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CHAPTER 10
STEAM AND POWER CONVERSION SYSTEM

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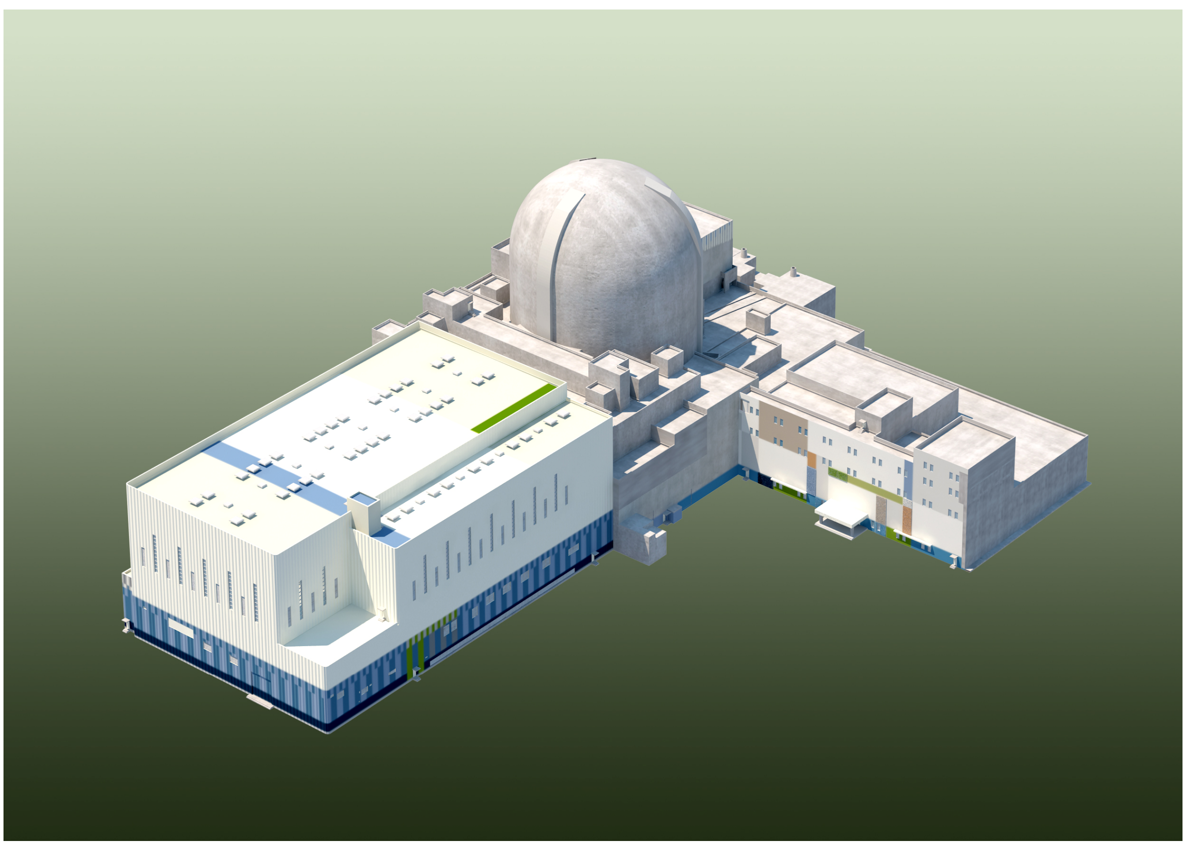

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KOREA HYDRO & NUCLEAR POWER CO., LTD

CHAPTER 10 – STEAM AND POWER CONVERSION SYSTEM

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ACRONYM AND ABBREVIATION LIST

ABD	Abnormal Blow Down
AC	Alternating Current
AFAS	Auxiliary Feedwater Actuation Signal
AFW	Auxiliary Feedwater
AFWS	Auxiliary Feedwater System
AFWST	Auxiliary Feedwater Storage Tank
ALARA	As Low As Reasonably Achievable
AOO	Anticipated Operational Occurrence
AOV	Air Operated Valve
ATS	Automatic Turbine Startup
ATWS	Anticipated Transients Without Scram
AVT	All Volatile Treatment
BDS	Blowdown Subsystem
BTP	Branch Technical Position
CBD	Continuous Blowdown
CBV	Cation Bed ion exchanger Vessel
COL	Combined License
CP	Condensate Polishing
CV	Control Valve
Cv	Charpy V-notch
CW	Circulating Water
CWS	Circulating Water System
DBA	Design Basis Accident
DBE	Design Basis Event
DC	Direct Current
DPS	Diverse Protection System
EBD	Emergency Blowdown
EOST	Electrical Overspeed Trip
ESFAS	Engineered Safety Feature Actuation System

ETS	Emergency Trip System
FAC	Flow-Accelerated Corrosion
FATT	Fracture Appearance Transition Temperature
FLB	Feedwater Line Break
FWCS	Feedwater Control System
GDC	General Design Criterion
HCBD	High Capacity Blowdown
HEI	Heat Exchange Institute
HP	High Pressure
IEEE	Institute of Electrical and Electronics Engineers
ISV	Intermediate Stop Valve
IV	Intercept Valve
LP	Low Pressure
LOOP	Loss of Offsite Power
LCP	Local Control Panel
MBV	Mixed Bed ion exchanger Vessel
MCR	Main Control Room
MFIV	Main Feedwater Isolation Valve
MOST	Mechanical Overspeed Trip
MSADV	Main Steam Atmospheric Dump Valve
MSADVIV	MSADV Isolation Valve
MSGTR	Multiple Steam Generator Tube Rupture
MSIS	Main Steam Isolation Signal
MSIV	Main Steam Isolation Valve
MSIVBV	Main Steam Isolation Valve Bypass Valve
MSLB	Main Steam Line Break
MSR	Moisture Separator Reheater
MSS	Main Steam System
MSSV	Main Steam Safety Valve
MSV	Main Stop Valve
MSVH	Main Steam Valve House

NNS	Non-Nuclear Safety
NRC	Nuclear Regulatory Commission
NRV	Non Return Check Valve
NSSS	Nuclear Steam Supply System
POSRV	Pilot-Operated Safety Relief Valve
QA	Quality Assurance
RCS	Reactor Coolant System
RG	Regulatory Guides
RPCS	Reactor Power Cutback Systems
RRS	Reactor Regulating System
RSR	Remote Shutdown Room
SBCS	Steam Bypass Control System
SBLOCA	Small Break Loss-Of-Coolant Accident
SBO	Station Blackout
SG	Steam Generator
SGBDS	Steam Generator Blowdown System
SGMSR	Steam Generator's Maximum Steaming Rate
SGTR	Steam Generator Tube Rupture
SSC	Structures, Systems, and Components
SSE	Safe Shutdown Earthquake
TB	Turbine Building
TBS	Turbine Bypass System
TBV	Turbine Bypass Valve
T/G	Turbine Generator
TGBCCW	Turbine Generator Building Closed Cooling Water
TGBOCWS	Turbine Generator Building Open Cooling Water System
TGCS	Turbine Generator Control System
TGSS	Turbine Gland Sealing System
UPS	Uninterruptible Power Supply
VWO	Valve Wide Open
WLS	Wet Layup Subsystem

WWTS	Wastewater Treatment System

CHAPTER 10 – STEAM AND POWER CONVERSION SYSTEM

10.1 Summary Description

The function of the steam and power conversion system is to convert the heat energy generated by the nuclear reactor into electrical energy. The heat energy produces steam in two steam generators capable of driving a turbine generator unit. The steam and power conversion system uses a condensing cycle with regenerative feedwater heating. Turbine exhaust steam is condensed in a surface-type condenser. The condensate from the steam is returned to the steam generators through the condensate and feedwater system.

