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10.0 Steam and Power Conversion System

10.1 Summary Description

The components of the Steam and Power Conversion (S&PC) System are designed to produce electrical power utilizing the steam generated by the reactor, condense the steam into water, and return the water to the reactor as heated feedwater, with a major portion of its gaseous, dissolved, and particulate impurities removed in order to satisfy the reactor water quality requirements.

The S&PC System includes the main steam system, the main turbine generator system, main condenser, condenser evacuation system, turbine gland seal system, turbine bypass system, extraction steam system, condensate cleanup system, and the condensate and feedwater pumping and heating system. The heat rejected to the main condenser is removed by a circulating water system and discharged to the power cycle heat sink.

Steam, generated in the reactor, is supplied to the high-pressure turbine and the steam moisture separators/reheaters. Steam leaving the high-pressure turbine passes through a combined moisture separator/reheater prior to entering the low pressure turbines. The moisture separator drains, steam reheater drains, and the drains from the two high pressure feedwater heaters are pumped back to the reactor feedwater pump suction by the heater drain pumps. The low pressure feedwater heater drains are cascaded to the condenser.

Steam exhausted from the low-pressure turbines is condensed and deaerated in the condenser. The condensate pumps take suction from the condenser hotwell and deliver the condensate through the filters and demineralizers, gland steam condenser, steam jet air ejector condensers, offgas recombiner condensers, and through the low-pressure feedwater heaters to the reactor feed pumps. The reactor feed pumps discharge through the high pressure feedwater heaters to the reactor.

Major S&PC System design features are summarized in Table 10.1-1. The system main conceptual features are illustrated on Figure 10.1-1, assuming a triple pressure condenser. This type of condenser and other site dependent ABWR plant features and parameters are reported herein based on typical central U.S. site conditions. They are given here to more completely define the ABWR Turbine Island standard design and to be used as references in reviewing future ABWR plant-specific licensing submittals, and confirming that such submittals are indeed consistent with the standard design. Nothing in the ABWR Standard Plant design is meant to preclude the use of a once through cooling system and a single pressure condenser nor will such changes affect the Nuclear Island.

Normally, the turbine power heat cycle utilizes all the steam being generated by the reactor; however, an automatic pressure-controlled turbine bypass system designed for

33% of the rated steam flow is provided to discharge excess steam directly to the condenser. Although the ABWR Standard Plant design is for 33% bypass, this capability could be increased to a full load reject capability without affecting the Nuclear Island.

Individual components of the S&PC System are based on proven conventional designs suitable for use in large, central station power plants.

All auxiliary equipment is sized for the maximum calculated unit capability with turbine valves wide open.

The S&PC System is designed for sustained long-term operation with a heat input equal to the rated 3919 MWt available from the NSSS when the reactor core is generating its rated 3926 MW thermal output. The S&PC System is designed to operate at 105% of maximum guaranteed turbine throttle flow (assumed to correspond to turbine valves wide open) for transients and short-term loading conditions.

The inlet pressure at the turbine main steam valves will not exceed rated pressure, except when operating above 95% of the maximum guaranteed turbine flow. It will be permissible to increase the inlet pressure to 103% of rated pressure, provided the control valve position is adjusted so that the resulting steam flow does not exceed the steam flow that is obtained when operating at rated pressure with control valves wide open.

The necessary biological shielding for personnel protection is provided for all radiation producing components of the power conversion system, including the main turbines, moisture separator/reheaters, feedwater heaters, condenser and steam jet air ejector.

The reference guaranteed rating and valves-wide-open flow quantities and fluid energy levels are shown on the turbine cycle heat balances (Figures 10.1-2 and 10.1-3, respectively).

The majority of the S&PC System is located in the Turbine Building which is a non-seismic, non-safety-related building.

Non-safety-related instrumentation is provided to measure and control flow, pressure, differential pressure, temperature, and level throughout the steam and condensate system. The instrumentation provides input signals to the plant computer, recorders and control systems which maintain the normal operation of the plant.

Safety-related instrumentation is provided to detect the fast closure of the turbine main stop control valve oil pressure, stop valve position, turbine first-stage pressure and main condenser pressure.

10.1.1 Protective Features

10.1.1.1 Loss of External Electrical Load and/or Turbine Trip

Load rejection capabilities of the Steam and Power Conversion System are discussed in Section 10.3.

10.1.1.2 Overpressure Protection

The following components are provided with overpressure protection in accordance with the ASME Boiler and Pressure Vessel Code, Section VIII:

(1) Moisture separator/reheater vessels

(2) Selected low pressure feedwater heaters

(3) High pressure feedwater heaters

(4) Heater drain tank

10.1.1.3 Turbine Overspeed Protection

Turbine overspeed protection is discussed in Subsection 10.2.2.4.

10.1.1.4 Turbine Integrity

Turbine integrity is discussed in Subsections 10.2.3 and 3.5.1.

Table 10.1-1 Summary of Important Design Features and Performance Characteristics of the Steam and Power Conversion System

Nuclear Steam Supply System, Full Power Operation	
Rated reactor core power, MWt	3,926
Rated NSSS power, MWt	3,919
Reactor steam outlet pressure, MPaA	7.17
Reactor nominal outlet steam moisture,%	0.1
Reactor inlet feedwater temperature, °C	215.6
Turbine-Generator	
Nominal Rating, MWe	~1,400
Turbine type	Tandem compound, six flow, 132.08 cm last-stage bucket
	1 high pressure turbine
	3 low pressure turbines
Operating speed, rad/s	188.5
Turbine throttle steam pressure, MPaA	6.79
Throttle steam nominal moisture,%	0.4
Moisture Separator/Reheaters (MSRs)	
Number of MSRs per unit	4
Stages of moisture separation	1
Stages of reheat	1
Main Condenser (Site Dependent)	
Type	Multiple pressure
Design duty, kW	~25.49 x 10^5
Circulating water flow rate, m^3/h	~136290
Circulating water temperature rise, °C	~16.8
Condensate Pumps	
Number of pumps	4 x 33–50% (3 operating and 1 standby)
Pump type	Vertical, centrifugal multi-stage
Driver type	Fixed speed motor

Table 10.1-1 Summary of Important Design Features and Performance Characteristics of the Steam and Power Conversion System (Continued)

Design Conditions:	
Normal flow, m^3/h	~1817.2
Total head, m	426.72
Rated motor power, kW	~3800
Feedwater Heaters	
Low Pressure Heaters	
a. No. 1	
Number per stage	3
Stage pressure, kPaA	24.5
Duty per shell, kW	22.4×10^3
b. No. 2	
Number per stage	3
Stage pressure, kPaA	60.8
Duty per shell, kW	48.85
c. No. 3	
Number per stage	3
Stage pressure, kPaA	147
Duty per shell, kW	51.88×10^3
d. No. 4	
Number per stage	3
Stage pressure, kPaA	330
Duty per shell, kW	54.90×10^3
High Pressure Heaters	
e. No. 5	
Number per stage	2
Stage pressure, kPaA	1,353
Duty per shell, kW	171.55×10^3
f. No. 6	
Number per stage	2
Stage pressure, kPaA	2,311
Duty per shell, kW	128.73×10^3

Table 10.1-1 Summary of Important Design Features and Performance Characteristics of the Steam and Power Conversion System (Continued)

Reactor Feedwater Pumps	
Number of pumps	3 normally operating (33–65%), variable speed
Pump type	Horizontal, centrifugal, single stage
Driver type	electric motors
Design conditions:	
Main pumps:	
Normal flow, m^3/h	~4202.27
Total head, m	~640.08
Rated motor power, kW	~11,200
Heater Drain Pumps	
Number of pumps	2 x 50%
Pump type	Horizontal, centrifugal
Driver type	Fixed speed motor
Design conditions:	
Normal flow, m^3/h	~1362.9
Total head, m	~228.6
Rated motor power, kW	~1850
Heater Drain Tank	
Number of tanks	2*
Design, pressure kPa	1,517
Tank capacity	56,700 L*

* Nominal depending on specific Turbine Building layout considerations.

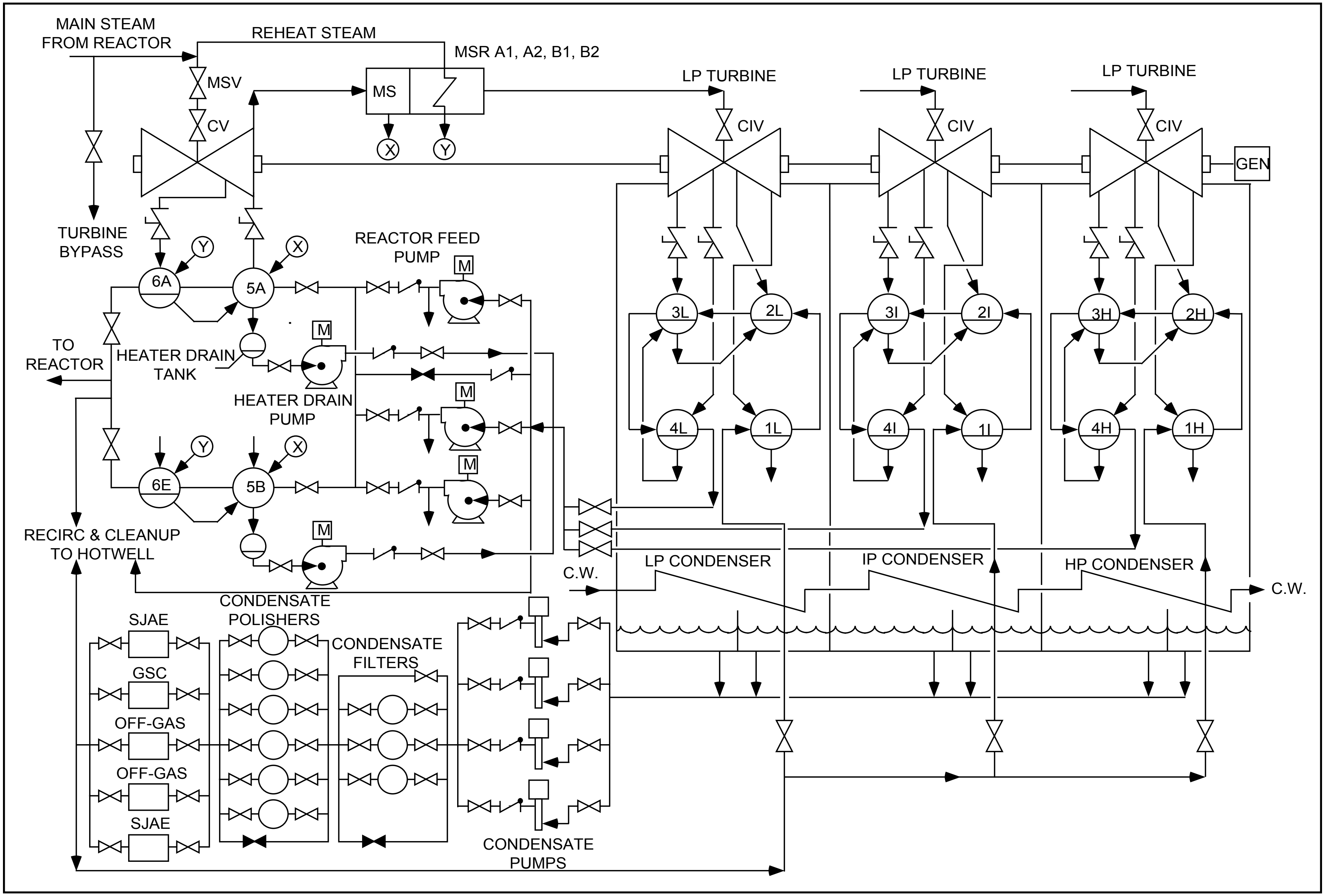

Figure 10.1-1 Reference Steam & Power Conversion System

The following figures are located in Chapter 21 :

Figure 10.1-2 Reference Heat Balance for Guaranteed Reactor Rating

Figure 10.1-3 Reference Heat Balance for Valves-Wide-Open (VWO)

10.2 Turbine Generator

10.2.1 Design Bases

10.2.1.1 Safety Design Bases

The turbine generator (T-G) does not serve nor support any safety function and has no safety design basis. The turbine generator is, however, a potential source of high energy missiles that could damage safety-related equipment or structures. The turbine is designed to minimize the possibility of failure of a turbine blade or rotor. Turbine integrity is discussed in Subsection 10.2.3. The effects of potential high energy missiles are discussed in Chapter 3. In addition, the main steam turbine stop valves are analyzed to demonstrate structural integrity under safe shutdown earthquake (SSE) loading conditions.

10.2.1.2 Power Generation Design Bases

Power Generation Design Basis One—The T-G is intended for either base load or load following operation. The gross generator outputs at reference guaranteed reactor rating and valves-wide-open (VWO) operation are given on the heat balances shown on Figures 10.1-2 and 10.1-3, respectively.

Power Generation Design Basis Two—The T-G load change characteristics are compatible with the instrumentation and control system which coordinates T-G and reactor operation.

Power Generation Design Basis Three—The T-G is designed to accept a sudden loss of full load without exceeding design overspeed.

Power Generation Design Basis Four—The T-G is designed to permit periodic under load testing of steam valves important to overspeed protection, emergency overspeed trip circuits, and several other trip circuits.

Power Generation Design Basis Five—The failure of any single component will not cause the rotor speed to exceed the design speed.

Power Generation Design Basis Six - The T-G is designed to support the plant availability goals by utilizing 2/3 or 2/4 coincident trip logic for all but the vibration trips (which are at least 2/2 per bearing). Similarly, all turbine control functions which are required for power generation will use at least dual redundant controllers and triply redundant control inputs.

Power Generation Design Basis Seven - The T-G auxiliary systems (stator cooling, lube oil cooling, etc.) are designed either with enough redundancy to support full power operation with a single failure or to provide a signal to the reactor power control system to automatically reduce power to within the capability of the remaining on-line capacity.

10.2.1.3 Functional Limitations Imposed by the Design or Operational Characteristics of the Reactor Coolant System

10.2.1.3.1 Turbine Stop Valve

During an event resulting in turbine stop valve fast closure, turbine inlet steam flow will not be reduced faster than that shown in Figure 10.2-1.

10.2.1.3.2 Turbine Control Valve

During any event resulting in turbine control valve fast closure, turbine inlet steam flow will not be reduced faster than that shown in Figure 10.2-2.

The turbine control valve steam flow shutoff rate, upon a step reduction to zero in pressure regulation flow demand (no resulting bypass steam flow demand), will be within the region shown in Figure 10.2-3. Any single control system failure or T-G event will not cause a faster steam flow reduction than that shown in Figure 10.2-3 without initiating an immediate reactor trip.

The turbine control valves are capable of full stroke opening and closing times not greater than 7 seconds for adequate pressure control performance.

10.2.1.3.3 Automatic Load Maneuvering Capability

Within the automatic load following region of the power/flow operating map (Figure 15.0-1), steam flow will automatically respond to a load demand step as follows:

(1) For positive load demand signal changes less than 10% Nuclear Boiler Rated (NBR), power change rates are limited only by the response rates of the reactor.

(2) For positive load demand signal changes greater than 10% NBR, the resulting first 10% NBR thermal power change may be at 1% NBR/s, with the balance of the power change taking place at rates up to 15% NBR/min (0.25% NBR/s). This is accomplished by permitting the load demand signal to initially step upwards 10%, followed by a 15% NBR/min ramp.

(3) For negative load demand signal changes, rates are not limited.

10.2.2 Description

10.2.2.1 General Description

The turbine-generator consists of an 188.5 rad/s turbine, moisture separator/reheaters, generator, exciter, controls, and associated subsystems.

The turbine consists of a double-flow, high-pressure unit, and three double flow low-pressure units in tandem. The high-pressure unit has a single stage of steam extraction.

Moisture separation and reheating of the high-pressure turbine exhaust steam is performed by four combined moisture separator/reheaters (MSRs). Two MSRs are located on each side of the T-G centerline. The steam passes through the low-pressure turbines, each with four extraction points for the four low-pressure stages of feedwater heating, and exhausts into the main condenser. In addition to the external MSRs, the turbines are designed to separate water from the steam and drain it to the next lowest extraction point feedwater heater.

