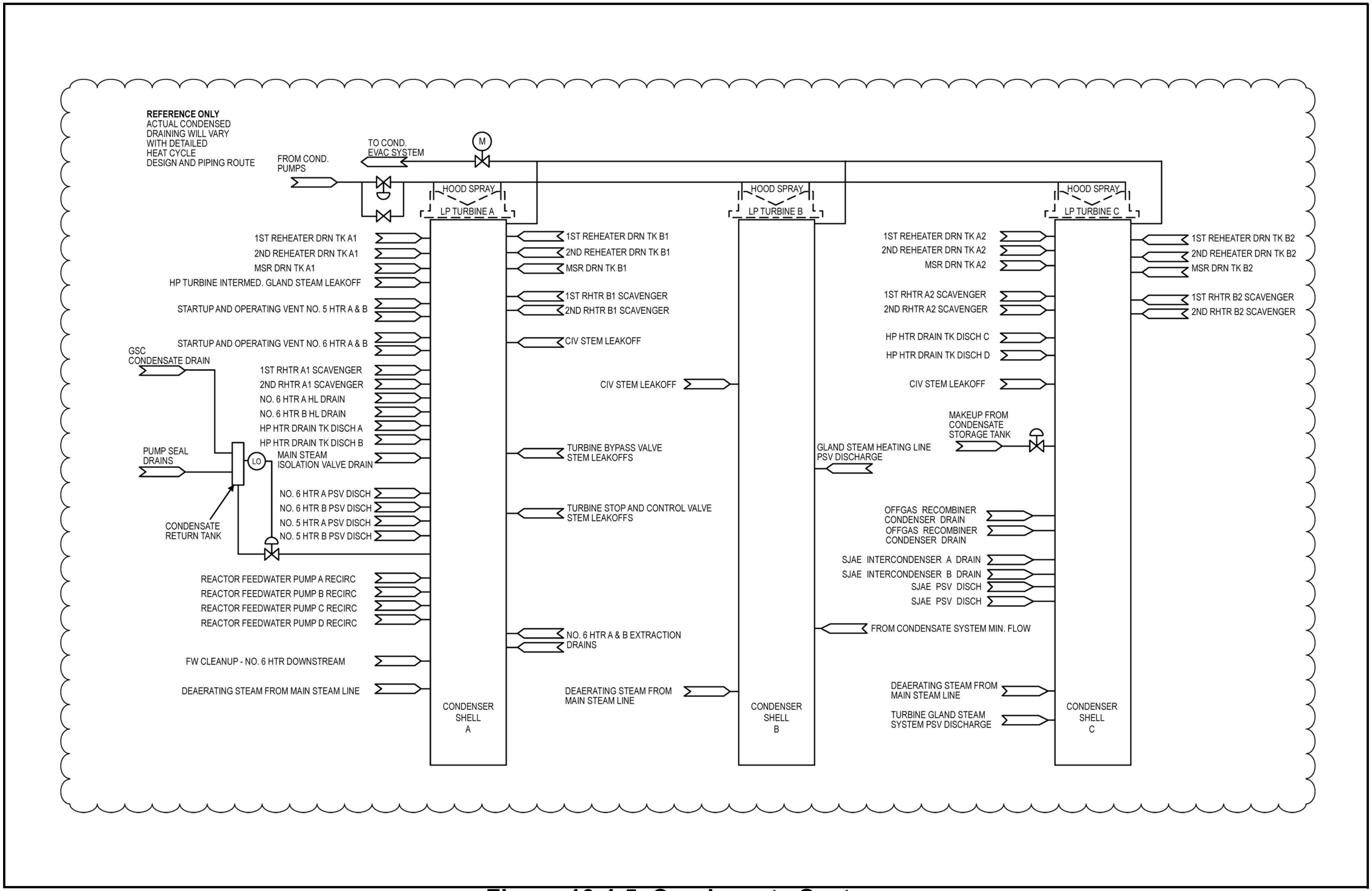

Figure 10.4-5 Condensate System