The steam and power conversion system comprises the following major process systems:

a. Turbine generator (T/G)

b. Main steam system (MSS)

c. Condensate and feedwater systems

d. Turbine bypass system (TBS)

e. Circulating water system (CWS)

f. Steam generator blowdown system (SGBDS)

g. Auxiliary feedwater system (AFWS)

The following figures and tables describe the steam and power conversion system:

a. Table 10.1-1: Steam and Power Conversion System Major Design Data

b. Figure 10.1-1: Heat Balance Diagram

c. Figure 10.1-2: Overall System Flow Diagram

d. Figure 10.3.2-1: Main Steam System Flow Diagram

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i. Figure 10.4.9-1: Auxiliary Feedwater System Flow Diagram

The steam generated in the two steam generators (SGs) is supplied to the high-pressure turbine by the MSS. The steam is expanded through the high-pressure turbine, passes through the two moisture separator reheaters (MSRs), and then flows to the three low-pressure turbines.

The exhaust steam from the low-pressure turbines is condensed in a conventional surface type condenser. The condenser removes air and other non-condensable gases from the condensate and transfers heat to the CWS.

The condensate from the steam is returned to the SGs through the condensate and feedwater systems. The condensate from the condenser hotwell is transferred through the low-pressure (LP) feedwater heaters to the deaerator storage tank by the condensate pumps.

The feedwater booster pumps take suction from the deaerator storage tank and discharge to the feedwater pumps. Feedwater is discharged from the feedwater pumps, passes through two trains of high-pressure (HP) feedwater heaters, and is delivered to the SGs.

A TBS capable of relieving 55 percent of full-load main steam flow is provided to dissipate heat from the reactor coolant system (RCS) during turbine or reactor trip. This system consists of eight turbine bypass valves (TBVs) to limit an increase in pressure in the SGs following cessation of flow to the turbine. Closing the main stop valves blocks the normal steam flow path to the turbine, and decay heat is removed by directing bypass steam to the condenser. The TBS is described further in Subsection 10.4.4.

Two turbine-driven and two motor-driven auxiliary feedwater pumps are provided to provide reasonable assurance that adequate feedwater is supplied to the SGs in the event of a loss of the main and startup feedwater pumps. The auxiliary feedwater system (AFWS) is described in Subsection 10.4.9.

Overpressure protection of the shellside of the SGs and main steam line piping up to the inlet of the TBV is provided by spring-loaded main steam safety valves (MSSVs).

Radioactive material is monitored to prevent discharging it to the environment.

The turbines are tandem compound, 1,800 rpm, and supplied with steam from the nuclear steam supply system. A three-phase synchronous electric generator is coupled directly to the turbine shaft. The generator consists of a hydrogen gas cooling system, a seal oil system to prevent hydrogen gas leakage from generator casing, and a stator winding cooling water system for the stator bars. The generator is equipped with a collector housing for the static rectifier type excitation system that is directly coupled to the generator shaft. Each turbine generator (T/G) is designed for an output of around 1,425 MW, which depends on the plant condition for the nuclear steam supply system (NSSS) thermal output of 4,000 MWt. The T/G is described in Section 10.2, and the principal T/G conditions and the rated NSSS conditions are presented in Table 10.1-1.

The following portions of the steam and power conversion system have safety-related functions:

a. Main steam piping and components from each SG nozzle outlet up to and including the main steam valve house (MSVH) penetration anchor wall (see Section 10.3)

b. Main feedwater piping and components from each SG nozzle inlet up to and including the MSVH penetration anchor wall (see Subsection 10.4.7)

c. Auxiliary feedwater system (AFWS) (see Subsection 10.4.9)

d. SG blowdown piping between each SG blowdown nozzle and its respective outermost containment isolation valve (see Subsection 10.4.8)

10.1.1 Protective Features

Protection for Loss of External Electrical Load or Turbine Trip

In the event of a loss of load or turbine trip, the TBS discharges steam from the SGs directly to the main condenser through the TBVs, bypassing the turbine. This process removes energy from the RCS and minimizes transient effects on the RCS. Load rejection capabilities are described in Section 10.3 and Subsections 10.4.4, 15.2.1, and 15.2.2.

Overpressure Protection

Overpressure protection for the shellside of the SGs and the main steam line piping up to the inlet of the TBV is provided by spring-loaded MSSVs in accordance with ASME Section III (Reference 1). Five MSSVs are installed on each of the main steam lines upstream of the main steam isolation valve (MSIV) outside the containment. As the SG pressure rises and pressure setpoints are reached, the MSSVs open and discharge the high-pressure steam to the atmosphere. MSSVs are described in Subsection 10.3.2.2.3.

Overpressure protections for the following components are provided in accordance with ASME Section VIII, Division 1 (Reference 2):

a. MSRs

b. LP feedwater heaters

c. HP feedwater heaters

d. Deaerator/feedwater storage tank

e. MSR drain tanks

Protection for Loss of Main Feedwater Flow

When a loss of main feedwater event occurs, including a loss of offsite power (LOOP), the AFWS provides an independent means of supplying secondary quality makeup water to the

steam generators for removal of residual heat from the reactor core. The AFWS is described in Subsection 10.4.7.

Turbine Overspeed Protection

The turbine generator control system (TGCS) provides automatic control of turbine speed and acceleration through the entire speed range. The speed control function serves as the first line of defense against turbine overspeed. If the speed control function fails to protect the turbine overspeed, the overspeed protection system is activated. The overspeed protection system consists of two major subsystems:

a. Mechanical overspeed trip (MOST) system in the front standard

b. Electrical overspeed trip (EOST) system

The MOST is the emergency overspeed protection that acts to bring the turbine to a safe shutdown condition upon reaching a setpoint that is 110 percent of the rated speed. The EOST system consists of two speed calculating modules: primary and backup. Each module uses the three binary signals from the speed conditioning units to the 2-out-of-3 tripping device in the common safety system. Each setpoint is 111.5 percent of the rated speed. Turbine overspeed protection is described in Subsection 10.2.2.3.2.

Turbine Missile Protection

The design of the turbine rotor minimizes the probability that the turbine rotor will generate turbine missiles (see Subsection 10.2.3). Turbine missile protection is designed and controlled to minimize the potential for turbine missile generation (see Subsection 3.5.1.3).

The APR1400 plant design has a favorable orientation of the T/G to avoid potential impact on safety-related structures, systems, and components (SSCs). The orientation of the T/G, as shown in Figure 1.2 and Figure 3.5-1, is found to be favorable when considering its location relative to essential safety-related SSCs. These layout drawings show the general arrangement of the T/G and associated equipment in relation to essential safety-related SSC. Failure of the T/G equipment does not preclude safe shutdown of the reactor (see Subsection 10.2.4).

Radioactivity Protection

The steam and power conversion system may become contaminated through steam generator tube leakage. Radioactive containments are detected by radiation monitors in the SG blowdown line (iodine activity), main steam line (noble gas activity), and the condenser vacuum exhaust (noble gas activity) (see Subsection 10.3.5). This design feature provides a redundant and diverse method of detecting steam generator tube leakage.

Radiological aspects of primary-to-secondary system leakage and limiting conditions for operation are described in Chapter 11.

Flow-Accelerated Corrosion Protection

Flow-accelerated corrosion (FAC) resistant materials are used in steam and power conversion systems for components exposed to single-phase and two-phase flow where significant FAC or erosion/corrosion can occur. Factors considered in the evaluation of FAC include system piping and component configuration and geometry, water chemistry, piping and component material, fluid temperature, and fluid velocity.

Pipe size and layout are also considered to minimize the potential for FAC in systems with single-phase and two-phase flow conditions. For other carbon steel piping with relatively mild FAC degradation, additional thickness is applied for the design life.

To maintain a noncorrosive environment, the secondary side water chemistry (see Subsection 10.3.5) uses an all-volatile chemistry for pH adjustment and for corrosion prevention chemicals.

An FAC monitoring program for the steam and power conversion systems that contain water or wet steam is described in Subsection 10.3.6.3.

10.1.2 Combined License Information

No combined license (COL) information is required with regard to Section 10.1.