The generator is a direct driven, three-phase, 60 Hz, 188.5 rad/s synchronous generator with a water-cooled stator and hydrogen cooled rotor.

The turbine-generator uses a digital monitoring and control system which, in coordination with the turbine Steam Bypass and Pressure Control System, controls the turbine speed, load, and flow for startup and normal operations. The control system operates the turbine stop valves, control valves, and combined intermediate valves (CIVs). T-G supervisory instrumentation is provided for operational analysis and malfunction diagnosis.

Automatic control functions are programmed to protect the Nuclear Steam Supply System through appropriate corrective actions (Section 7.7).

T-G accessories include the bearing lubrication oil system, electrohydraulic control (EHC) system, turning gear, hydrogen and CO_2 system, seal oil system, stator cooling water system, exhaust hood spray system, turbine gland sealing system, and turbine supervisory instrument (TSI) system.

The T-G unit and associated piping, valves, and controls are located completely within the Turbine Building. There are no safety-related systems or components located within the Turbine Building with the exception of the Reactor Protection System (RPS) sensors on the T-G unit. The safety-related switches or transducers used to detect fast closure of the turbine main stop and control valves and high-high condenser back pressure are fail safe, hence any local failure associated with the T-G unit will not adversely affect any safety-related equipment. Failure of T-G equipment cannot preclude safe shutdown of the reactor.

10.2.2.2 Component Description

The MSRs, MSR drain tanks, stator water coolers, and stator water demineralizer are designed to ASME Code Section VIII requirements. The balance of the T-G is designed to Turbine Manufacturer’s Standards.

Main Stop and Control Valves—Four high-pressure main stop and control valves admit steam to the high-pressure (HP) turbine. The primary function of the main stop valves is to quickly shut off the steam flow to the turbine under emergency conditions. The primary function of the control valves is to control steam flow to the turbine in response to the turbine control system.

The main stop valves are operated in an open-closed mode either by the emergency trip, fast acting valve for tripping, or by a small solenoid valve for testing. The disks are totally unbalanced and cannot open against full differential pressure. A bypass is provided to pressurize the below seat areas of the four valves. Springs are designed to close the main stop valve in approximately 0.20 second under the emergency conditions listed in Subsection 10.2.2.5.

Each stop valve contains a permanent steam strainer to prevent foreign matter from entering the control valves and turbine.

The control valves are designed to ensure tight shutoff. The valves are of sufficient size, relative to their cracking pressure, to require a partial balancing. Each control valve is operated by a single acting, spring-closed servomotor opened by a high pressure fire-resistant fluid supplied through a servo valve. The control valve is designed to close in approximately 0.20 second.

High-Pressure Turbine—The HP turbine receives steam through four steam leads, one from each control valve outlet. The steam is expanded axially across several stages of stationary and moving blades. Steam pressure immediately downstream of the first stage is used as a load reference signal for reactor control. Extraction steam from the turbine supplies the last stage of feedwater heating. HP turbine exhaust steam is collected in eight cold reheat pipes, four at each end of the turbine. Most of the exhaust steam is routed to the MSR inlet, but part of it is diverted and supplies the next to last stage of feedwater heating.

Moisture Separator Reheaters—Four horizontal cylindrical-shell, combined moisture separator/reheaters (MSRs) are installed in the steam path between the high and low pressure turbines. The MSRs serve to dry and reheat the HP turbine steam exhaust (crossaround steam), before it enters the low-pressure turbines. This improves cycle efficiency and reduces moisture-related erosion and corrosion in the low-pressure turbines. Crossaround steam is piped into the bottom of the MSR. Moisture is removed in chevron-type moisture separators, and is drained to the moisture separator drain tank and from there to the heater drain tank. The dry crossaround steam next passes upward across the reheater which is supplied with main steam. Finally, the crossaround steam is routed to the combined intermediate valves (CIVs), which are located just upstream of the low-pressure turbines inlet nozzles.

The reheaters drain, via drain tanks, to the forward pumped heater drain system, which discharges to the reactor feedwater pump suction. Safety valves are provided on the MSR for overpressure protection.

Combined Intermediate Valves—Two combined intermediate valves (CIVs) are provided for each LP turbine, one in each steam supply line, called the hot reheat line. The CIV consists of two valves—the intercept valve and the intermediate stop valve, which share a common casing. Although they utilize a common casing, these valves have entirely separate operating mechanisms and controls. The function of the CIVs is to protect the turbine against overspeed from steam and water energy stored between the main stop and control valves and the CIVs. One CIV is located on each side of each LP turbine.

Steam from the MSRs enters the single inlet of each valve casing, passes through the permanent basket strainer, past the intercept valve and stop valve disks, and enters the LP turbine through a single inlet. The CIVs are located as close to the LP turbine as possible to limit the amount of uncontrolled steam available for overspeeding the turbine. Upon loss of load, the intercept valve first closes then throttles steam to the LP turbine, as required to control speed and maintain synchronization. It is capable of opening against full system pressure. The intermediate stop valves close only if the intercept valves fail to operate properly. These valves are capable of opening against a pressure differential of approximately 15% of the maximum expected system pressure. The intermediate stop valve and intercept valve are designed to close in approximately 0.2 second.

Low-Pressure Turbines—Each LP turbine receives steam from two CIVs. The steam is expanded axially across several stages of stationary and moving buckets. Turbine stages are numbered consecutively, starting with the first HP turbine stage.

Extraction steam from the LP turbines supplies the first four stages of feedwater heating. A fifth extraction stage may be provided to remove moisture and protect the last-stage buckets from erosion induced by water droplets. This extraction is drained directly to the condenser.

Extraction Non-return Valves—Upon loss of load, the steam contained downstream of the turbine extractions could flow back into the turbine, across the remaining turbine stages, and into the condenser. Associated condensate could flash to steam under this condition and contribute to the backflow of steam or could be entrained with the steam flow and damage the turbines. Extraction non-return valves are installed in the extraction lines to the first, second, third and, if required, forth stage of turbine extractions to guard against this backflow and the resulting potential damage due to water entrainment or overspeed condition.

Generator—The generator is a direct-driven, three-phase, 60 Hz, 188.5 rad/s, four-pole synchronous generator with water-cooled stator and hydrogen cooled rotor.

The rotor is manufactured from a one-piece forging and includes layers of field windings embedded in milled slots. The windings are held radially by steel slot wedges at the rotor outside diameter. The wedge material maintains its mechanical properties at elevated temperature. The magnetic field is generated by DC power which is fed to the windings through collector rings located outboard of the main generator bearings.

The rotor body and shaft is machined from a single, solid steel forging. Detailed examinations include:

(1) material property checks on test specimens taken from the forging;

(2) photomicrographs for examination of microstructure;

(3) magnetic particle and ultrasonic examination;

(4) surface finish tests of slots for indication of a stress riser.

Bulk Hydrogen System—The bulk hydrogen and CO_2 system is illustrated on Figure 10.2-4. The hydrogen system is designed to provide the necessary flow and pressure at the main generator for purging carbon dioxide during startup and supply makeup hydrogen for generator leakage during normal operation.

The system consists of hydrogen supply piping with all the necessary valves, instrumentation, gas purity measuring equipment, hydrogen gas dryers, and bulk hydrogen storage unit.

Fires and explosions during filling and/or purging of the generator are prevented by inerting the generator with CO_2 so that a flammable mixture of hydrogen and oxygen cannot be produced. Unneeded hydrogen is vented outside through a flame arrestor.

The bulk hydrogen system utilizes the guidelines given in EPRI report NP-5283-SR-A with respect to these portions of the guidelines involving hydrogen that do not deal specifically with the HWC system. Specifically, the bulk hydrogen system piping and components will be located to reduce risk from their failures. The bulk hydrogen storage is located outside but near the Turbine Building. The hydrogen lines are provided with a pressure reducing station that limits the maximum flow to less than 100 standard cubic meters per minute before entering the Turbine Building. Equipment and controls used to mitigate the consequences of a hydrogen fire/explosion will be designed to be accessible and remain functional during the postulated postaccident condition. The design features and/or administrative controls shall be provided to ensure that the hydrogen supply is isolated when normal building ventilation is lost.

The arrangement of buildings at the facility and location of building doors and the bulk hydrogen storage tanks will be designed to ensure that damage to buildings containing safety-related equipment due to combustion of hydrogen or an explosion is unlikely.

Additionally, the bulk hydrogen system piping in the Turbine Building is designed in accordance with the industry practice.

10.2.2.3 Normal Operation

During normal operation, the main stop valves and CIVs are wide open. Operation of the T-G is under the control of the Electro-Hydraulic Control (EHC) System. The EHC System is comprised of three basic subsystems: the speed control unit, the load control unit, and the flow control unit. The normal function of the EHC System is to generate the position signals for the four main stop valves, four main control valves, and six CIVs.

10.2.2.4 Turbine Overspeed Protection System

In addition to the normal speed control function provided by the turbine control system, a separate turbine overspeed protection system is included. The turbine overspeed system is a highly reliable and redundant system which is classified as non-safety-related.

Protection against turbine overspeed is provided by the mechanical overspeed trip and electrical backup overspeed trip. Redundancy is achieved by using at least two independent channels from the signal source to the output device. The sensing device, line and output device are of a different nature for each individual channel in order to increase reliability.

The overspeed sensing devices are located in the front bearing standard and, therefore, are protected from the effects of missiles or pipe break. The hydraulic lines are fail-safe; that is, if one were to be broken, loss of hydraulic pressure would result in a turbine trip. The electric trip signals are redundant. One circuit could be disabled by damage to the wiring, but the other system is fail-safe (i.e., loss of signal results in a turbine trip). These features provide inherent protection against failure of the overspeed system caused by missiles or pipe whipping.

The electrical backup overspeed trip consists of independent circuits. Each circuit monitors a separate speed signal and activates trip logic at various speed levels. The output of these circuits is used in tripping and monitoring of the turbine.

Two air relay dump valves are provided which actuate on turbine trip. The valves control air to the extraction non-return valves, which limit contributions to turbine overspeed from steam and water in the extraction lines and feedwater heaters. The closing time of the extraction non-return valves is less than 2 seconds.

Upon loss of generator load, the EHC System acts to prevent rotor speed from exceeding design overspeed. [See Subsection 10.2.3.4, item (4)] Failure of any single component will not result in rotor speed exceeding design overspeed. The following component redundancies are employed to guard against overspeed:

(1) Main stop valves/Control valves

(2) Intermediate stop valves/Intercept valves

(3) Primary speed control/Backup speed control

(4) Fast acting solenoid valves/Emergency trip fluid system

(5) Speed control/Overspeed trip/Backup overspeed trip

The main stop valves and control valves provide full redundancy in that these valves are in series and have completely independent operating controls and operating mechanisms. Closure of either all four stop valves or all four control valves shuts off all main steam flow to the HP turbine. The combined intermediate stop and intercept valves are also in series and have completely independent operating controls and operating mechanisms. Closure of either valve or both valves in each of the six sets of combined intermediate stop and intercept valves shuts off all MSR outlet steam flow to the three LP turbines.

The speed control unit utilizes at least two speed signals. An increase in turbine speed tends to close the control valves. Loss of two speed signals will initiate a turbine trip via the Emergency Trip System (ETS).

Fast acting solenoid valves initiate fast closure of control valves under load rejection conditions that might lead to rapid rotor acceleration. The ETS initiates fast closure of the valves whether the fast-acting solenoid valves work or not.

If speed control should fail, the overspeed trip devices must close the steam admission valves to prevent turbine overspeed. Component redundancy and fail-safe design of the ETS hydraulic system and trip circuitry provide turbine overspeed protection. Three speed signals independent of the speed control unit provide input to the backup, overspeed trip. For reliability, two-out-of-three logic is employed in both mechanical and electrical overspeed trip circuitry. Single component failure does not compromise trip protection. Two separate electrical buses supply power to the trip circuits. The primary power source is shaft mounted. Non-Class 1E uninterruptible power and battery systems are backup power supplies. Loss of power trips the turbine through fail-safe circuitry.

10.2.2.5 Turbine Protection System

In addition to the overspeed trip signals discussed, the ETS closes the main stop and control valves and the CIVs to shut down the turbine on the following signals:

(1) Emergency trip pushbutton in control room

(2) Moisture separator high level

(3) Low condenser vacuum

(4) Low lube oil pressure

(5) LP turbine exhaust hood high temperature

(6) High reactor water level

(7) Thrust bearing wear

(8) Overspeed (electrical and mechanical)

(9) Manual trip handle on front standard

(10) Loss of stator coolant

(11) Low hydraulic fluid pressure

(12) Any generator trip

(13) Loss of EHC electrical power

(14) Excessive turbine shaft vibration

(15) Loss of two speed signals

All of the above trip signals except vibration and manual trips use 2/3 or 2/4 coincident trip logic.

When the ETS is activated, it overrides all operating signals and trips the main stop and control valves, and combined intermediate valves by way of their disk/dump valves.

10.2.2.6 Turbine-Generator Supervisory Instruments

Although the turbine is not readily accessible during operation, the turbine supervisory instrumentation is sufficient to detect any potential malfunction. The turbine supervisory instrumentation includes monitoring of the following:

(1) Vibration and eccentricity

(2) Thrust bearing wear

(3) Exhaust hood temperature and spray pressure

(4) Oil system pressures, levels, and temperatures

(5) Bearing metal and oil drain temperatures

(6) Shell temperature

(7) Valve positions

(8) Shell and rotor differential expansion

(9) Shaft speed, electrical load, and control valve inlet pressure indication

(10) Hydrogen temperature, pressure, and purity

(11) Stator coolant temperature and conductivity

(12) Stator-winding temperature

(13) Exciter air temperatures

(14) Turbine gland sealing pressure

(15) Gland steam condenser vacuum

(16) Steam chest pressure

(17) Seal oil pressure

10.2.2.7 Testing

The electrical and mechanical overspeed trip devices can be tested remotely at rated speed, under load, by means of controls on the EHC test panel. Operation of the overspeed protection devices under controlled, overspeed condition is checked at startup and after each refueling or major maintenance outage.

Provisions for testing each of the following devices while the unit is operating are included:

(1) Main stop and control valves

(2) Turbine bypass valves

(3) Low pressure turbine combined intermediate valves (CIVs)

(4) Overspeed governor

(5) Turbine extraction nonreturn valves

(6) Condenser vacuum trip system

(7) Thrust bearing wear detector

(8) Remote trip solenoids

(9) Lubricating oil pumps

(10) Control fluid pumps

10.2.3 Turbine Integrity

10.2.3.1 Materials Selection

Turbine rotors and parts are made from vacuum melted or vacuum degassed Ni-Cr-Mo-V alloy steel by processes which minimize flaw occurrence and provide adequate fracture toughness. Tramp elements are controlled to the lowest practical concentrations consistent with good scrap selection and melting practice, and consistent with obtaining adequate initial and long-life fracture toughness for the environment in which the parts operate. The turbine materials have the lowest fracture appearance transition temperatures (FATT) and highest Charpy V-notch energies obtainable, on a consistent basis, from water quenched Ni-Cr-Mo-V material at the sizes and strength levels used. Since actual levels of FATT and Charpy V-notch energy vary depending upon the size of the part, and the location within the part, etc., these variations are taken into account in accepting specific forgings for use in turbines for nuclear application. The fracture appearance transition temperature (50% FATT), as obtained from Charpy tests performed in accordance with specification ASTM A-370, will be no higher than -17.8°C for low-pressure turbine disks. The Charpy V-notch energy at the minimum operating temperature of each low-pressure disk in the tangential direction should be at least 81.4 N·m.

10.2.3.2 Fracture Toughness

Suitable material toughness is obtained through the use of selected materials as described in Subsection 10.2.3.1, to produce a balance of adequate material strength and toughness to ensure safety while simultaneously providing high reliability, availability, efficiency, etc. during operation.