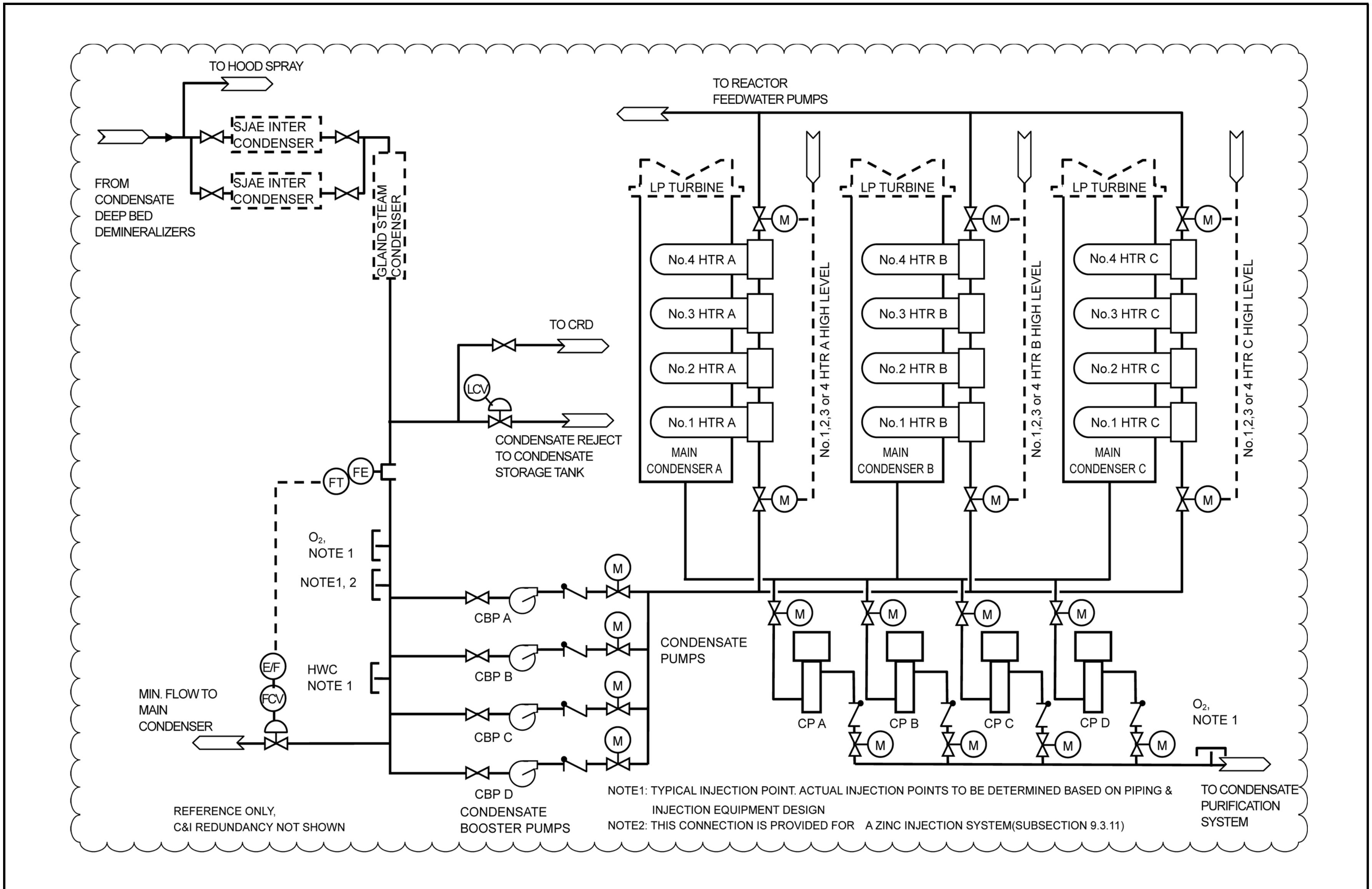

Figure 10.4-5 Condensate System (Continued)