10.1.3 References

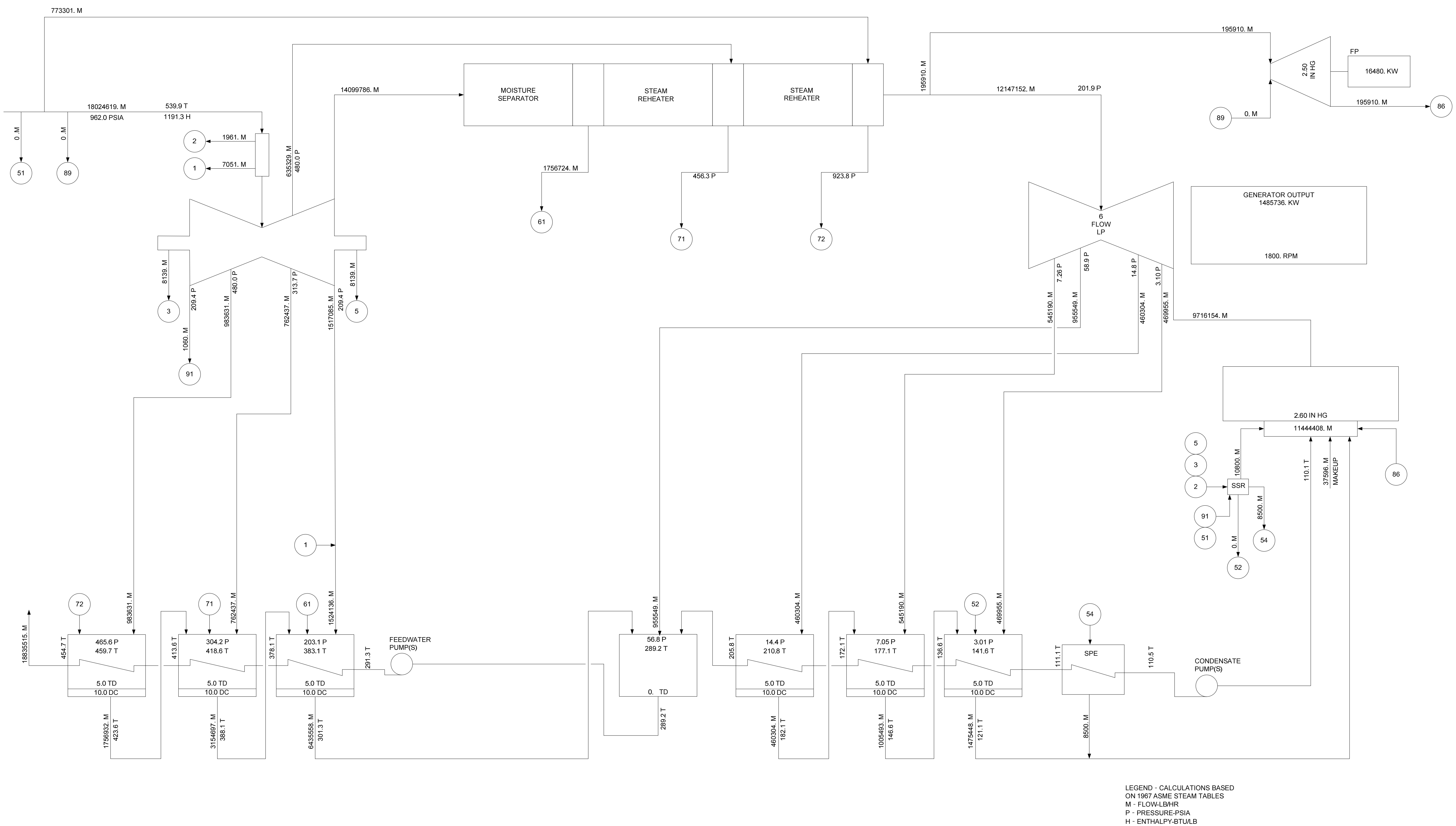
1. ASME Boiler and Pressure Vessel Code, Section III, "Rules for Construction of Nuclear Facility Components," 2007 Edition with 2008 Addenda.

2. ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, "Rules for Construction of Pressure Vessels," 2010.

Table 10.1-1

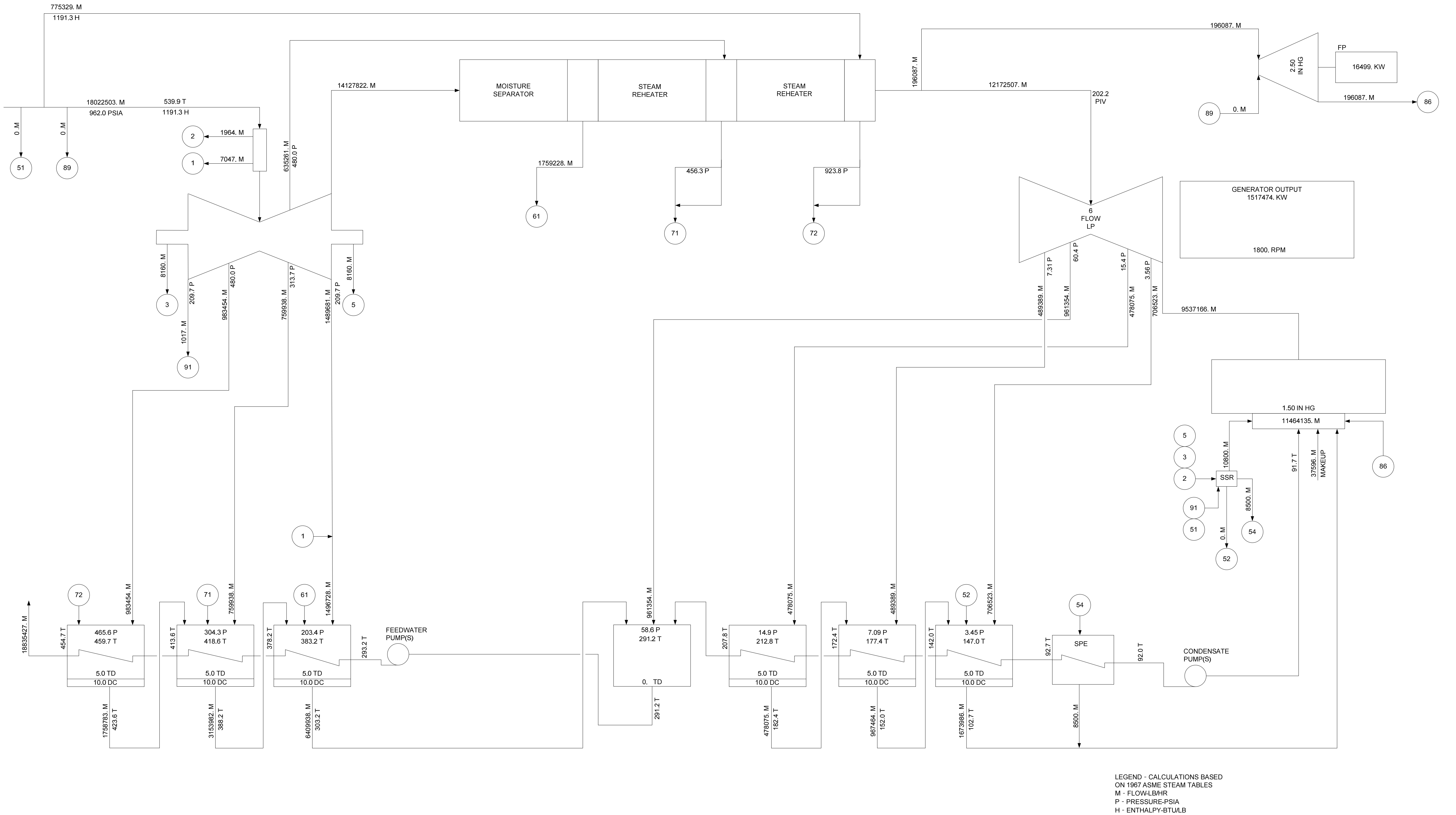
Steam and Power Conversion System Major Design Data