Stress calculations include components due to centrifugal loads, interference fit, and thermal gradients where applicable. The ratio of material fracture toughness, K_{IC} (as derived from material tests on each major part or rotor), to the maximum tangential stress at speeds from normal to 115% of rated speed is at least 10 $\sqrt{mm}$. Adequate material facture toughness needed to maintain this ratio is assured by destructive tests on material samples using correlation methods which are as conservative, or more so, than those presented in Reference 10.2-1. However, this method of obtaining fracture toughness, K_{IC}, will be used only on materials which exhibit a well-defined Charpy energy and fracture appearance transition curve and strain-rate insensitive. The COL applicant will provide the test data and the calculated toughness curve to the NRC staff for review. (See Subsection 10.2.5.1 for COL license information.)

Turbine operating procedures are employed to preclude brittle fracture at startup by ensuring that metal temperatures are (a) adequately above the FATT, and (b) as defined above, sufficient to maintain the fracture toughness to tangential stress ratio at or above 10 $\sqrt{mm}$. Sufficient warmup time is specified in the turbine operating instruction to assure that toughness will be adequate to prevent brittle fracture during startup.

10.2.3.3 High Temperature Properties

The operating temperatures of the high-pressure rotors are below the stress rupture range. Therefore, creep-rupture is not a significant failure mechanism.

Basic stress and creep-rupture data are obtained in standard laboratory tests at appropriate temperatures with equipment and procedures consistent with ASTM recommendations in Reference 10.2-2, Subsection 10.2.6.

10.2.3.4 Turbine Design

The turbine assembly is designed to withstand normal conditions and anticipated transients, including those resulting in turbine trip, without loss of structural integrity. The design of the turbine assembly meets the following criteria:

(1) Turbine shaft bearings are designed to retain their structural integrity under normal operating loads and anticipated transients, including those leading to turbine trips.

(2) The multitude of natural critical frequencies of the turbine shaft assemblies existing between zero speed and 20% overspeed are controlled in the design and operation so as to cause no distress to the unit during operation.

(3) The maximum tangential stress resulting from centrifugal forces, interference fit, and thermal gradients does not exceed 0.75 of the yield strength of the materials at 115% of rated speed.

(4) The design overspeed of the turbine is 5% above the highest anticipated speed resulting from a loss of load. The basis for the assumed design overspeed will be submitted to the NRC staff for review. (See Subsection 10.2.5.2 for COL license information.)

(5) The turbine disk design will facilitate inservice inspection of all high stress regions. The turbine rotor design is based on using solid forged monoblock rotors rather than shrunk-on disks.

10.2.3.5 Preservice Inspection

The preservice procedures and acceptance criteria are as follows:

(1) Forgings are rough machined with minimum stock allowance prior to heat treatment.

(2) Each finished machined rotor is subjected to 100% volumetric (ultrasonic), and surface visual examinations, using established acceptance criteria. These criteria are more restrictive than those specified for Class 1 components in the ASME Boiler and Pressure Vessel Code, Sections III and V, and include the requirement that subsurface sonic indications are either removed or evaluated to ensure that they will not grow to a size which will compromise the integrity of the unit during its service life.

(3) All finished machined surfaces are subjected to a magnetic particle test with no flaw indications permissible.

(4) Each fully bucketed turbine rotor assembly is spin tested at the highest ainticipated speed resulting from a loss of load.

Additional preservice inspections include air leakage tests performed to determine that the hydrogen cooling system is tight before hydrogen is introduced into the generator casing. The hydrogen purity is tested in the generator after hydrogen has been introduced. The generator windings and all motors are megger tested. Vibration tests are performed on all motor-driven equipment. Hydrostatic tests are performed on all coolers. All piping is pressure tested for leaks. Motor-operated valves are factory leak tested and inplace tested once installed.

10.2.3.6 Inservice Inspection

The inservice inspection program for the turbine assembly includes the disassembly of the turbine and complete inspection of all normally inaccessible parts, such as couplings, coupling bolts, turbine shafts, low-pressure turbine buckets, low-pressure and high-pressure rotors. During plant shutdown coinciding with the inservice inspection schedule for ASME Section III components, as required by the ASME Boiler and Pressure Vessel Code, Section XI, turbine inspection is performed in sections during the refueling outages so that in 10 years total inspection has been completed at least once.

This inspection consists of visual and surface examinations as indicated below:

(1) Visual examination of all accessible surfaces of rotors.

(2) Visual and surface examination of all low-pressure buckets.

(3) 100% visual examination of couplings and coupling bolts.

The inservice inspection of valves important to overspeed protection includes the following:

(1) All main stop valves, control valves, extraction nonreturn valves, and CIVs will be tested under load. Test controls installed on the main control room turbine panel permit full stroking of the stop valve, control valves, and CIVs. Valve position indication is provided on the panel. Some load reduction is necessary before testing main stop and control valves, and CIVs. Extraction nonreturn valves are tested by equalizing air pressure across the air cylinder. Movement of the valve arm is observed upon action of the spring closure mechanism.

(2) Main stop valves, control valves, extraction nonreturn valves, and CIVs will be tested by the COL applicant in accordance with the BWROG turbine surveillance test program, by closing each valve and observing by the valve position indicator that it moves smoothly to a fully closed position. Closure of each main stop valve, control valve and CIV during test will be verified by direct observation of the valve motion.

    Tightness tests of the main stop and control valves are performed at least once per maintenance cycle by checking the coastdown characteristics of the turbine from no load with each set of four valves closed alternately.

(3) All main stop valves, main control valves, and CIVs will be inspected once during the first three refueling or extended maintenance shutdowns. Subsequent inspections will be scheduled by the COL applicant in accordance with the BWROG turbine surveillance test program. The inspections will be conducted for:

    (a) Wear of linkages and stem packings.

    (b) Erosion of valve seats and stems.

    (c) Deposits on stems and other valve parts which could interfere with valve operation.

    (d) Distortions, misalignment.

Inspection of all valves of one type will be conducted if any unusual condition is discovered.

10.2.4 Evaluation

The turbine-generator is not nuclear safety-related and is not needed to effect or support a safe shutdown of the reactor.

The turbine is designed, constructed, and inspected to minimize the possibility of any major component failure.

The turbine has a redundant, testable overspeed trip system to minimize the possibility of a turbine overspeed event.

Unrestrained stored energy in the extraction steam system has been reduced to an acceptable minimum by the addition of nonreturn valves in selected extraction lines.

The T-G equipment shielding requirements and the methods of access control for all areas of the Turbine Building ensure that the dose criteria specified in 10CFR20 for operating personnel are not exceeded.

All areas in proximity to T-G equipment are zoned according to expected occupancy times and radiation levels anticipated under normal operating conditions.

Specification of the various radiation zones in accordance with expected occupancy is listed in Chapter 12.

If deemed necessary during unusual occurrences, the occupancy times for certain areas will be reduced by administrative controls enacted by health physics personnel.

The design basis operating concentrations of N-16 in the turbine cycle are indicated in Section 12.2.

The connection between the low-pressure turbine exhaust hood and the condenser is made by means of a stainless steel expansion joint.

Since there is no nuclear safety-related mechanical equipment in the turbine area and since the condenser is at subatmospheric pressure during all modes of turbine operation, failure of the joint will have no adverse effects on nuclear safety related equipment.

The T-G trip logic and control schemes will respectively use coincident logic and redundant controllers and input signals to assure that the plant availability goals are achieved and spurious trips are avoided.

10.2.5 COL License Information

10.2.5.1 Low Pressure Turbine Disk Fracture Toughness

The COL applicant will provide turbine material property data and assure sufficient turbine warmup time as required by Subsection 10.2.3.2.

10.2.5.2 Turbine Design Overspeed

The COL applicant will provide the basis for the turbine overspeed as required by Subsection 10.2.3.4(4).

10.2.5.3 Turbine Inservice Test and Inspection

The COL applicant will provide the turbine inservice test and inspection requirements as noted in Subsection 10.2.3.6.

10.2.6 References

10.2-1 J. A. Begley and W.A. Logsdon, Westinghouse Scientific Paper 71-1E7 MSLRF-P1.

10.2-2 ASTM Section III, Vol 03.01, E139-83 “Standard Practice for Conducting Creep, Creep Rupture and Stress Rupture Tests for Metallic Materials.”