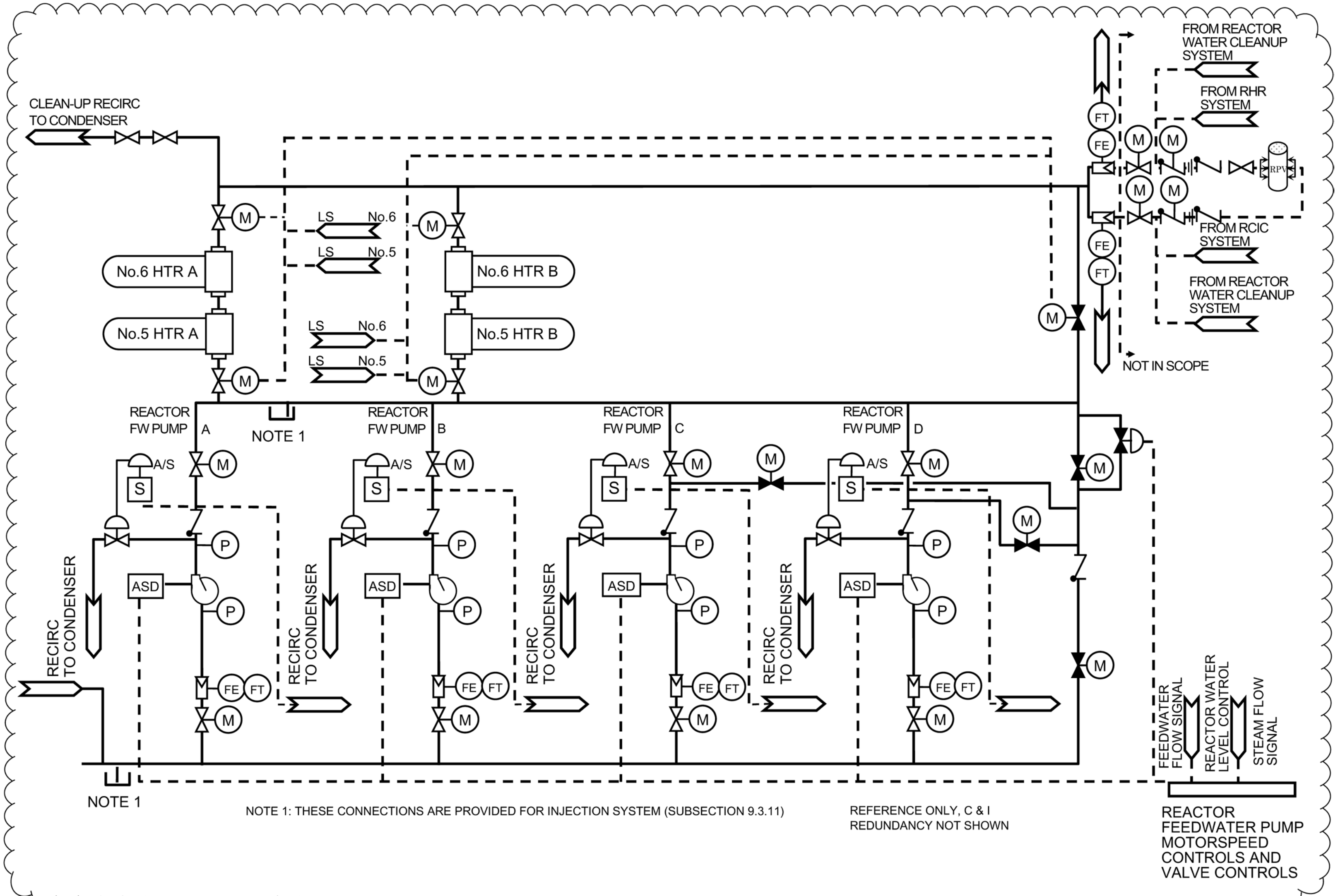

Figure 10.4-6 Feedwater System

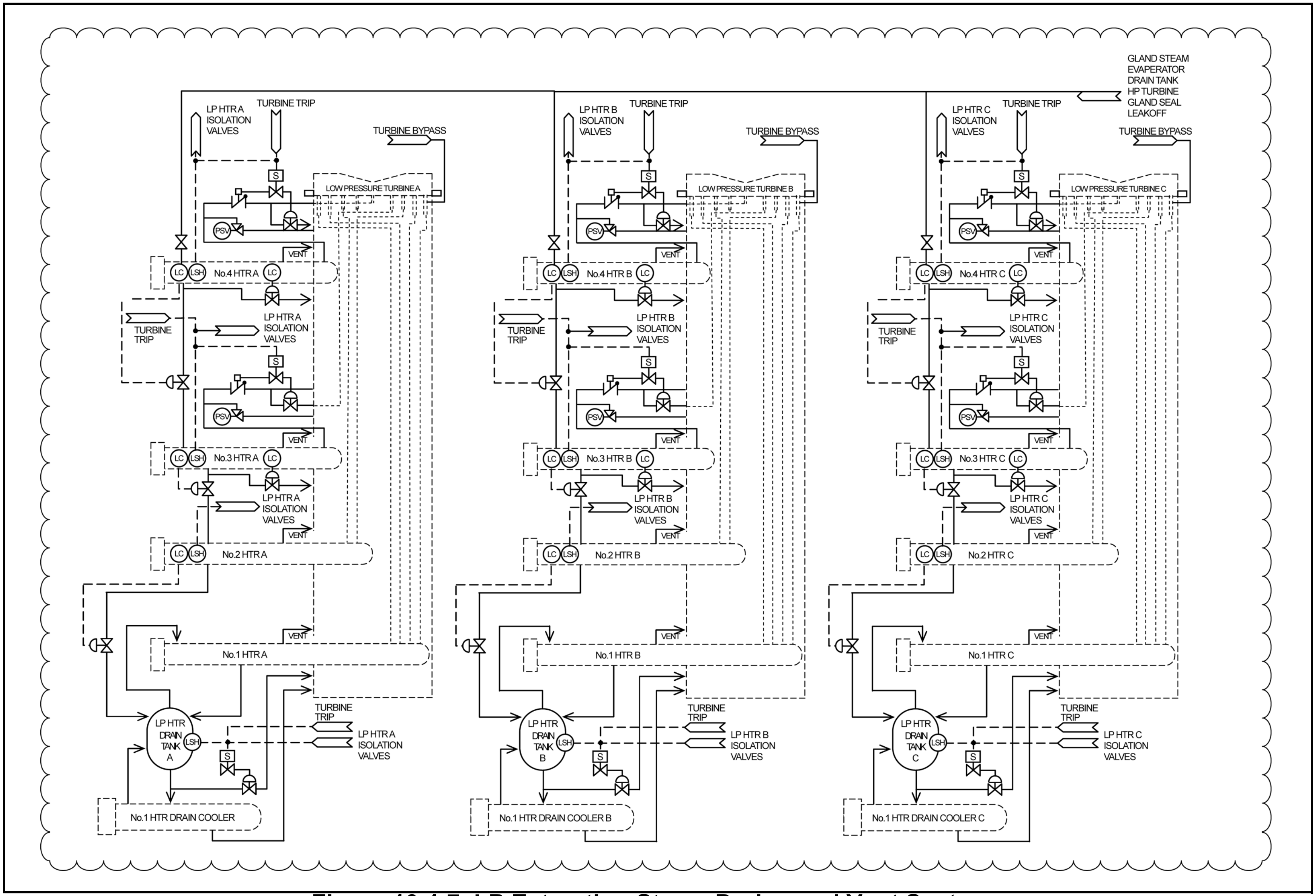