Data	Value
Major Steam System Design Data	
Rated NSSS power	4,000 MWt
MSS design pressure/temperature	84.37 kg/cm^{2}A (1,200 psia) / 298.9 °C (570 °F)
MSS operating pressure/temperature (at steam generator steam nozzle outlets)	69.74 kg/cm^{2}A (992 psia) / 284.2 °C (543.6 °F)
Main steam flow (maximum guaranteed rate(MGR) condition)	8.14×10^6 kg/hr (17.95×10^6 lb/hr)
Main feedwater temperature (MGR condition)	232.2 °C (450 °F)
Main feedwater flow (MGR condition, with 0.2 % SGBDS flow)	8.16×10^6 kg/hr (17.99×10^6 lb/hr)
Downcomer flow (MGR condition, with 0.2 % SGBDS flow)	8.16×10^5 kg/hr (17.99×10^5 lb/hr)
Economizer flow (MGR condition, with 0.2 % SGBDS flow)	7.34×10^6 kg/hr (16.19×10^6 lb/hr)
SGBDS flow rate, normal/abnormal/high	0.2 % / 1 % / 13.9 % of main flow rate
Turbine Generator Design Data	
Generator output	1,425 MWe at 0.090 kg/cm^{2}A(2.6 in HgA)
Operating speed	1,800 rpm
Turbine type	Tandem-compound, 6-flow, 52 in last-stage blade
Frequency	60 Hz, three phase
Power factor	0.90
Voltage	24 kV nominal



VWO, 0.2% MU, ENGLISH

Figure 10.1-1 Heat Balance Diagram (Condenser Pressure: 0.0898 kg/cm^{2}a (2.6 inHgA)) – VWO (1 of 4)



VWO, 0.2% MU, ENGLISH

Figure 10.1-1 Heat Balance Diagram (Condenser Pressure: 0.0518 kg/cm^{2}a (1.5 inHgA)) – VWO (2 of 4)

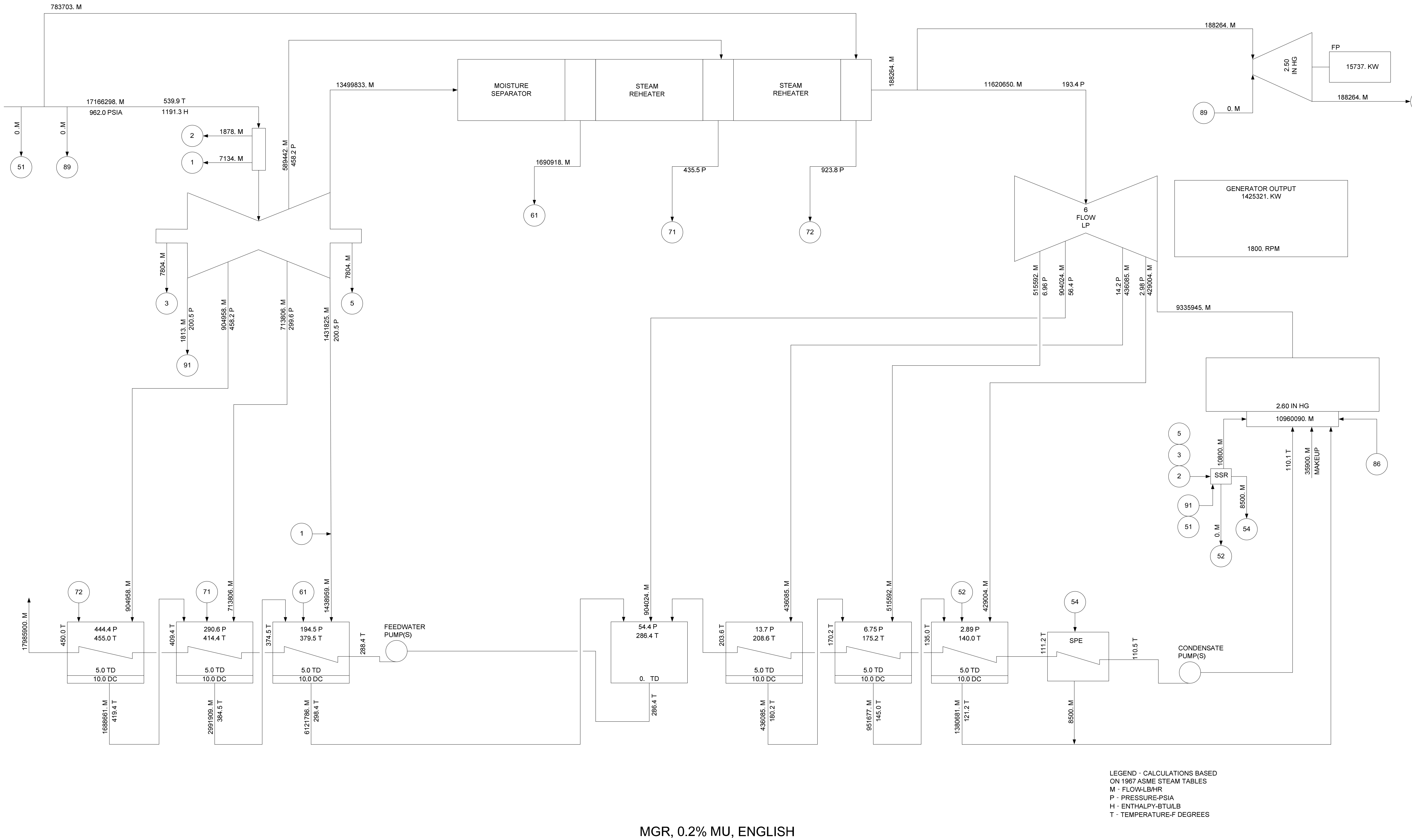


Figure 10.1-1 Heat Balance Diagram (Condenser Pressure: 0.0898 kg/cm^{2}a (2.6 inHgA)) – MGR (3 of 4)