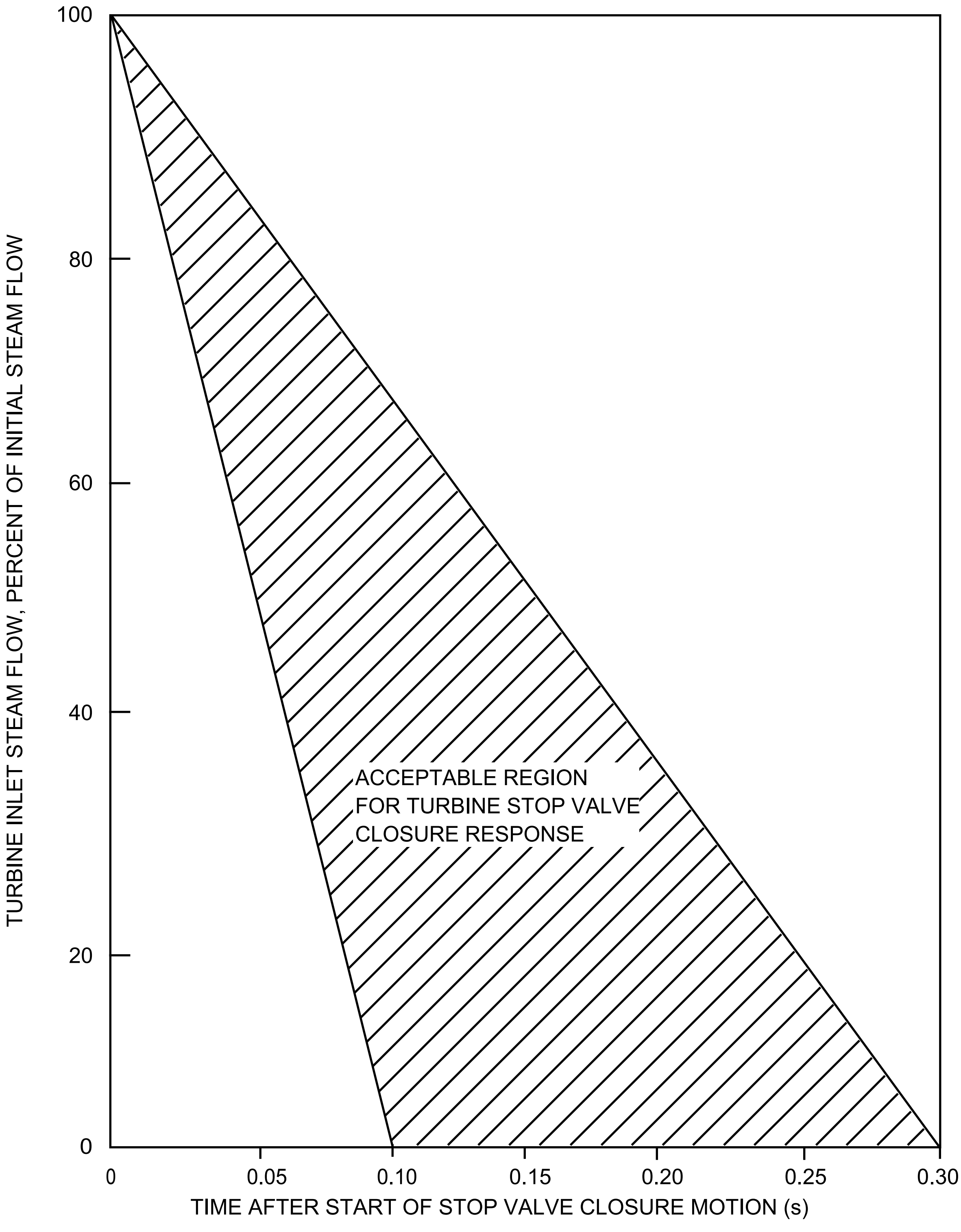

Figure 10.2-1 Turbine Stop Valve Closure Characteristic

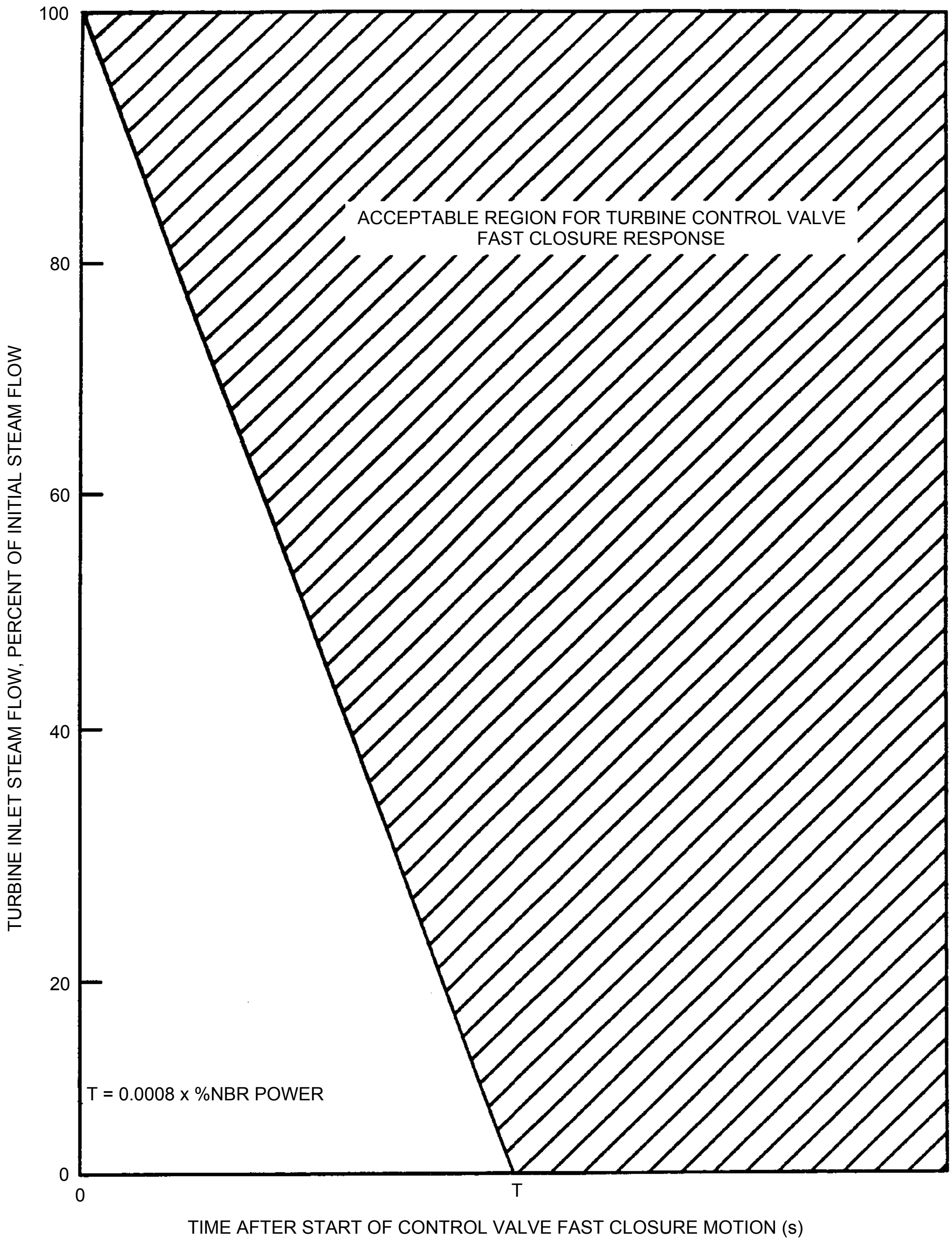

Figure 10.2-2 Turbine Control Valve Fast Closure Characteristic

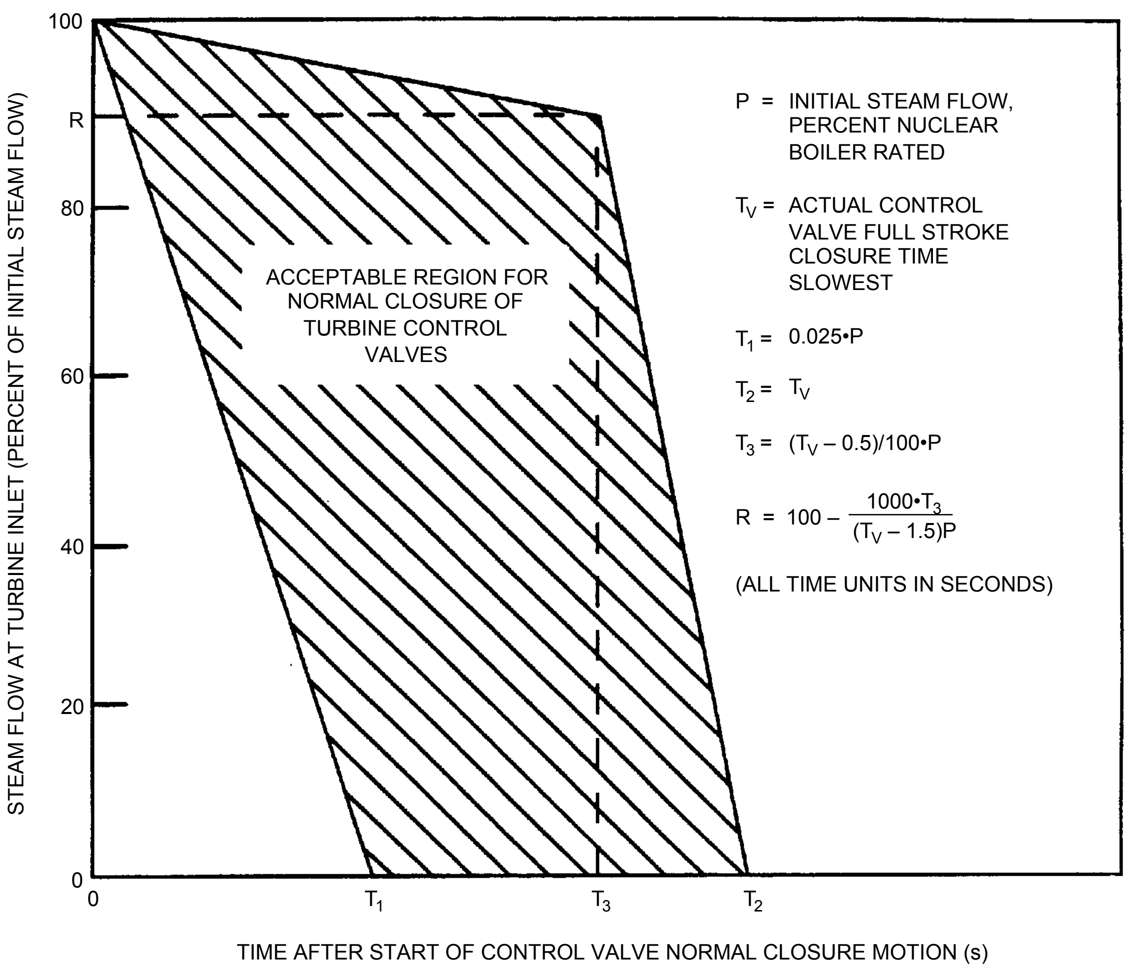

Figure 10.2-3 Acceptable Range for Control Valve Normal Closure Motion

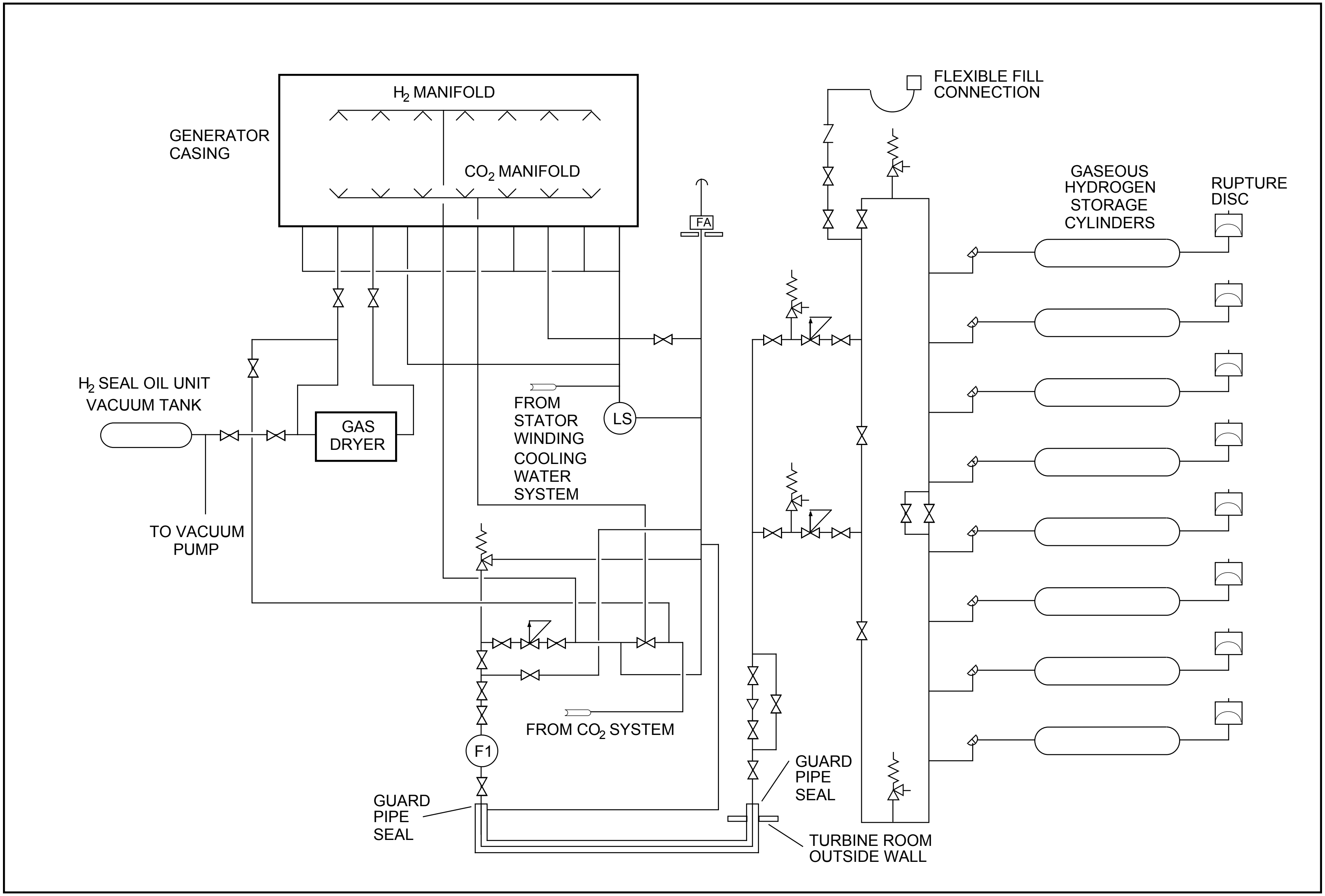

Figure 10.2-4 Generator Hydrogen and CO_2 System

10.3 Main Steam Supply System

The function of the Main Steam Supply System is to convey steam generated in the reactor to the turbine plant. This section discusses that portion of the main steam supply system bounded by, but does not include, the seismic interface restraint, turbine stop valves and turbine bypass valves. This portion does include the steam auxiliary valve(s). This portion of the main steam supply system is designated as the turbine main steam system.

The main steamline pressure relief system, main steamline flow restrictors, main steamline isolation valves (MSIVs), and main steam piping from the reactor nozzles through the outboard MSIVs to the seismic interface restraint are described in Subsections 5.2.2, 5.4.4, 5.4.5, and 5.4.9, respectively.

10.3.1 Design Bases

10.3.1.1 Safety Design Bases

The Main Steam Supply System is not required to effect or support safe shutdown of the reactor or to perform in the operation of reactor safety features; however, the supply system is designed:

(1) To accommodate operational stresses such as internal pressure and dynamic loads without failures.

(2) To provide a seismically analyzed fission product leakage path to the main condenser.

(3) With suitable accesses to permit inservice testing and inspections.

(4) To close the steam auxiliary valve(s) on an MSIV isolation signal. These valves fail closed on loss of electrical power to the valve actuating solenoid or on loss of pneumatic pressure.

The main steam system piping consists of four lines from the seismic interface restraint to the main turbine stop valves. The header arrangement upstream of the turbine stop valves allows them to be tested online and also supplies steam to the power cycle auxiliaries, as required.

The main steam system is analyzed, fabricated and examined to ASME Code Class 2 requirements, classified as non-Seismic Category I, and subject to pertinent QA requirements of Appendix B, 10CFR50. Inservice inspection shall be performed in accordance with ASME Section XI requirements for Code Class 2 piping. ASME authorized nuclear inspector and ASME Code stamping is not required.

Main steam piping from the seismic interface restraint to the main stop, main turbine bypass, including the steam auxiliary valves(s) is analyzed to demonstrate structural integrity under safe shutdown earthquake (SSE) loading conditions. Refer to Subsection 3.2.5.3 for seismic classification for the lines.

10.3.1.2 Power Generation Design Bases

Power Generation Design Basis One—The system is designed to deliver steam from the reactor to the turbine-generator system for a range of flows and pressures varying from warmup to rated conditions. It also provides steam to the reheaters, the steam jet air ejectors, the turbine gland seal system, the offgas system and the deaerating section of the main condenser and the turbine bypass system.

10.3.2 Description

10.3.2.1 General Description

The Main Steam Supply System is illustrated in Figure 10.3-1. The system design data is provided in Table 10.3-1. The main steam piping consists of four 700A pipe size diameter lines from the outboard MSIVs to the main turbine stop valves. The four main steamlines are connected to a header upstream of the turbine stop valves to permit testing of the MSIVs during plant operation with a minimum load reduction. This header arrangement is also provided to ensure that the turbine bypass and other main steam supplies are connected to operating steamlines and not to idle lines. The main steam process downstream of the turbine stop valves is illustrated in Figure 10.3-2.

The design pressure and temperature of the main steam piping is 8.62 MPaG and 302°C, respectively, the same values as the design parameters of the reactor. The main steam-lines are classified as discussed in Section 3.2.

A drain line is connected to the low points of each main steamline, both inside and outside the containment. Both sets of drains are headered and connected with isolation valves to allow drainage to the main condenser. To permit intermittent draining of the steamline low points at low loads, orificed lines are provided around the final valve to the main condenser. The steamline drains, except through Control Building, maintain a continuous downward slope from the steam system low points to the orifice located near the condenser. The drain line from the orifice to the condenser also slopes downward. To permit emptying the drain lines for maintenance, drains are provided from the line low points going to the radwaste system.

The drains from the steamlines inside containment are connected to the steamlines outside the containment to permit equalizing pressure across the MSIVs during startup and following a steamline isolation.

See Subsection 10.3.7.2 for COL license information pertaining to allowable MSIV leakage.

10.3.2.2 Component Description

The Main Steam Supply System lines are made of carbon steel and are sized for a normal steady-state velocity of 45.72 m/s, or less. The lines are designed to permit hydrotesting following construction and major repairs without addition of temporary pipe supports.

10.3.2.3 System Operation

Normal Operation—At low plant power levels, the Main Steam System may be used to supply steam to the turbine gland steam seal system. At high plant power levels, turbine gland sealing steam is normally supplied from the high pressure heater drain tank or related turbine extraction.

Steam is supplied to the crossaround steam reheaters in the T-G system when the T-G load exceeds approximately 15% and supply steam pressure is controlled by regulating valves in the 15 to approximately 60% load range.

If a large, rapid reduction in T-G load occurs, steam is bypassed directly to the condenser via the turbine bypass system (see Subsection 10.4.4 for a description of the turbine bypass system).

10.3.3 Evaluation

All components and piping for the main steam supply system are designed in accordance with the codes and standards listed in Section 3.2. This ensures that the Main Steam Supply System accommodates operational stresses resulting from static and dynamic loads, including steam hammer and normal and abnormal environmental conditions. The COL applicant shall provide operating and maintenance procedures that include adequate precautions to avoid steam hammer and relief valve discharge loads (see Subsection 10.3.7.1 for COL license information requirements).

The break of a main steamline or any branch line will not result in radiation exposures in excess of the limits of 10CFR100 to persons located offsite because of the safety features designed into the system. The main steamline pipe break accident is addressed in Chapter 15, and high energy pipe failure is discussed in Section 3.6.

10.3.4 Inspection and Testing Requirements

Inspection and testing will be in accordance with the requirements of Section 3.2. The main steamline will be hydrostatically tested to confirm leaktightness.

10.3.5 Water Chemistry (PWR)

This section applies to a pressurized water reactor (PWR), and is therefore not applicable.

10.3.6 Steam and Feedwater System Materials

Steam and feedwater component materials are identified in Table 5.2-4.

10.3.6.1 Fracture Toughness of Class 2 Components

The fracture toughness properties of the ferritic materials of these components will meet the requirements of NC-2300, "Fracture Toughness Requirements for Materials" (Class 2) of ASME Code Section III, as invoked by Regulatory Guide 1.26, "Quality Group Classification and Standards for Water-, Steam-, and Radioactive-Waste-Containing Components of Nuclear Power Plants." This also includes the portion of the main steam supply system defined in Section 10.3.

10.3.6.2 Materials Selection and Fabrication

The materials specified for use in Class 2 components will conform to Appendix I to ASME Code Section III, and to Parts A, B, and C of Section II of the Code.

Regulatory Guide 1.85, "Code Case Acceptability ASME Section III Materials", describes acceptable code cases that will be used in conjunction with the above specifications.

The following criteria are applicable to all components:

(1) Regulatory Guide 1.71, "Welder Qualification for Areas of Limited Accessibility", provides the following criteria for assuring the integrity of welds in locations of restricted direct physical and visual accessibility:

   (a) The performance qualification should require testing of the welds when conditions of accessibility to production welds are less than 30 to 35 cm in any direction from the joint.

   (b) Requalification is required for different accessibility conditions or when other essential variables listed in the Code, Section IX, are changed.

   (c) The qualification and requalification tests required by (a) and (b) above may be waived, provided that the joint is to be 100% radiographed or ultrasonically examined after completion of the weldment. Examination procedures and acceptance standards should meet the requirements of ASME Code Section III. Records of the examination reports and radiographs should be retained and made part of the Quality Assurance documentation of the completed weld.

(2) Regulatory Guide 1.37, "Quality Assurance Requirements for Cleaning of Fluid Systems and Associated Components of Water-Cooled Nuclear Power Plants" describes acceptable procedures for cleaning and handling Class 2 components of the steam and feedwater systems. Vented tanks with deionized

or demineralized water are an acceptable source of water for final cleaning or flushing of finished surfaces. The oxygen content of the water in these vented tanks need not be controlled.

(3) Acceptance criteria for nondestructive examination of tubular products are given in ASME Code Section III, Paragraphs NC 2550 through 2570.

10.3.7 COL License Information

10.3.7.1 Procedures to Avoid Steam Hammer and Discharge Loads

The COL applicant will provide operating and maintenance procedures that include adequate precautions to avoid steam hammer and discharge loads (Subsection 10.3.3).

10.3.7.2 MSIV Leakage

The COL applicant will provide the amount of allowable MSIV leakage for review by the NRC (Subsection 10.3.2).