Figure 10.4-7 LP Extraction Steam Drains and Vent Systems

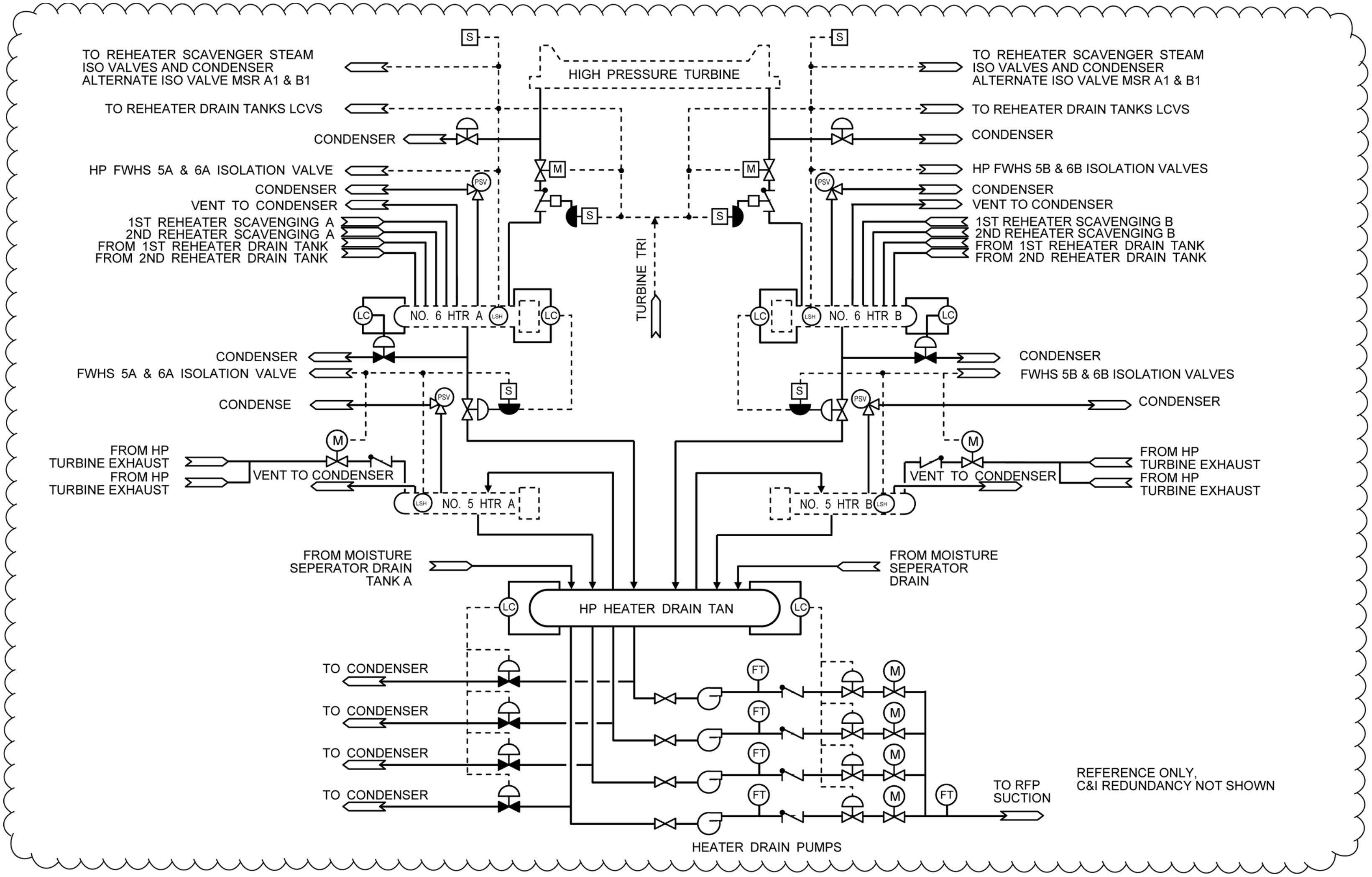