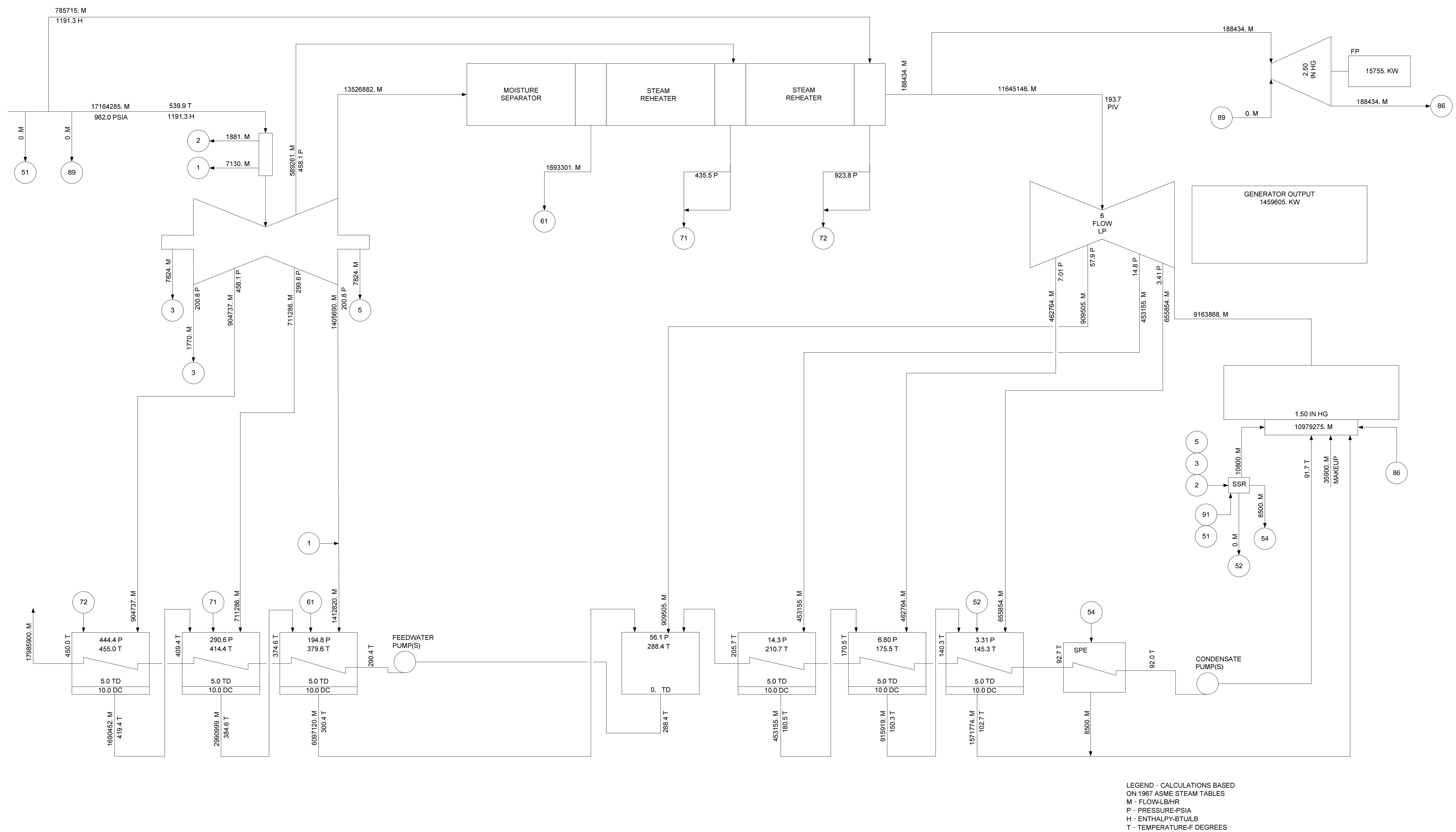


Figure 10.1-1 Heat Balance Diagram (Condenser Pressure: 0.0518 kg/cm^{2}a (1.5 inHgA)) – MGR (4 of 4)

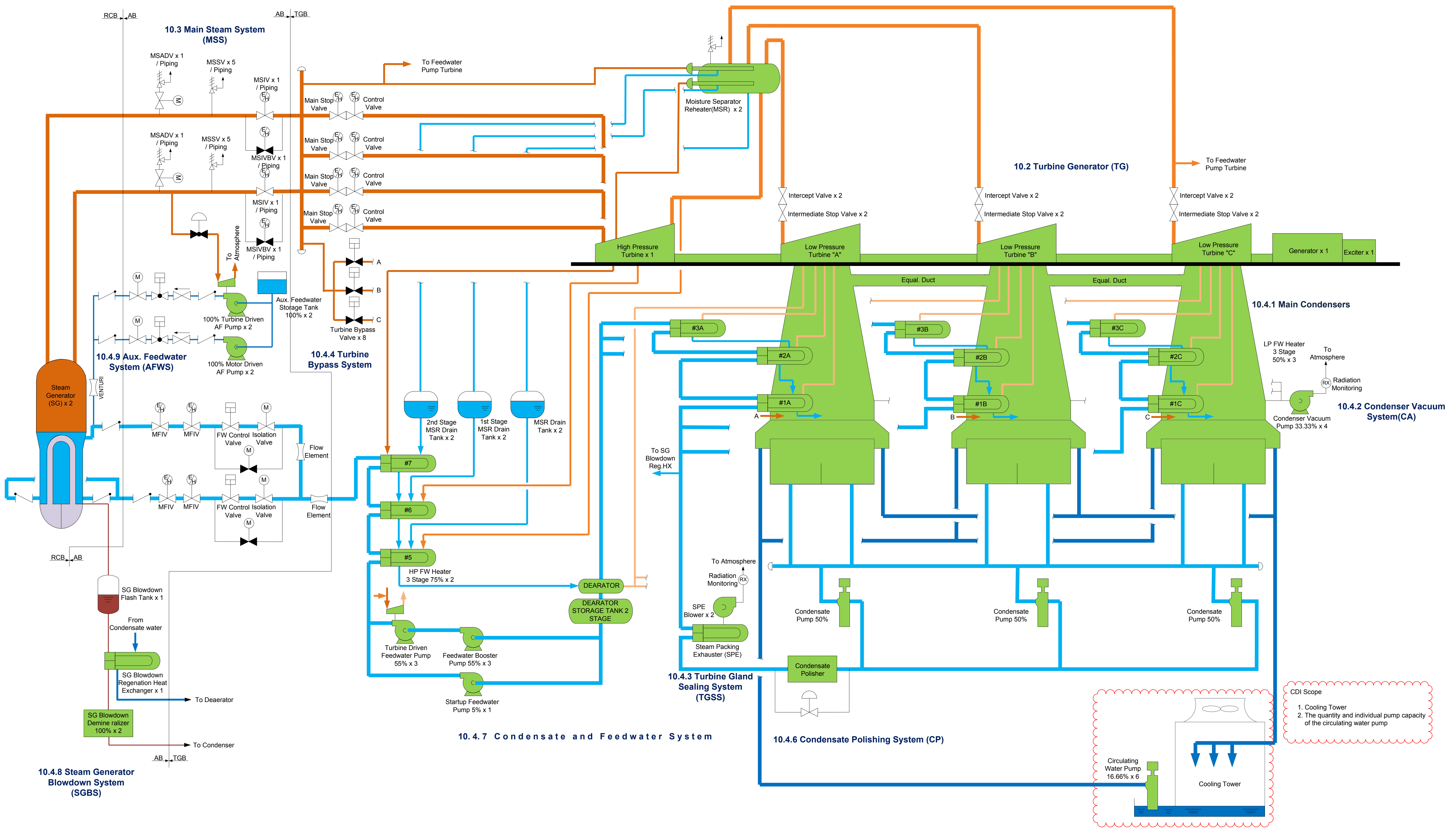


Figure 10.1-2 Overall System Flow Diagram

10.2 Turbine Generator

10.2.1 Design Bases

10.2.1.1 Safety Design Bases

The turbine generator (T/G) system does not perform or support any safety-related function and therefore has no safety design basis. Classification of the T/G system equipment and components in regard to the seismic and safety and quality group is provided in Table 3.2-1 of Section 3.2.

However, because it is possible for the T/G system to generate high-energy missiles that could damage safety-related structures, systems, and components (SSCs), it is designed and controlled to minimize the potential for turbine missile generation. The T/G system is designed to meet the requirements of General Design Criterion (GDC) 4 as related to the protection of SSCs from the effects of turbine missiles described in subsection 3.5.1.3. Also, with the turbine rotor designs that utilize large integral forgings, the total turbine missile generation probability is reduced unlike shrink-fit type rotor which consists of built up wheels and shaft.

10.2.1.2 Non-Safety Power Generation Design Bases

T/G converts the energy of the steam produced in the steam generators into mechanical shaft power and then into electrical energy. The principal design features of the T/G are as follows:

a. The T/G is designed for base load operation and has load following capability.

b. The T/G is capable of a load change with a following 3.75 percent per minute load gradient in the load increase or decrease. The T/G load change characteristics are compatible with the plant control system, which coordinates the T/G and reactor operations.

c. The generator output at the rated thermal power of the reactor and at the T/G main steam valve wide open(VWO) condition is shown in the heat balance diagrams in Figure 10.1-1.

d. The T/G is designed to be monitored and controlled automatically by the turbine generator control system (TGCS) at normal or abnormal conditions, as described in Subsection 10.2.2.3. The TGCS includes redundant mechanical and electrical trip devices to prevent excessive overspeed greater than 110 percent of the rated speed of T/G. The maximum expected overspeed of the turbine does not exceed 110 percent of the rated speed. The design overspeed of the T/G is at least 5 percent above the maximum expected overspeed resulting from a loss of load.

e. The main stop valves (MSVs), control valves (CVs), intermediate stop valves (ISVs), intercept valves (IVs), overspeed protection system, and other protection devices are designed to allow regular testing of each protection device with minimum effect on the online turbine operation.

f. The T/G system is designed so that the single failure of any component or subsystem does not disable the turbine overspeed trip function.

g. The T/G system provides the proper drainage of related piping and components to prevent water induction to the inside the turbine.

h. The moisture separator reheaters (MSRs), MSR drain tanks, pressure vessels, and piping in the T/G auxiliary systems are designed to the requirements of ASME Section VIII (Reference 4). The other parts of the T/G are designed to the T/G manufacturer's standards.

i. Generator rating, temperature rise, and class of insulation are in accordance with IEEE Standard C50.13 (Reference 5).