Table 10.3-1 Main Steam Supply System Design Data

Main Steam Piping	
Design flow rate at 6.79 MPaA and 0.40% moisture, kg/h	~7.71E+06
Number of lines	4
Nominal diameter	700A
Minimum wall thickness, mm	38.1
Design pressure,MPaG	8.62
Design temperature, °C	302
Design code	ASME III, Class 2
Seismic design	Analyzed for SSE design loads

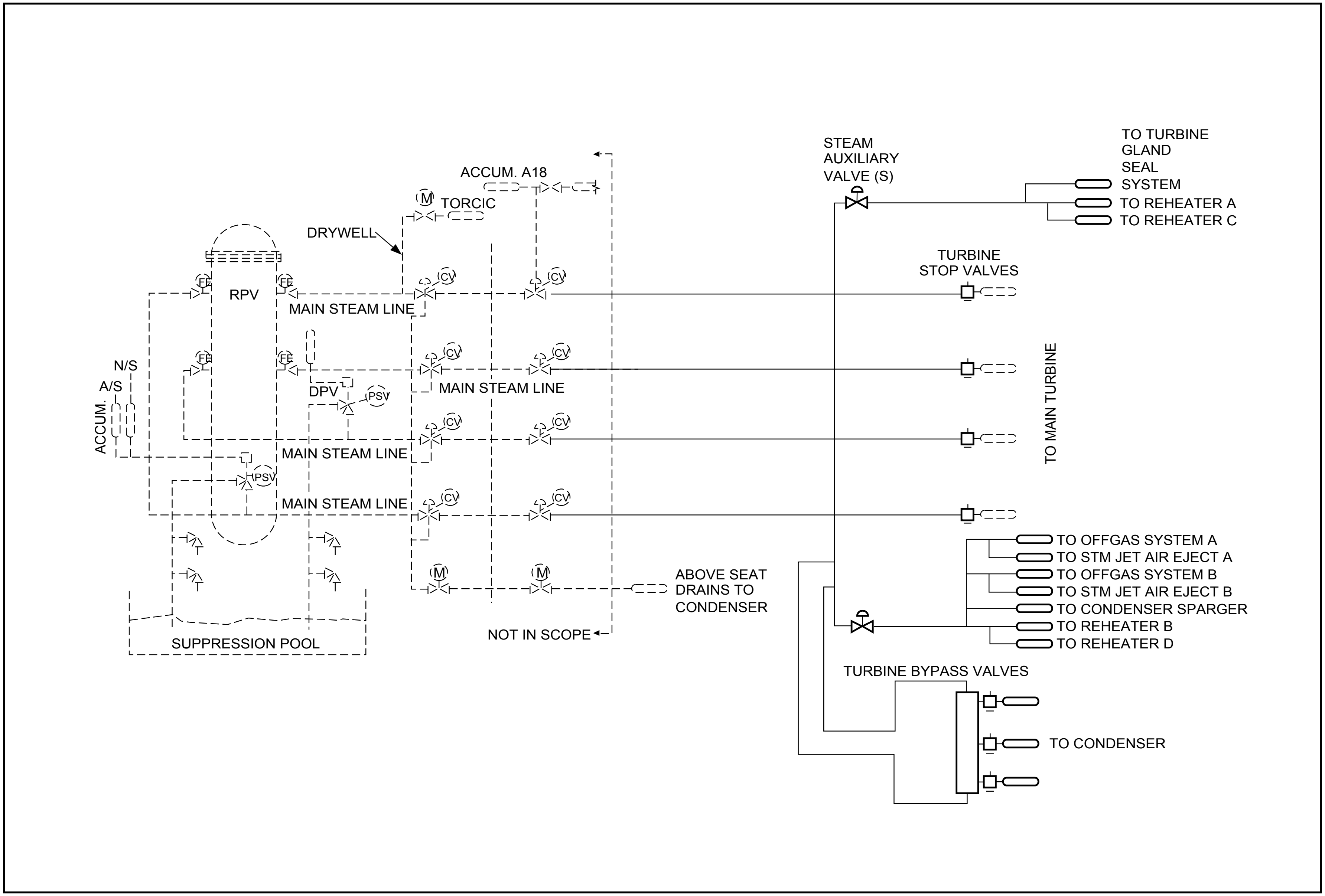

Figure 10.3-1 Main Steam Supply System

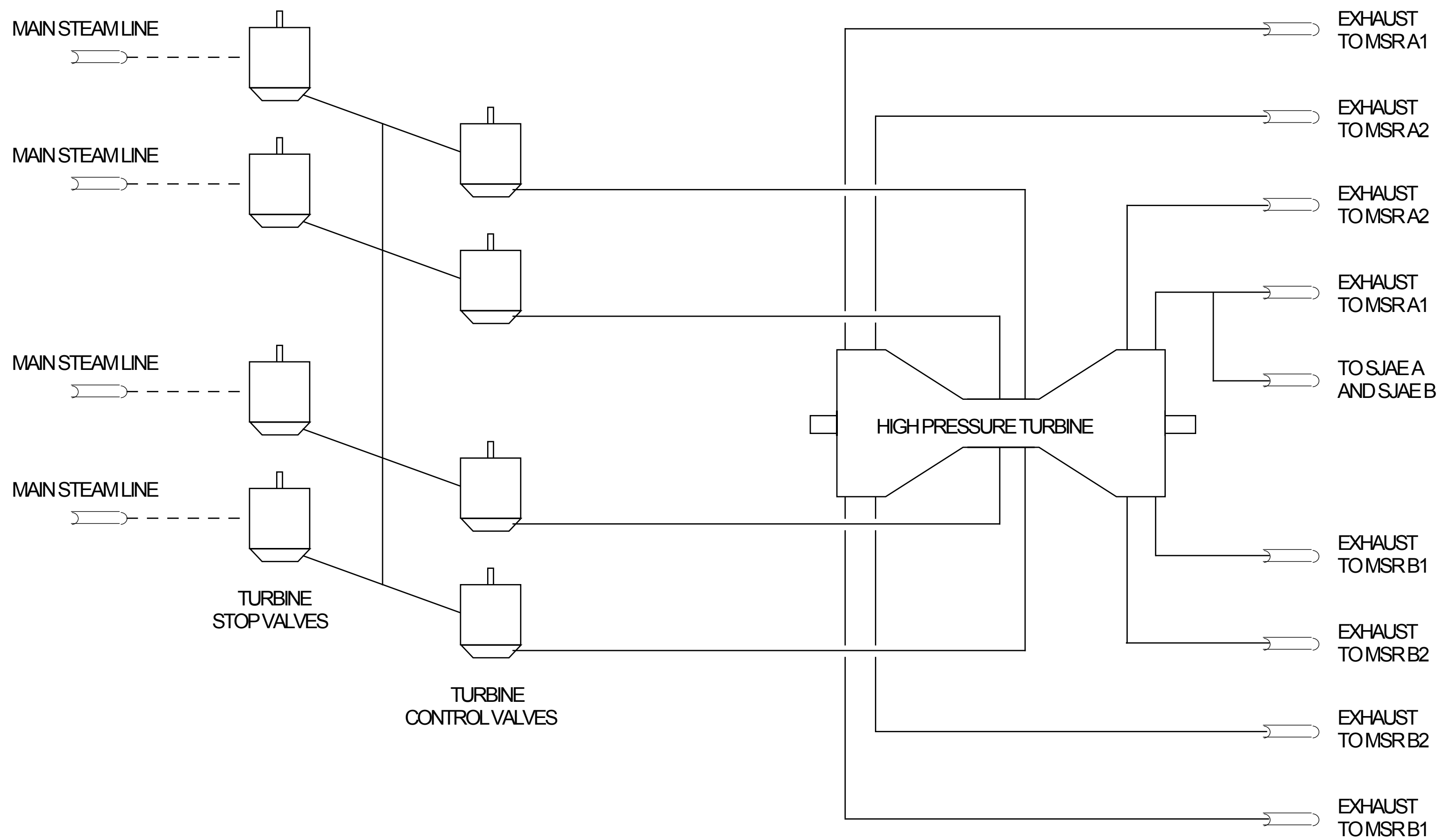

Figure 10.3-2 Main Turbine System

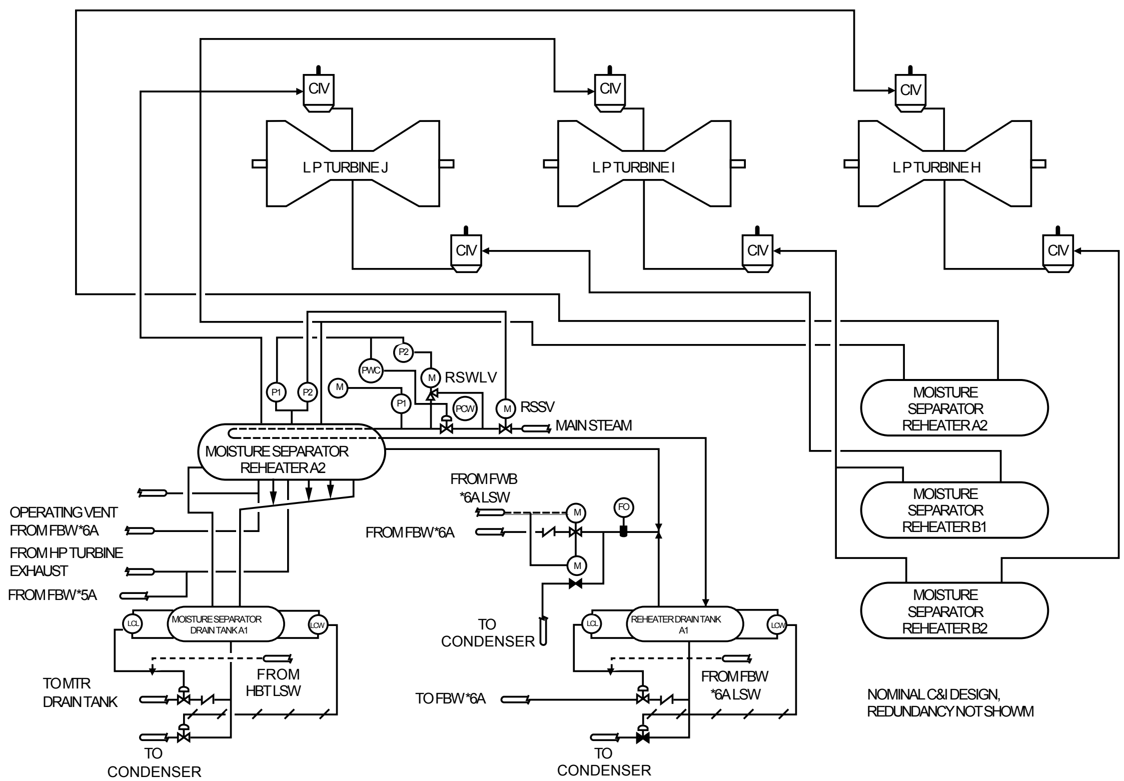

Figure 10.3-2 Main Turbine System (Continued)

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 multipressure, three-shell, reheating/deaerating unit. Each shell is located beneath its respective low-pressure turbine.

The three condenser shells are designated as the low-pressure shell, the intermediate-pressure shell, and the high-pressure shell. Each shell has at least two tube bundles. Circulating water flows in series 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 and reference data that is typical of condensers operating with closed loop circulating water systems. Nothing in this section precludes the use of a single pressure condenser and parallel (instead of series) circulating water system since these will have no effect on the Nuclear Island.

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 availibility 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, Recirculation Flow 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 at0.074 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.

Condenser pressure is an input to the Reactor Recirculation System. Recirculation pump runback is initiated upon the trip of a circulating water pump when condenser pressure is higher than some site specific preset value. Runback is automatically initiated 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 (Figure 10.4-1) consists of two 100%-capacity, double stage, steam jet air ejector (SJAE) units (complete with intercondenser) for power plant operation, and a mechanical vacuum pump 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 pump establishes a vacuum in the main condenser and other parts of the power cycle. The discharge from the vacuum pump is then routed to the Turbine Building compartment exhaust system, since there is then little or no effluent radioactivity present. Radiation detectors in the Turbine Building compartment exhaust system 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 0.034 to 0.051 MPa absolute is established in the main condenser by the mechanical vacuum pump and when sufficient nuclear steam pressure is available.

During normal power operations, the SJAEs are normally driven by crossaround steam, with the main steam supply on automatic standby. The main steam supply, however, is normally used during startup and low load operation, and auxiliary steam is available for normal use of the SJAEs during early startup, should the mechanical vacuum pump prove to be unavailable.

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 pump by a pressure transmitter or switch. Upon reaching a preset vacuum, the pressure switch energizes a solenoid valve, which allows additional seal water to be pumped to the vacuum pump. 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 pump exhaust stream is discharged to the Turbine Building compartment exhaust system, which provides for radiation monitoring of the system effluents prior to their release to the monitored vent stack and the atmosphere.

The vacuum pump is tripped and its discharge valve is 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 Figure 10.4-2. The turbine gland seal system consists of a 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 seal steam header pressure is regulated automatically by a pressure controller. During startup and low load operation, the seal steam is supplied from the main steam line or auxiliary steam header. Above approximately 50% load, however, sealing steam is normally provided from the heater drain tank vent header. 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 1.52 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, which eventually exhausts to the plant vent and the atmosphere (Section 11.3), makes a negligible contribution to overall plant radiation release. 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.

10.4.4 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 40% electrical step-load reduction without reactor trip. The systems will also allow a turbine trip but 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 40% of the T-G rated load without reactor trip and without the operation of safety/relief valves. A load rejection in excess of 40% is expected to result in reactor trip but without operation of any steam safety valve.

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 servo 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 automatic load-following mode, a 10% load reduction can be accommodated without opening the bypass valves, and a 25% load reduction can be accommodated with momentary opening of the bypass valves. These load changes are accomplished by change in reactor recirculating flow without any control rod motion.

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 load demand and load reference signals from the turbine speed load control system. The SB&PC System uses these three signals to position the turbine control valves, the bypass valves, and, indirectly the reactor internal recirculation pump speed. 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) screen house 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 0°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 at least three fixed speed 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 is designed to permit isolation of each set of the three series connected 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 and the pump and condenser isolation valves are closed in the event of a system isolation signal from the condenser pit high-high level switches. 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 series connected 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.

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 condenser pit. 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.

Level switches or transmitters monitor water level in the condenser discharge water boxes and provide a permissive for starting the circulating water pumps. These level switches ensure that the supply piping and the condenser water boxes are full of water prior to circulating water pump startup, 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 each half of 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 computer 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 screen house intake. 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:

> screen house 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 natural draft cooling tower. Water circulation, water makeup, (losses due to evaporation, wind, and blowdown) 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 GE 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 turbidity and 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 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 33-50% capacity condensate pumps (three normally operating and one on automatic standby), three normally operated 33-65% capacity reactor feedwater pumps, 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 in parallel through five auxiliary condenser/coolers, (one gland steam exhauster condenser and two sets of SJAE condensers and offgas recombiner condenser (coolers). 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 reheaters and from the two sets of high-pressure feedwater heaters, are directed to the heater drain tanks. The reheater and top heater drains are deaerated in the crossaround heaters so that, after mixing with condensate, the drains are compatible with the reactor feedwater quality requirements for oxygen content during normal power operations. Each 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 head.

Another bypass, equipped with a feedwater flow control valve, is provided around the high-pressure heaters to perform two independent functions. During startup, the bypass and its flow control valve are 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 heater bypass function is to maintain full feedwater flow capability when a high-pressure heater string must be isolated for maintenance.

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 reactor feedwater pump suction header 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.

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, and their drains are cascaded to the next lower stage heaters of the same string except for the lowest pressure heaters which drain to the main condensers. 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 their respective heater drain tanks. 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 plant 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 vents from the steam side of the feedwater heaters are piped to the main condenser except for the highest pressure heater operating vents which discharge to the cold reheat lines. Discharges from shell relief valves on the steam side of the feedwater heaters are piped to the main condenser.

Heater Drain Tank—Heater drain tank(s) are 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 tanks and tank drain lines are designed to maintain the drain pumps available suction head 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 15.24m) and optimizing the drain lines which would affect the drain system transient response, particularly the drain pump suction line.

Heater Drain Pumps—Two motor-driven heater drain pumps operate in parallel, each taking suction from the heater drain tank and discharging into the suction side of the reactor feedwater pumps. The drain system design allows each heater drain pump to be individually removed from service for maintenance while the balance of the system remains in operation, while the affected string drains dump to the condenser.