Figure 10.4-8 HP Extraction Steam Drains and Vent System

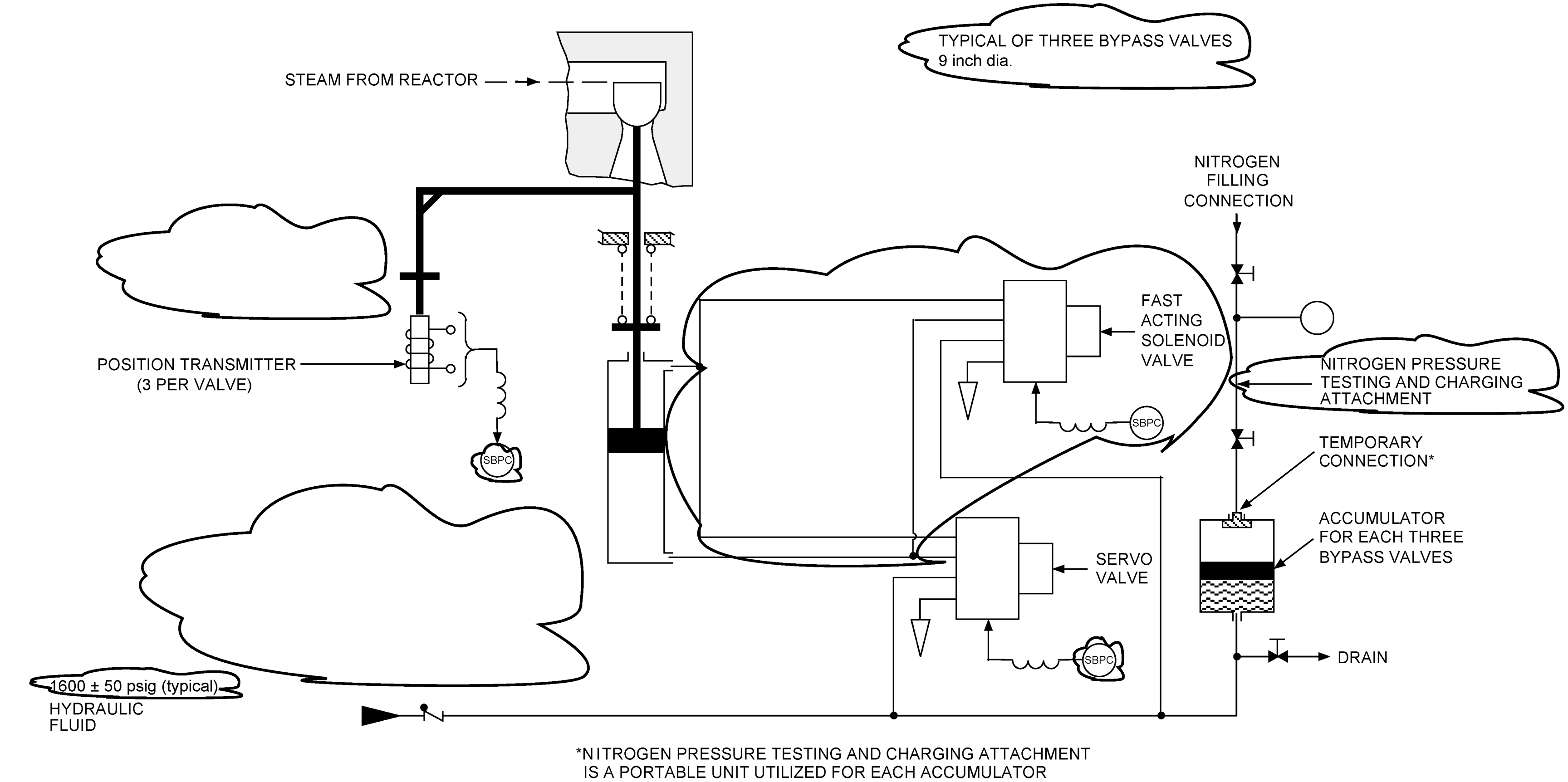

Figure 10.4-9 Bypass Valve Control, Electro-Hydraulic Control Unit