10.2.2 Description

10.2.2.1 General Description

The T/G system consists of an 1,800 rpm turbine, two sets of MSRs, generator, exciter, controls, and associated subsystems.

The TGCS uses a digital monitoring and control system that controls the turbine speed, load, and flow for startup and normal operations. The control system operates the turbine MSVs, CVs, ISVs, and IVs. T/G supervisory instrumentation is provided for operational analysis and malfunction diagnosis.

The extraction steam piping is constructed of low alloy steel such as Cr-Mo steel or equivalent material for erosion and corrosion resistance. The source of the extraction steam for feedwater heating at each stage is presented in Table 10.2.2-1.

Upon loss of load, the steam contained in downstream of the extractions can flow back into the turbine across the remaining turbine stages and into the condenser. Associated condensate can flash to steam under this condition and contribute to the backflow of steam or can be entrained with the steam flow and damage the turbines. Non-return check valves are employed to minimize the potential for these conditions to contribute to the turbine overspeed.

The T/G foundation is a reinforced concrete structure. The T/G foundation and equipment anchorage are designed to the same seismic design requirement as the turbine building. Additional information on seismic design requirements is provided in Section 3.7.

10.2.2.2 Component Description

The T/G consists of a double-flow high-pressure (HP) turbine, three double-flow low-pressure (LP) turbines, and a direct-coupled generator in tandem, as shown in Figure 10.2.2-1.

The valves and piping arrangements are shown in Figure 10.2.2-2. Two MSRs with two stages of reheating are located on each side of the T/G centerline. The single direct-driven generator is water-cooled and rated 1,425 MWe at 0.090 kg/cm^{2}A (2.6 in HgA).

T/G accessories include the bearing lubrication oil system, turbine generator control system (TGCS), turbine hydraulic system, turning gear, hydrogen gas control system, seal oil system, stator cooling water system, exhaust hood spray system, turbine gland seal system, MSR reheater heating steam system, excitation system, and turbine supervisory instrument system.

10.2.2.2.1 Main Stop Valves and Control Valves

The flow of main steam is directed from the steam generators (SGs) to the HP turbine through four MSVs and four CVs.

MSVs are designed to incorporate a steam strainer to limit foreign material from entering the control valves and turbine. The primary function is to quickly shut off steam flow to the HP turbine under emergency conditions. MSVs are hydraulically operated in an open-closed mode by the turbine overspeed protection system in response to turbine trip signals.

CVs are designed to provide steam flow throttling and shut-off that is adequate for turbine speed control. The primary function of the CVs is to control steam flow to the turbine in response to the TGCS. CVs are closed under trip conditions.

MSVs and CVs are hydraulically operated by a high pressure fire-resistant fluid supplied through a servo valve. Valve characteristics and closure times are provided in Table 10.2.2-2.

10.2.2.2.2 High Pressure Turbine

The HP turbine receives steam through four steam lines. The steam is expanded axially across several stages of stationary and moving blades. These stages consist of a blade-attached wheel and diaphragm structure. Extraction steam from the HP turbine at three locations is supplied to the fifth, sixth, and seventh stages of feedwater heaters, as described

in Table 10.2.2-1. After expanding through the HP turbine, the exhaust steam passes through the MSRs.

10.2.2.2.3 Moisture Separator Reheaters

The moisture in the HP turbine exhaust steam is separated and reheated by two sets of external MSRs. The MSRs are located on each side of the T/G centerline. Extraction from the HP turbine and main steam from the equalization header are supplied to the first and second stages of the reheater tube bundle in each reheater.

The MSRs use multiple banks of chevron-skip vanes for moisture removal. The moisture is removed by the external moisture separator.

Condensed steam in the reheater, which is drained to the reheat drain tank, flows into the shellside of the fifth, sixth, and seventh feedwater heaters and cascades to the deaerator.

10.2.2.2.4 Intermediate Stop Valves and Intercept Valves

Hydraulically operated ISVs and IVs are provided in each hot reheat line upstream of the LP turbine inlet.

Upon loss of load, the IVs first close and then throttle steam to the LP turbine to control speed. The ISVs and IVs close on a turbine trip. The ISVs and IVs are designed to close rapidly to control turbine overspeed. Valve characteristics and closure times are provided in Table 10.2.2-2.

10.2.2.2.5 Low Pressure Turbine

Each LP turbine receives steam from the MSRs through two hot reheat lines. The steam expands axially across several stages of stationary and moving blades.

The steam then passes through the LP turbines, each with extraction points for the LP stages of feedwater heating, and exhausts into the main condenser. Extraction steam from the LP turbines supplies the first stages of feedwater heating.

Condensate moisture from the moving blade at the latter stages is removed along the moisture groove. Drainage holes are drilled through the diaphragm rings to remove the moisture generated from the diaphragm rings located in high wet zones.

10.2.2.2.6 Extraction Non-return Check Valve

Non-return check valves are installed on extraction lines as shown in Figure 10.2.2-2. Provided valves in the higher pressure extraction lines are power assisted, spring-closed non-return check valves. The power-assisted, spring-closed actuators are designed to overcome friction and allow the valves to close rapidly on turbine trip. These non-return check valves are capable of closing within a time period to maintain stable turbine speeds in the event of a turbine generator system trip. Non-return check valve characteristic and closure time is provided in Table 10.2.2-2. The two low pressure heaters and their associated extraction lines are located in the condenser neck. The No. 3 heaters are installed horizontally in the heater bay. Because of the low energy levels of the entrained fluid in the two lowest pressure heaters, No. 2 heaters are provided with anti-flash baffle plates located inside the heaters.

10.2.2.2.7 Generator

The generator is a direct-driven, three-phase, 60 Hz, 1,800 rpm, four-pole synchronous generator with a water-cooled armature winding and hydrogen-cooled rotor. Generator rating, temperature rise, and class of insulation are in accordance with IEEE Standard C50.13 (Reference 5).

The rotor is manufactured from forged components and includes layers of field windings embedded in milled slots. The windings are held radially by slot wedges at the rotor outside diameter. The wedge material maintains its mechanical properties at elevated temperatures. The magnetic field is generated by direct current (DC) power, which is fed to the windings through collector rings located outboard of the main generator bearings.

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

a. Material property checks on test specimens taken from the forging

b. Magnetic particle and ultrasonic examination

c. Visual surface finish inspections of rotor slots for indication of a stress riser

10.2.2.2.8 Generator Cooling System

The generator cooling system consists of a hydrogen gas cooling system, seal oil system, and stator winding water-cooling system.

A conventional oil-sealed hydrogen cooling system provides rotor cooling. The stator conductors are water cooled by a stator water cooling system.

The generator oil sealing system is designed to prevent hydrogen gas inside the generator from leaking, and pressure is maintained higher than the hydrogen gas pressure inside the generator through the generator seal oil system.

The generator stator winding water-cooling system is designed to control the cooling water pressure and flow through the stator winding cooling water system to prevent the temperature inside the generator from increasing.

The hydrogen detraining system treats the oil that has drained from the casing through the seal ring. This system consists of a hydrogen detraining tank, which stores the seal oil from inside the generator; a liquid detector, which prevents the overflow of seal oil in the detraining tank; and a float trap, which recovers the atmosphere condition of hydrogen-side seal oil.