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—Three identical and independent 33–65% capacity reactor feedwater pumps (RFP) are provided. The three pumps manually 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 two 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 tanks. 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 high-pressure heater bypass 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 and the heater bypass startup flow control valve. These 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 (offgas recombiner condenser/coolers, 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	Transversal, 3 shells, Reheating/Deaerating
Design duty, kW-total 3 shells	254.91×10^4
Shell pressures w/26.7°C Circ. water, MPaA	0.007,0.009,0.012
Circulating water flow rate, m^3/h	136,290
Tubeside temp. rise-total 3 shells, °C	16.8
Shell design pressure range, MPaA	0 to 0.207
Hotwell storage capacity-total 3 shells, L	378,540
Channel design pressure range, MPaA	0 to 0.586
Surface Area, cm^2	929.03×10^6
Number of tube passes per shell	1
Applicable codes and standards	ASME Sect. VIII, Div. I, ANSI Standards, HEI Standards for Steam Surface Condensers

* Condenser surface and performance parameters are site dependent. Values quoted above are for reference purposes only.

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	0.828
	Normal steam supply source	Cross-around
Start-up Vacuum Pump System		
	Number of pumps and capacity	1 x 100%

Table 10.4-3 Circulating Water System

Circulating Water Pumps	
Number of pumps	3*
Pump type	Vertical, wet pit
Unit flow capacity, m^3/h	$\simeq$ 45,430
Driver Type	Fixed speed motor
Other System Features	
Pump discharge valve & actuator	Butterfly, motor
Condenser isolation valve & actuator	Butterfly, motor
Number of water box drain pump	1

* Number of pumps and pump flow are site dependent. Values quoted above are for reference purposes only.

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	1704
Design pressure, MPaG	$\simeq$ 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	$\simeq$ 1022
Specific flow rate, $L/s/m^2$	Normal: 0.234 (Max: 0.352)
Design pressure, MPaG	$\simeq$ 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	
Normal flowrate*, kg/h	~3,803,850
Number of lines	3
Nominal pipe size	500A
Fluid velocity, cm/s	~396.24
Fluid temperature, °C	157.22
Design code	ANSI B31.1
Seismic design	Analyzed for SSE design loads
Main Feedwater Piping	
Design (VWO) flowrate, kg/h	~8,164,620
Number of lines	2
Nominal pipe size	550A
Fluid velocity, m/s	~185.8
Fluid temperature, °C	223.89
Design code	ANSI B31.1
Seismic design	Analyzed for SSE design loads

* Based on VWO feedwater flow and one heater drain pump out of service.

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 (condensate pump capacity is 50%).	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 reduced 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.	50% of the high pressure drains are dumped to condenser.	None. The condensate and drain systems are designed to permit operation with normal full reactor power, feedwater temperature, and flow rate.
Heater drain pump	Drains from affected heater drain subsystem are dumped to condenser.	50% of HP feedwater heater drains are dumped to condenser.	None. The condensate and drain systems are designed to permit operation with normal full reactor power, feedwater temperature, and flow rate.
Reactor feedwater pump	None. Feedwater pumps are interconnected.	Operations may continue at full capacity, using 2 parallel pumps. Each reactor feedwater pump capacity is 65%.	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.