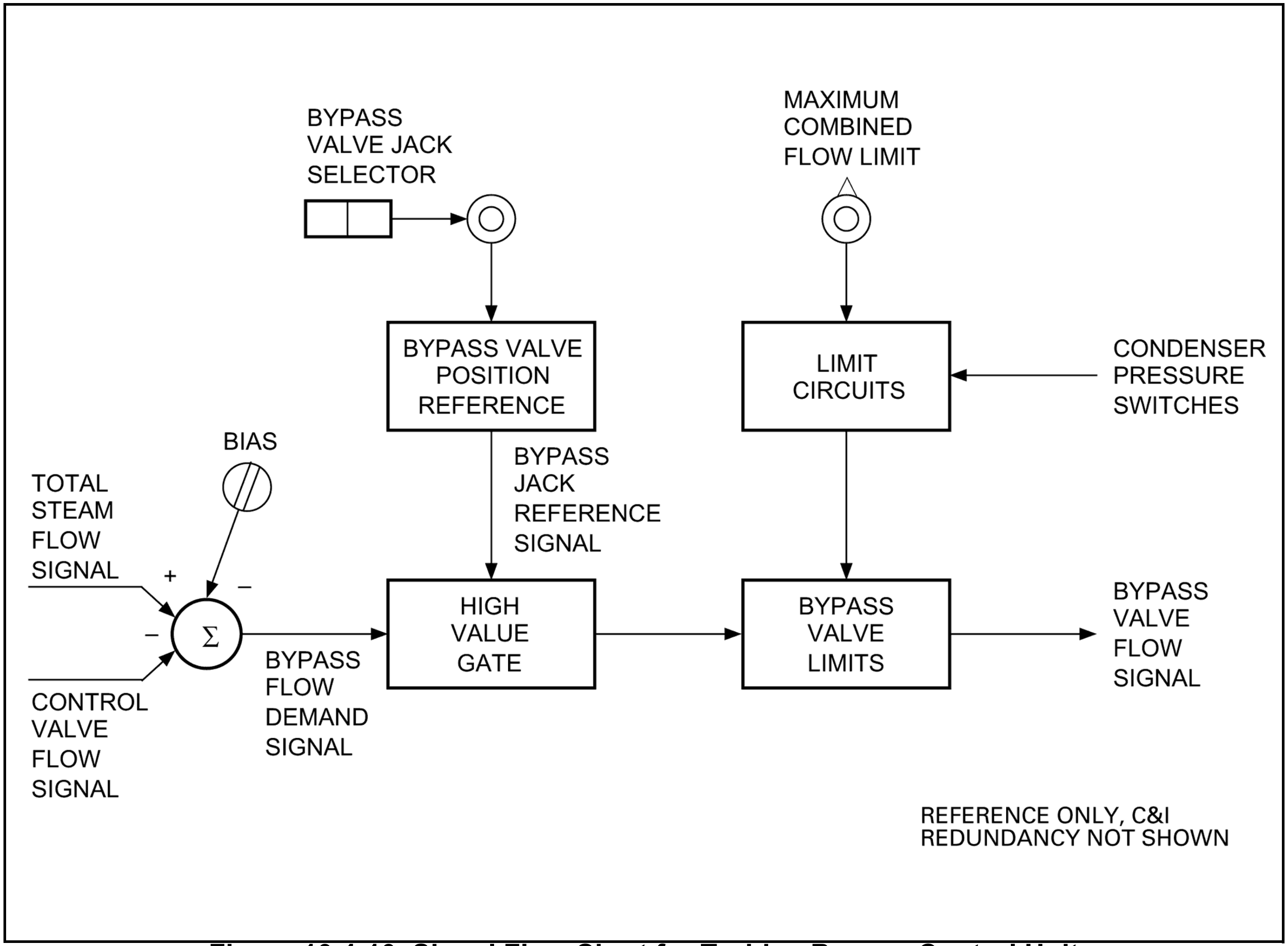

Figure 10.4-10 Signal Flow Chart for Turbine Bypass Control Unit