Hydrogen is supplied from high pressure storage tanks and an electrolysis hydrogen and oxygen generator. In order to prevent explosions and fires, the hydrogen piping and main generator are checked for leaks and then purged with carbon dioxide to remove all air and oxygen before the introduction of hydrogen. The hydrogen purged from the generator is vented through the turbine generator building roof and dissipates to the outside air. Provisions are included at various points in the distribution system to allow for carbon dioxide purging and safe venting of the hydrogen in the generator and piping prior to maintenance.

10.2.2.2.9 Generator Exciter

The excitation system regulates the generator terminal voltage. This system is a static bus-fed type and consists of a 3-phase full-wave rectifier, excitation transformer, and AC/DC bus duct. Excitation power can be obtained from an excitation transformer, which is connected directly to the generator terminals. The excitation system, generator field, and excitation transformer are connected by the AC/DC bus duct to each other.

The secondary side of the excitation transformer is connected to the 3-phase full-wave rectifier. The 3-phase full-wave rectifier uses a thyristor, which is a semiconductor device for power conversion from AC to DC.

10.2.2.3 Control and Protection

10.2.2.3.1 Normal Control

The turbine generator control system (TGCS) is a digital monitoring and control system that controls turbine speed, load, and flow for startup and normal operations. The TGCS operates the turbine MSVs, CVs, ISVs, and IVs. T/G supervisory instrumentation is provided for operational analysis and malfunction diagnosis.

Electric power for the TGCS is supplied by two AC sources for redundancy with a 120 V_{AC} single-phase station source and a vital control bus, preferably from an uninterruptible power supply (UPS).

The purpose of the TGCS is to provide the following:

a. Three redundant control processors

b. Three redundant control processors for all CVs with positioning signals

c. Interface with the plant control system from three redundant control processors

The TGCS is a microprocessor-based controller. The increase and decrease inputs are determined by operation of a keyboard or a cursor-positioning device that is a mouse or a track-ball on the control console in the control room.

The TGCS provides the following turbine control functions through circuitry and equipment:

a. Automatic control of turbine speed and acceleration through the entire speed range

b. Automatic control of load and loading rate from no load to full load, with continuous load adjustment and discrete loading rates

c. Semi-automatic control of speed and load when it becomes necessary to take portions of the automatic control out of service while continuing to supply power to the system

d. Limiting of load in response to preset limits on operating parameters

e. Detection of dangerous or undesirable operating conditions, annunciation of detected conditions, and initiation of proper control response to such conditions

f. Monitoring of the status of the control system, including the power supplies and redundant control circuits

g. Testing of valves and controls

10.2.2.3.1.1 Speed Control

The turbine speed is measured by three independent speed sensors. For overspeed protection, each module provides a binary output signal, which is normally energized, to the 2-out-of-3 tripping device.

For speed control, multiple speed feedback signals are derived from redundant sensors. A separate probe is provided for each of the triple redundant electrical governor channels. The active speed governor closes all CVs and IVs fully at 105 percent of the turbine normal

operating speed. An acceleration limiter built into the microprocessor-based controller is activated during a high load rejection. The valves are fully closed below 105 percent.

10.2.2.3.1.2 Load Control

The load control unit functions are as follows:

a. Sensing functions that detect and generate signals proportional to parameters that affect loading of the unit

b. Limiting functions that electrically constrain the flow reference signals in response to signals from the sensing circuits, from the speed control unit, or from devices detecting the state of plant components

c. Computing functions that generate flow reference signals for the valve sets, considering the desired load signal, the limiting functions, and the speed error signal from the speed control unit

d. Logic functions that provide reasonable assurance that the necessary permissives have been satisfied prior to changes in mode of operation, to communicate status information between the load control unit and other elements of the TGCS, and to provide switching signals to devices in the TGCS

10.2.2.3.1.3 Flow Control

When the output flow reference signal is at the limit value, the load set runback is initiated to drop the load setpoint. To prevent an excessive decrease of the main steam pressure, a main steam pressure limiter circuit is provided to close the controlling valve set when the main steam pressure falls below a preset level. The regulation of this circuit is fixed at 10 percent. When the main steam pressure falls below an adjustable setpoint, the flow reference signal to the controlling valve set is limited to the value permitted by the level of the main steam pressure. The pressure setpoint is adjustable from zero to rated pressure by using the keyboard or cursor-positioning device on the control console in the control room. Control room meters indicate the pressure setpoint that has selected, as well as the

actual main steam pressure. An acceleration limiter operates when the field breakers open and the turbine acceleration is too high.

First-stage feedback is incorporated into the control system to provide more linear turbine response to the desired load signal and to maintain near constant turbine output while testing control valves.

The turbine and its CVs are designed to pass the rated flow at the existing throttle pressure at the MSVs and CVs at the rated output of the nuclear steam supply system (NSSS). The load control function and maximum load limiter function are protected against overload. The feedback of live steam pressure is provided for a constant control gain.

All stop valves are hydraulically operated from the common hydraulic safety system equipped with limit switches for stroke testing. The closing time of all stop valves during testing is short and corresponds to the time at turbine trip.

10.2.2.3.1.4 Valve Control

The CVs position loop consists of electrical circuitry, an electro-hydraulic servo-valve, hydraulic actuator, and linear position transducer. By use of a valve position feedback control, the control valve flow control unit positions the CVs according to the flow demand signal from the load control unit or directly from the control panel. Valve position control is performed by using a feedback path that transmits the actual valve position back to a point where it is compared algebraically with the reference input. The error signal positions the hydraulic actuator using the servo-valve in order to make it zero value. CV testing is designed to allow regular testing of each valve with the effects to the online turbine operation minimized. This testing is performed by the position controller using the integrated servo-valve.

Three IVs are equipped with a position controller and a servo-valve.

Three control processors can control servo valves with up to three coils. These control processors are connected to each coil. In a failure of a controller, its output port or the physical connection to the output coil results in the other two servo drives compensating for the failed channel and keeping the valve properly positioned.

10.2.2.3.1.5 Power Load Unbalance

If the T/G is running at load and the load on the generator is suddenly lost, the following events take place in rapid succession:

a. The acceleration limiter operates on high acceleration.

b. The CVs and IVs are closed at the maximum rate.

c. The entrained steam between the valves and the turbine, in the turbine casing, and in crossover and extraction lines expands.

d. The expected overspeed is less than 10 percent at full load.

e. The IVs reopen when the actual speed is below the set value.

If the above sequence is not successful, the overspeed protection device is activated to protect the T/G. The main steam is bypassed to the condenser to reduce steam flow to the turbine (see Subsection 10.4.4).

10.2.2.3.1.6 Automatic Turbine Startup and Shutdown

The automatic turbine startup (ATS) receives commands from the operator using the operator interface or from a plant computer through a data link, compares it to the limits, and issues commands to the primary controllers. ATS routines are executed during all modes of operation. ATS routine results are used directly or also displayed during all modes of operation.

The primary mode of communication between the ATS and the operator is through the operator interface displays.

The ATS has the following phases:

a. Pre-roll monitoring and operation

b. Acceleration to the rated speed

c. Loading and unloading

d. Post trip securing

10.2.2.3.2 Overspeed Protection

The normal speed control system serves as the first line of defense against turbine overspeed. This system includes CVs, IVs, and fast-acting valve-closing functions within the TGCS. If this system fails to protect the overspeed, the overspeed protection system is activated to protect overspeed. The overspeed protection system consists of two major subsystems: (1) a mechanical overspeed trip (MOST) system in the front standard and (2) an electrical overspeed trip (EOST) system.

The MOST is the emergency overspeed protection and, upon reaching a setpoint that is 110 percent of the rated speed, acts to bring the turbine to a safe shutdown condition. The MOST consists of an unbalanced ring that is activated by a centrifugal force against a spring when the turbine overspeeds, thus causing an eccentric movement that strikes the trip finger on the emergency trip valve. This action causes a depressurization of the emergency trip system (ETS) hydraulic fluid and, via an interface relay, the common hydraulic safety system, closing all stop and control valves. If the MOST fails, the EOST activate the ETS trip valves, causing all steam valves to trip closed upon reaching the setpoint.