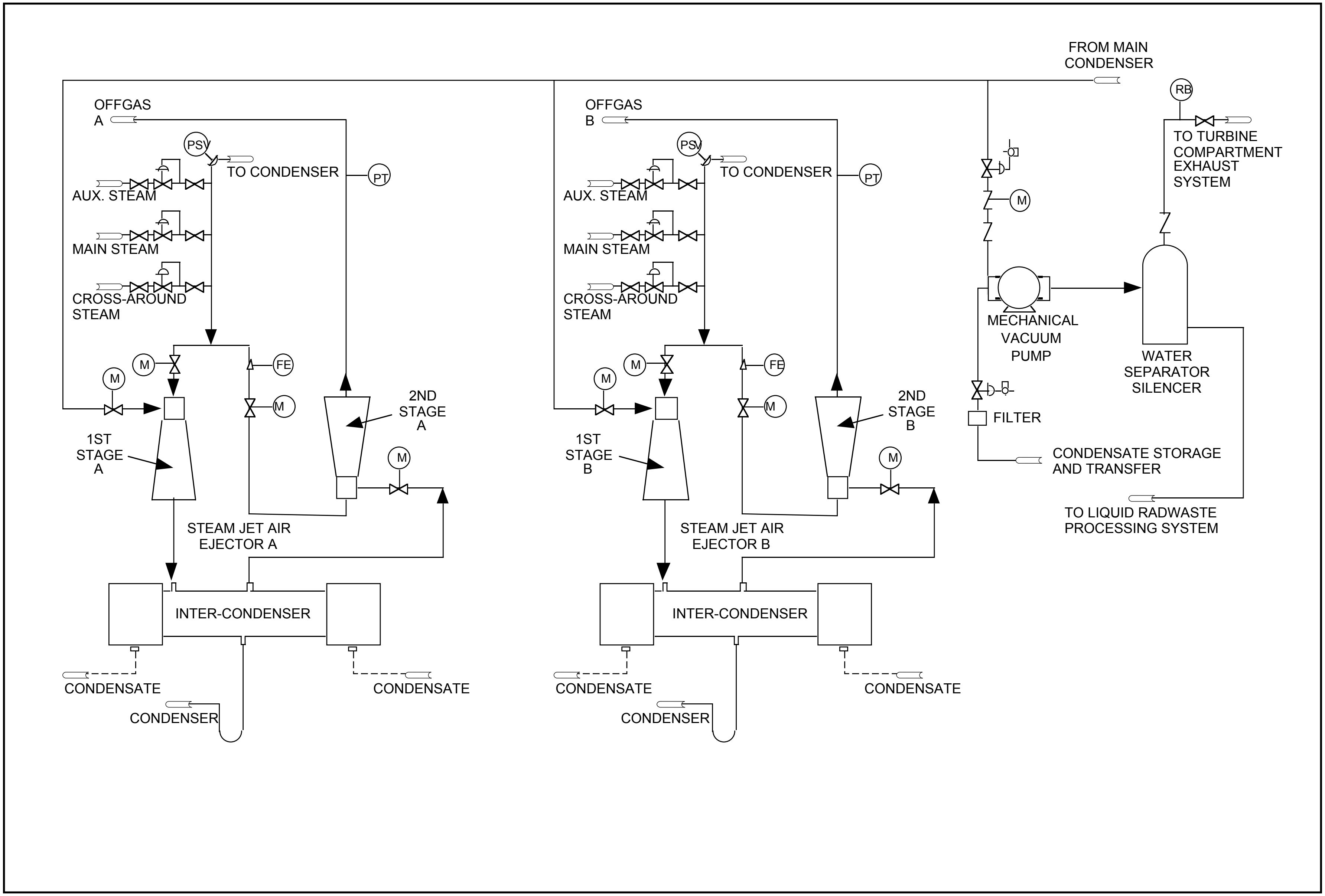

Figure 10.4-1 Main Condenser Evacuation System

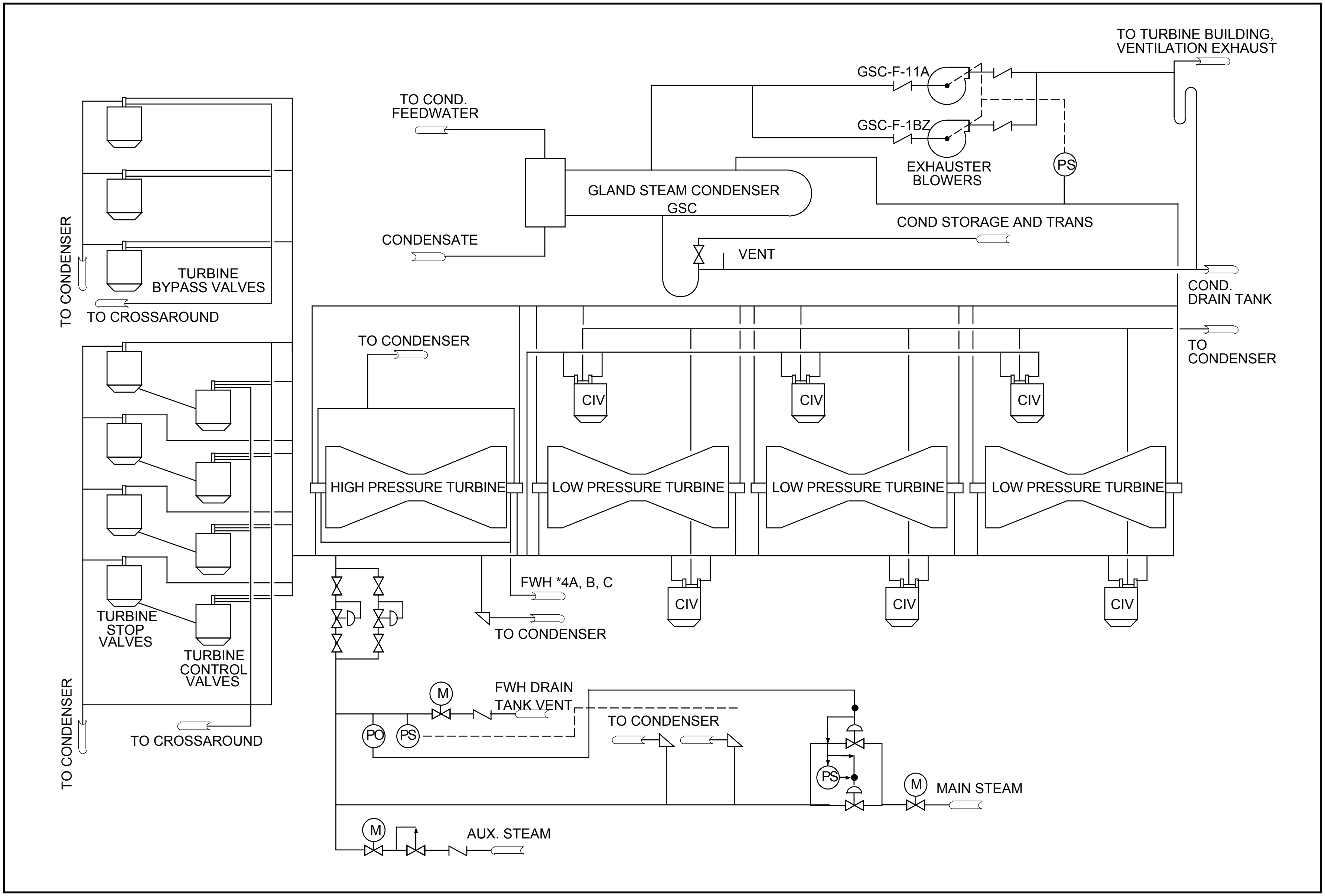

Figure 10.4-2 Turbine Gland Seal System

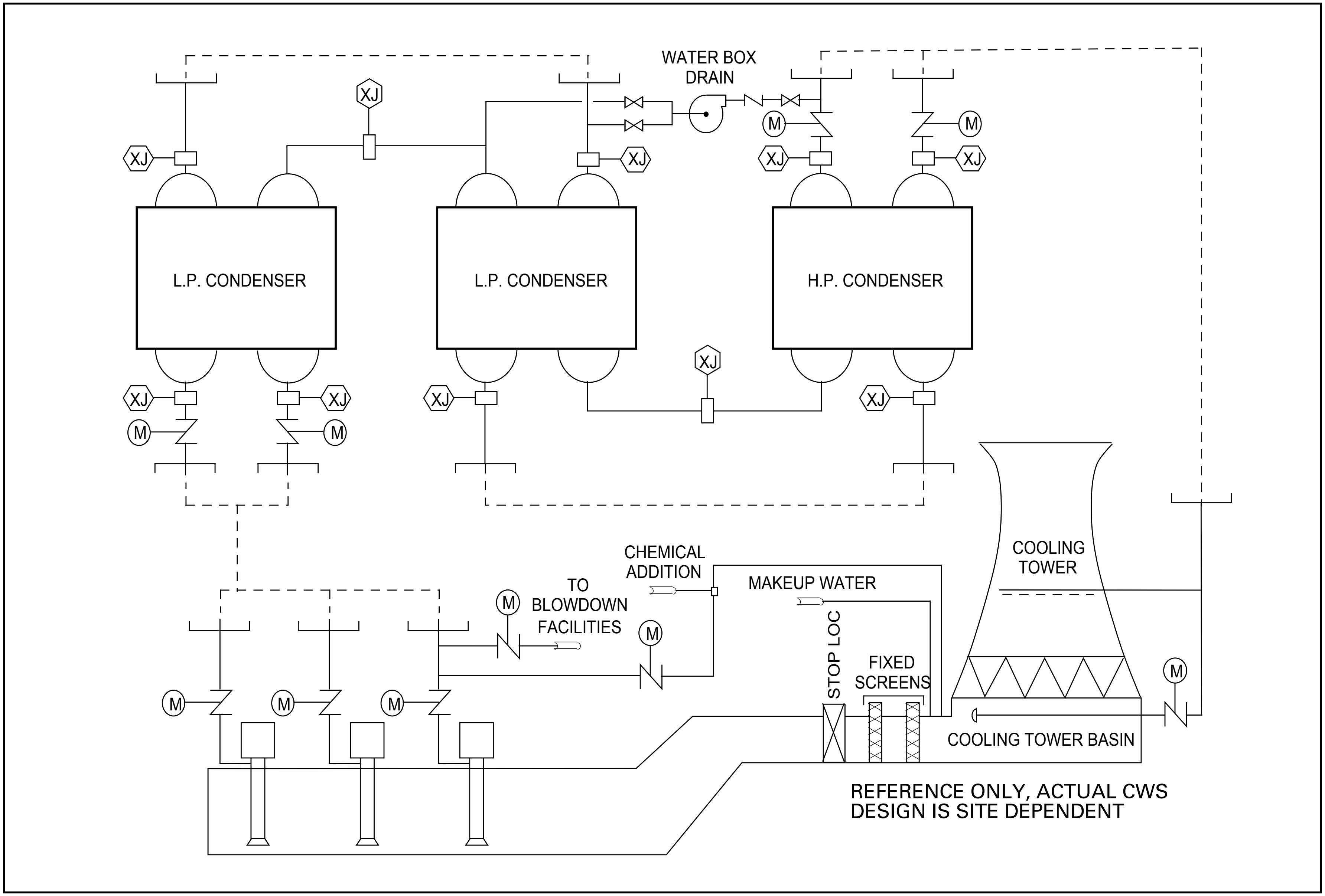

Figure 10.4-3 Circulating Water System

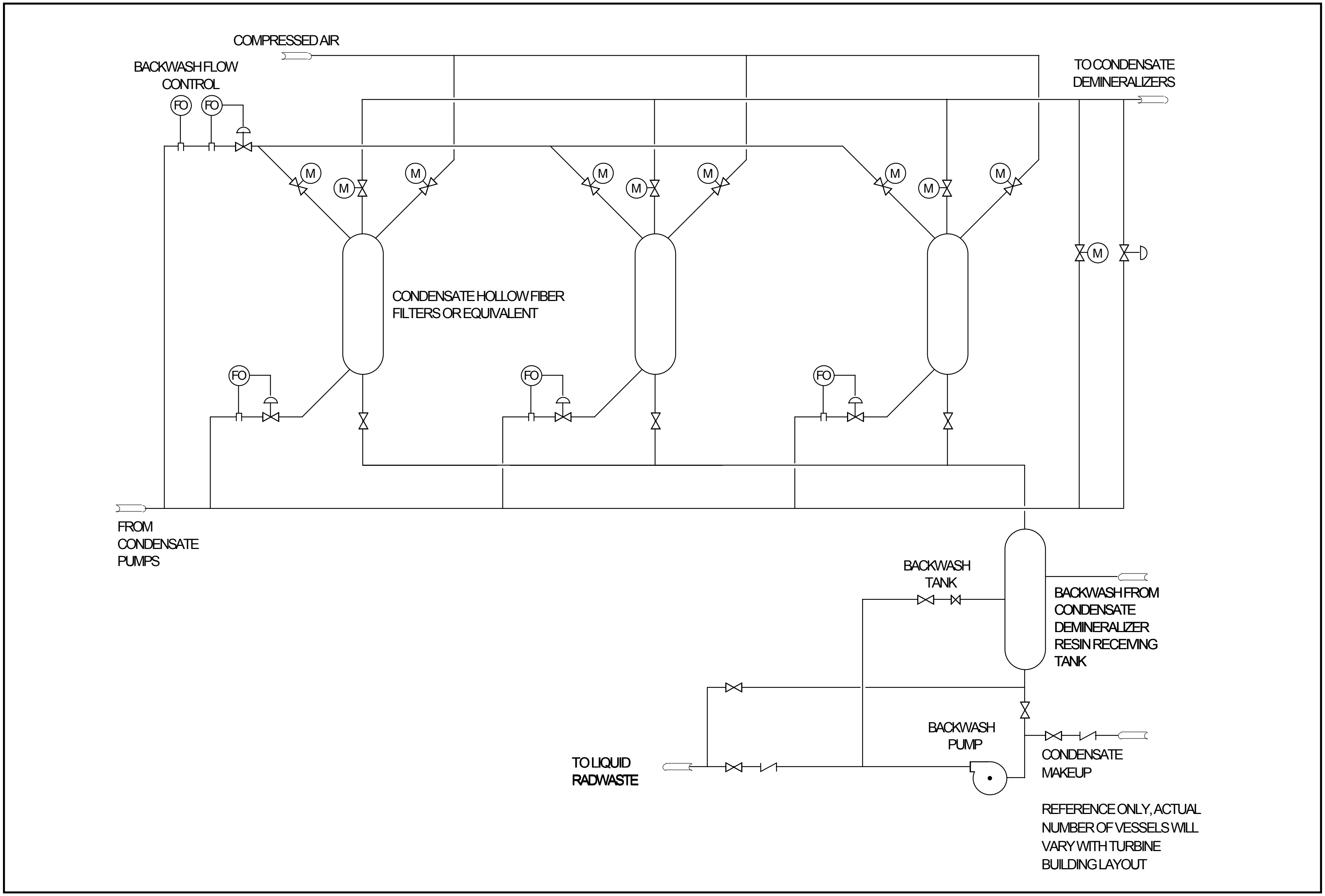

Figure 10.4-4 Condensate Purification System

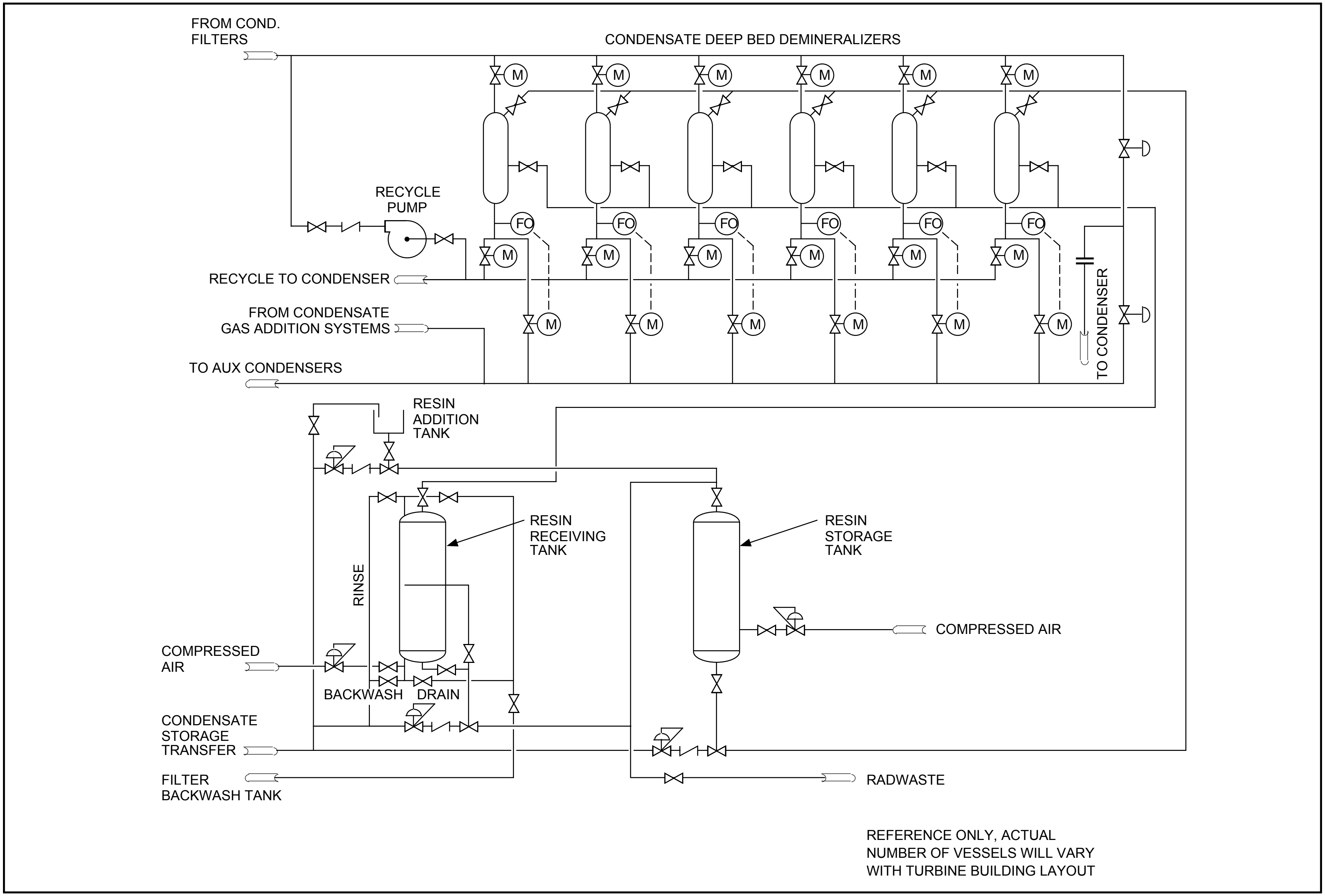

Figure 10.4-4 Condensate Purification System (Continued)

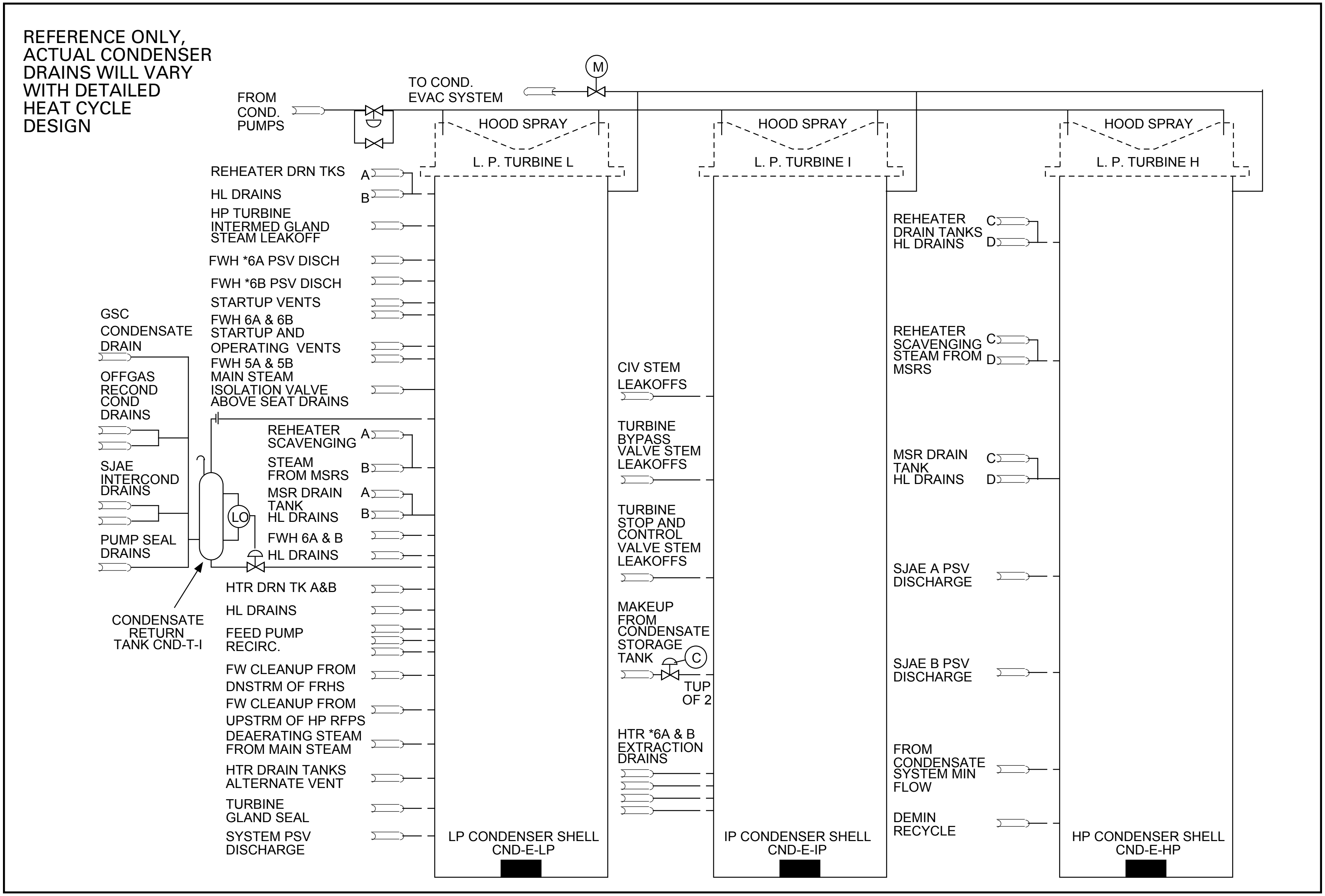

Figure 10.4-5 Condensate System

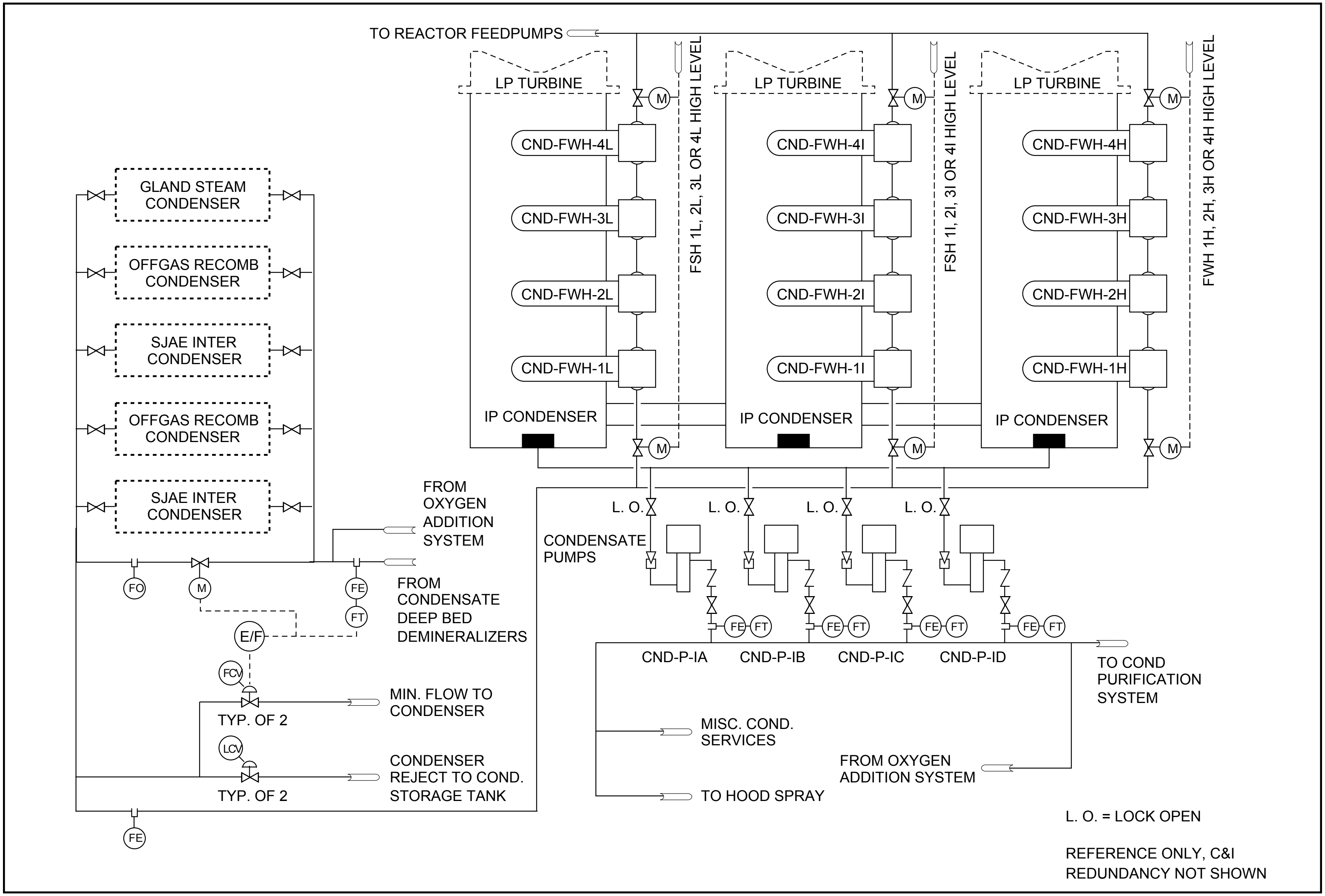

Figure 10.4-5 Condensate System (Continued)

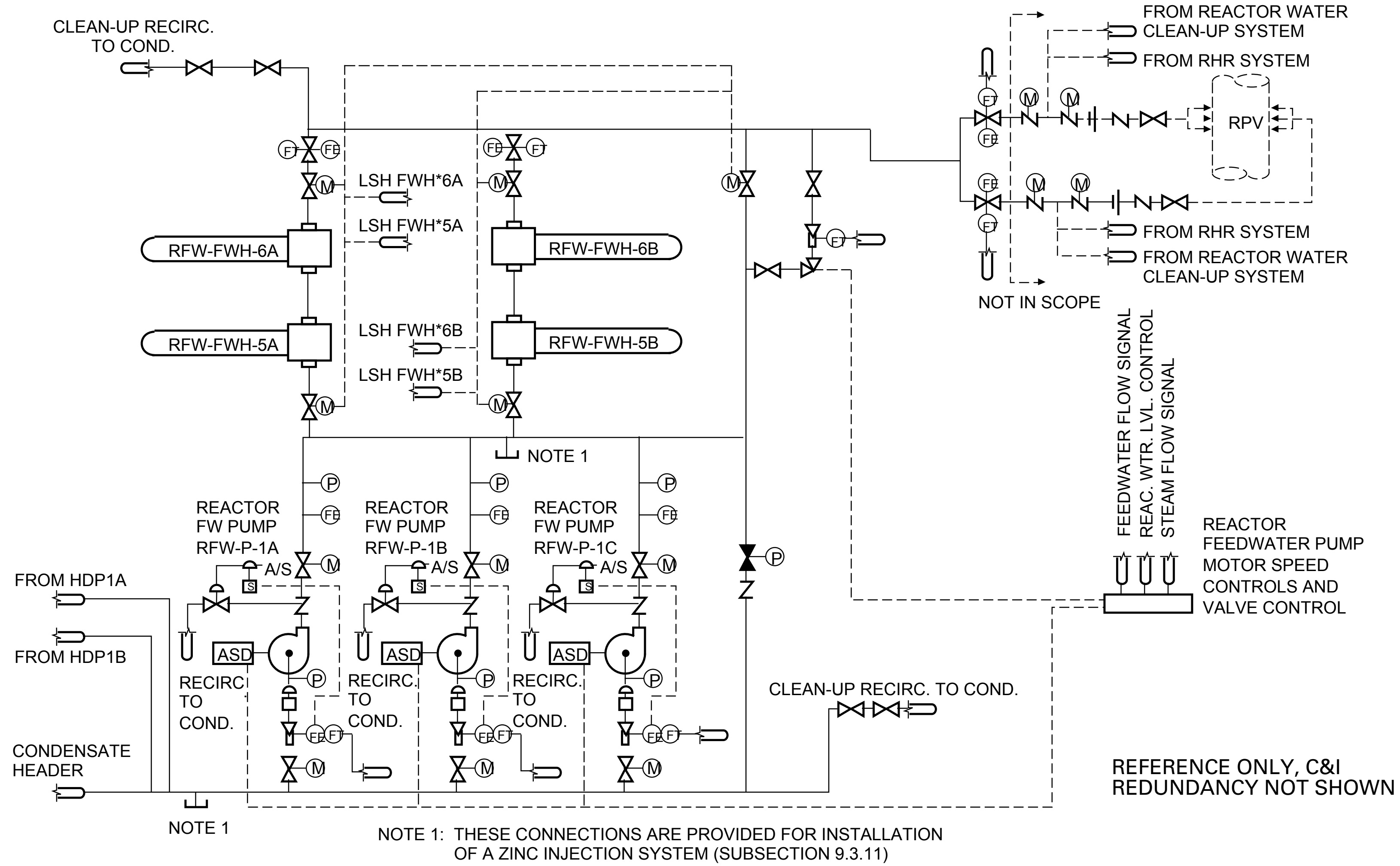

Figure 10.4-6 Feedwater System

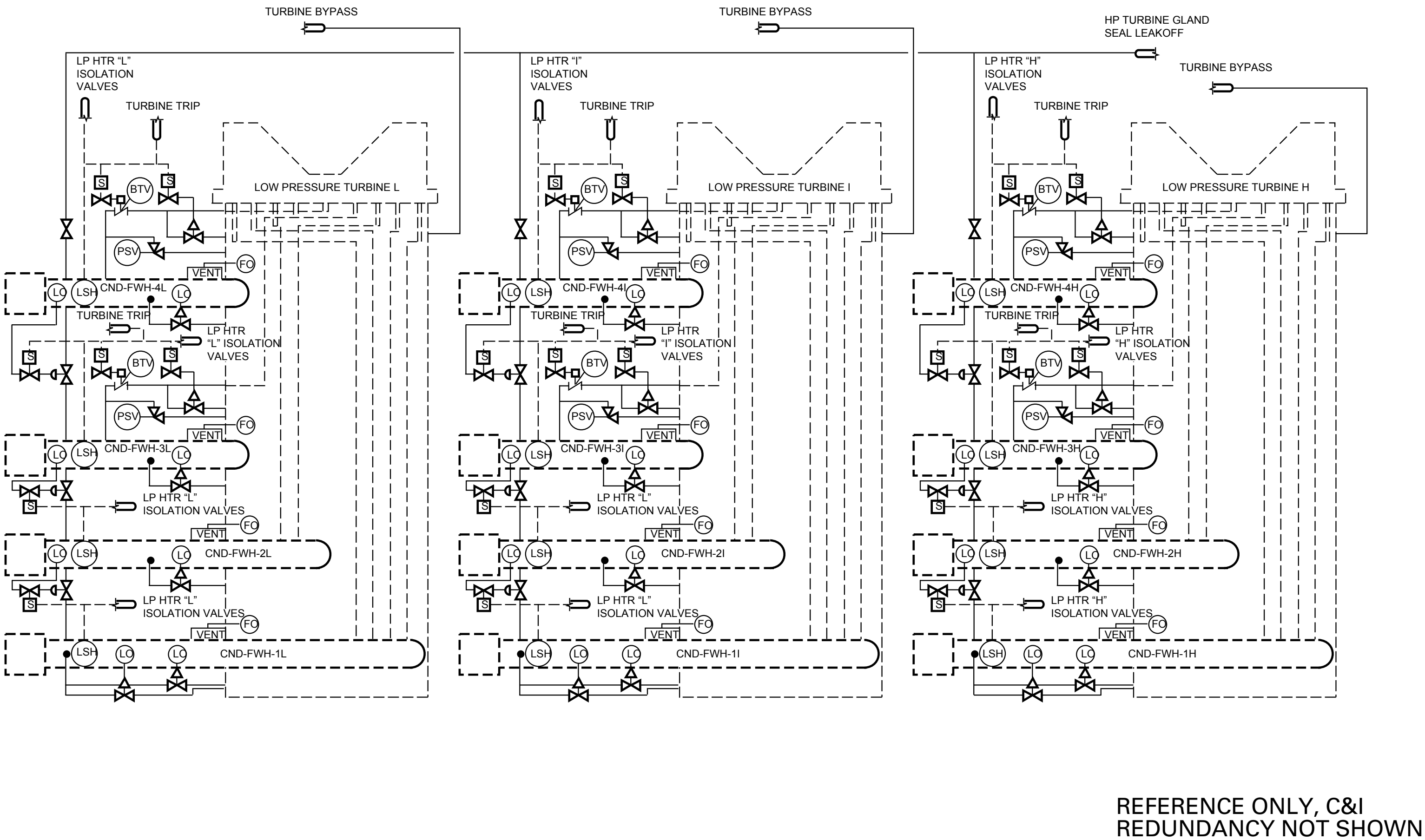

Figure 10.4-7 LP Extraction Steam Drains and Vent Systems

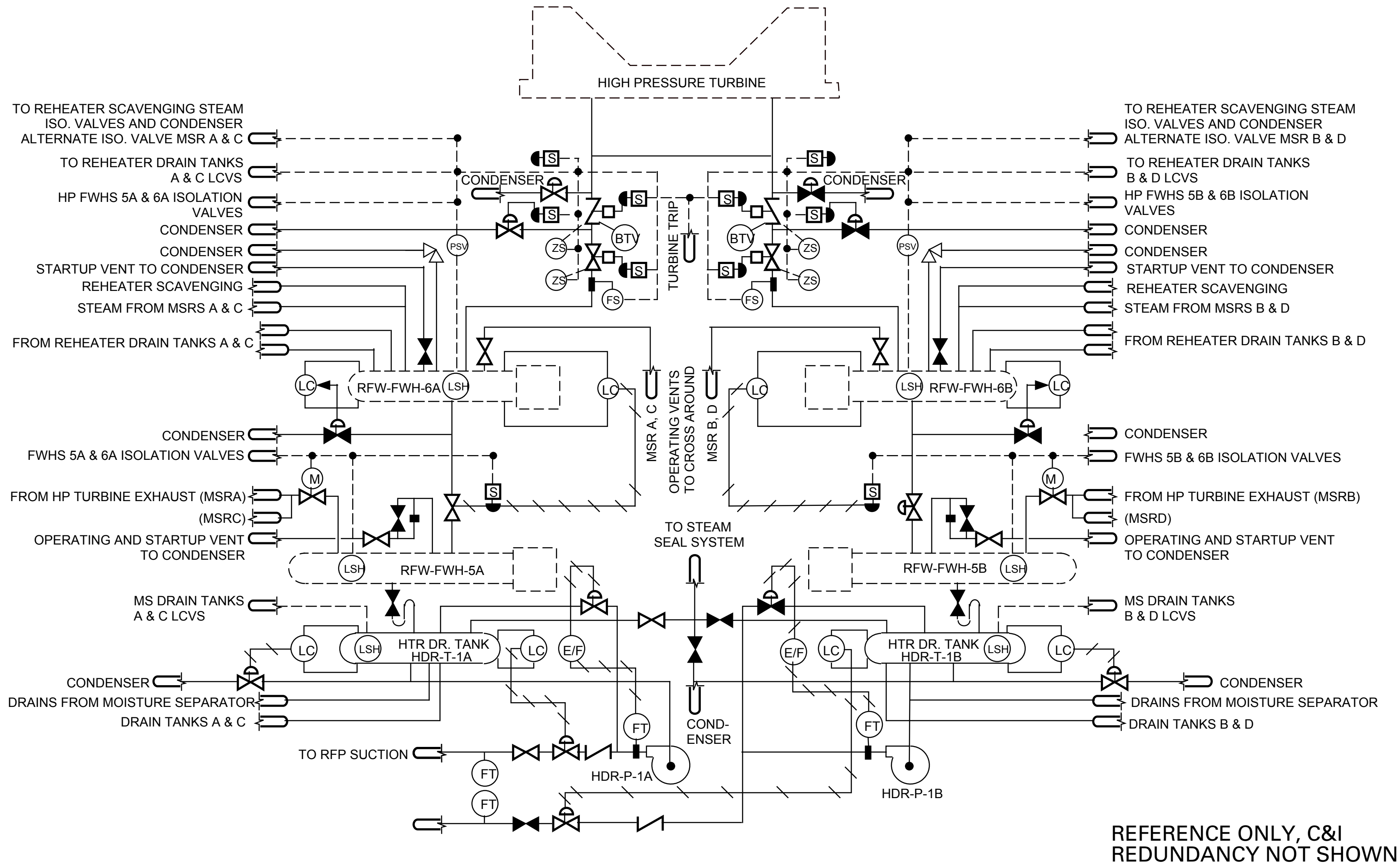

Figure 10.4-8 HP Extraction Steam Drains and Vent System

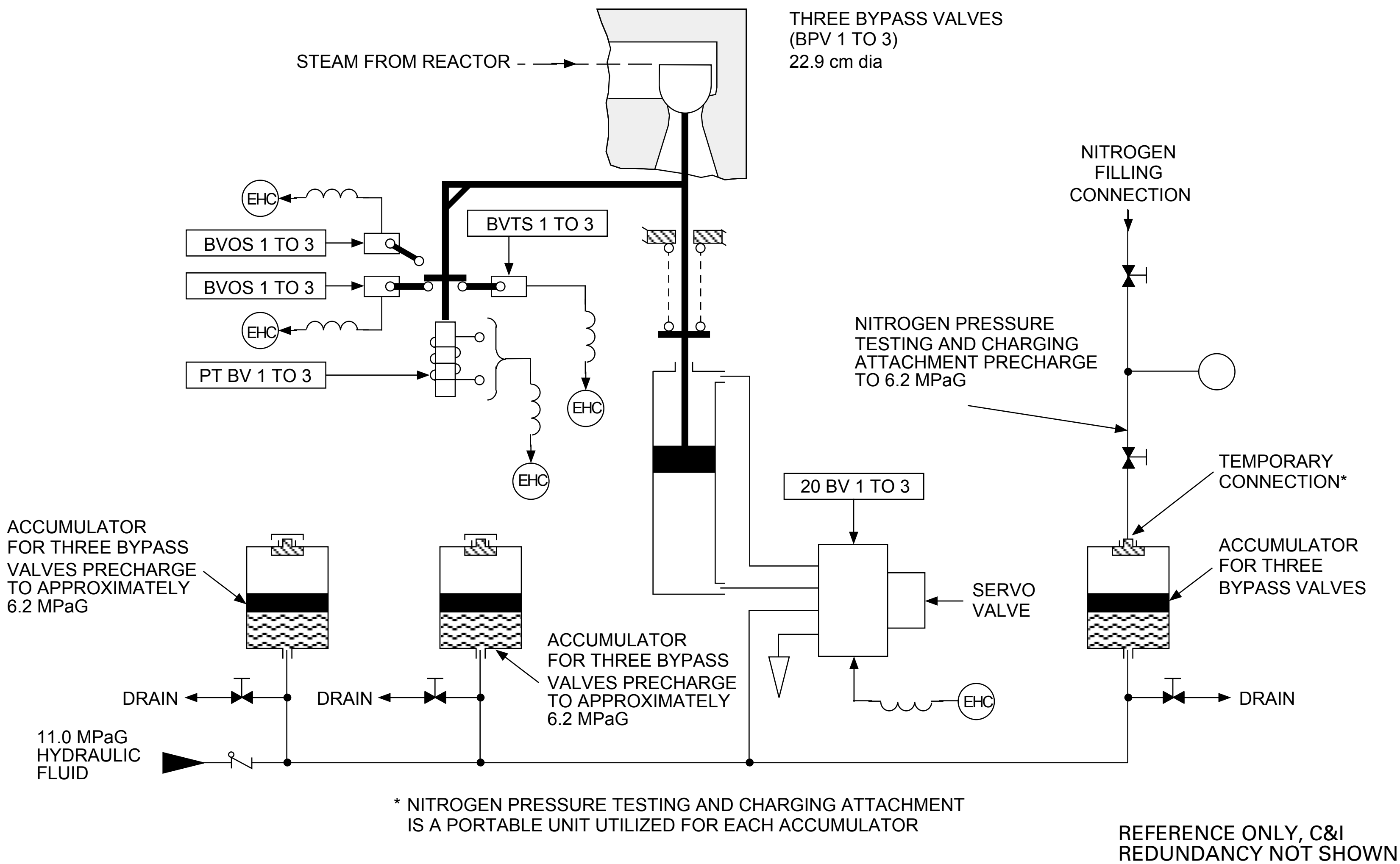

Figure 10.4-9 Bypass Valve Control, Electro-Hydraulic Control Unit

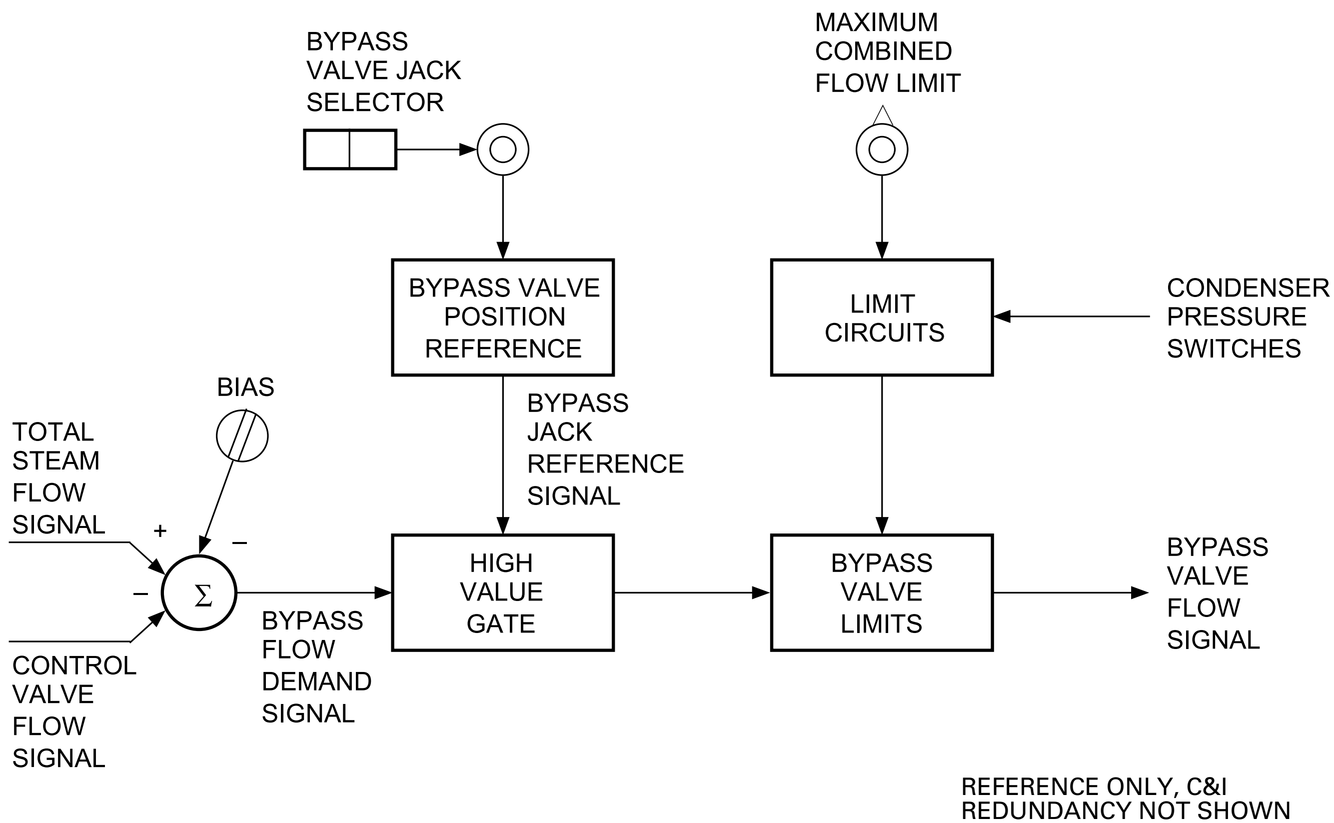

Figure 10.4-10 Signal Flow Chart for Turbine Bypas Control Unit