The EOST system consists of two speed calculating modules: primary and backup. Each module uses the three binary signals from the speed conditioning units to the 2-out-of-3 tripping device in the common safety system. The primary module calculates the trip setpoint from software logic, and the backup module calculates the trip setpoint from its module firmware, which is independent of the primary module. These modules trigger hydraulic solenoid valves, and all stop and control valves are then closed. Each setpoint is 111.5 percent of the rated speed.

The turbine overspeed trips close all stop and control valves within a certain period after a trip signal that precludes an unsafe turbine overspeed condition, as described in Table 10.2.2-3.

To further decrease the possibility of an overspeed condition, two redundant reverse-power relays prevent overspeed after a turbine trip and prevent overheating of the last stages of LP turbine blades. Additionally, a T/G protection device interfaces with the main steam bypass system, which bypasses main steam to the condenser to reduce steam flow to the turbine (see Subsection 10.4.4).

The turbine overspeed protection devices are listed in Table 10.2.2-3. Each device has an on-load test provision.

The three lines of defense against overspeed during all modes of operation are as follows:

a. Speed control and overspeed protection in the TGCS

b. One mechanical overspeed trip at 110 percent of the rated speed

c. Electrical overspeed protection in 2-out-of-3 logic scheme at 111.5 percent of the rated speed

In case of malfunction of any portion of the first line of defense against overspeed when the load is lost, the turbine accelerates to the trip speed, and the overspeed trip activates and trips the MSVs and ISVs as the second and third lines of defense. The main CV and IV actuators also trip. Subsequently, the turbine coasts down.

10.2.2.3.3 Turbine Protection

The main function of the ETS is to check the validity of the trip demand signals and to provide reasonable assurance that trip action results in immediate response to a valid trip demand. A redundant electrical signal transmission sends valid trip signals from the control and protection cabinet to redundant trip devices, which consist of an electronic solenoid valve and a mechanical solenoid valve in the turbine front standard.

The following requirements are met by the ETS:

a. Each trip input is applied to a triple redundant protection module. 2-out-of-3 majority voting is conducted within the protection system where possible to prevent spurious turbine trips and enhance protection system operation on an actual turbine trip.

b. Electromechanical trip devices that the hydraulic solenoid valves triggered using the electronic protection system are testable online using the appropriate lockout devices. The redundant trip systems in this area protect the turbine while one system is being tested. The entire protection system, from signal input to actual trip device, has online test capabilities.

c. Electrically signaled trips are initiated by contact closures. The loss of trip system power is annunciated.

d. Contacts representing the actuation of any trip function or alarm device are available for computer monitoring or annunciation.

The turbine includes instrumentation for a trip on excess vibration and a remote trip input signal from the plant control system on a reactor trip.

The trip and monitoring system initiates appropriate action on abnormal operating conditions and indicates the existence of these conditions to the operator.

The ETS closes the MSVs, CVs, ISVs, and IVs to shut down the turbine on the following signals:

a. Emergency trip in control room

b. Moisture separator high level

c. High condenser pressure

d. Low turbine lube oil pressure

e. LP turbine exhaust hood high temperature

f. Thrust bearing wear

g. Emergency trip at front standard

h. Loss of stator coolant

i. Low hydraulic fluid pressure

j. Selected generator trips

k. Loss of TGCS electrical power

l. Excessive turbine shaft vibration

m. Loss of two speed signals – either two normal speed control or two emergency

n. Abnormal shell and rotor differential expansion or rotor expansion

When the ETS is activated, it overrides all operating signals and trips the MSVs, CVs, ISVs, and IVs.

10.2.2.3.4 Inspection and Testing

The overspeed trip circuits and devices are tested remotely at or above the rated speed by means of controls in the main control room or can be tested with the turbine not in operation. Operation of the overspeed protection devices under controlled speed conditions is checked at startup and after each refueling or major maintenance outage. In some cases, operation of the overspeed protection devices can be tested just prior to shutdown. This eliminates the need to test overspeed protection devices during the subsequent startup if no maintenance is performed that affects the overspeed trip circuits and devices.

Inservice testing and functional checks are performed periodically. MSVs, CVs, ISVs, and IVs are exercised at least once within quarterly intervals by closing each valve and observing the remote valve position indicator for fully closed position status. This test also verifies operation of the fast close function of each MSV and CV during the last few percent of valve stem travel. Fast closure of the ISV and IV is tested in a same way. Non-return check valves are tested in accordance with vendor recommendations. Inspection and test requirements for the overspeed trip device are shown in Table 10.2.2-4

The checks include testing of components such as:

a. MSVs, CVs, ISVs, and IVs

b. Turbine trips and pressure switches for lube oil supervision

c. Electrical overspeed trips

d. Vacuum trips

e. Extraction power-assisted check valves

f. The control fluid pressure switch

g. All control devices and positioning of control valves

h. The mechanical overspeed trip device

i. Each lube oil pump

10.2.3 <u>Turbine Rotor Integrity</u>

Turbine rotor integrity is provided by the integrated combination of material selection, rotor design, fracture toughness requirements, tests, and preservice inspection. This combination results in a low probability of a condition that would cause a rotor failure.

10.2.3.1 Material Selection

Turbine rotor consists of integral forging depending on the design. The rotor forgings are made from vacuum treated or remelted Ni-Cr-Mo-V alloy steel components using processes that minimize flaw occurrence, provide reasonable assurance of uniform strength, and provide adequate fracture toughness. Undesirable elements, such as sulfur and phosphorus, are controlled to the lowest practicable 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 rotor material complies with the chemical property limits of ASTM A470 (Reference 6). The chemical composition of manufacturer's material for the rotor steel has lower or equal limitations than indicated in the ASTM standard for phosphorous, sulphur, and antimony as described in Table 10.2.3-1. The rotor forgings are heat treated and tested prior to the final machining process.

The LP turbine rotors are made from large integral forging. Their larger size limits the achievable properties. The fracture appearance transition temperature (FATT) can be changed according to size and location of rotor forgings. The FATT, which is obtained from Charpy tests in the tangential direction and performed in accordance with ASTM A370 (Reference 7), is no higher than -12 °C (10 °F) at the rotor body radial and no higher than -1 °C (30 °F) at the rotor body center core.

The Charpy V-notch (Cv) energy also can be changed according to the size and location. The Cv energy is measured from Charpy tests at ambient temperature (23.9 °C (75 °F) through 26.7 °C (80 °F)) in the tangential direction performed in accordance with ASTM A370 and at least 6.22 kg-m (45 ft-lbs) at the rotor body center bore. A minimum of three Cv specimens are tested in accordance with the specification in ASTM A370.

10.2.3.2 Fracture Toughness

The proper toughness of the turbine rotor is obtained through the use of selected materials as described in Subsection 10.2.3.1. High reliability and availability, efficiency, and safety are satisfied by keeping the balance between the strength and toughness of the turbine rotor.

The fracture toughness K_{IC} for actual rotor product is determined using a value of deep-seated FATT based on the measured FATT values from the center bore or trepan specimens from the rotor forging, and a correlation factor obtained from the past manufactured rotor material test data, and generated statistically lower bound of the data.

The fracture toughness K_{IC} and FATT had been measured from static K_{IC} tests, J_{IC} tests and Charpy impact tests at various test temperatures by using the past actual manufactured rotor material. For ductile fracture at fracture toughness test, K_{IC} value is estimated from J_{IC} value using proper conversion equation. Lower bound curve of K_{IC} with excess temperatures, which is temperature minus FATT value, is estimated by statistical analysis for actual K_{IC} data and FATT data.

The fracture toughness K_{IC} is evaluated to prevent the brittle fracture of turbine rotor. The operating temperature of the turbine rotor is higher than the FATT. The centrifugal forces and thermal gradients are considered in the calculation of turbine rotor bore stress. The ratio of the fracture toughness of the rotor material at an operating temperature to the maximum tangential stress at 115 percent of the rated speed, is at least $10\sqrt{\text{mm}}$ ($2\sqrt{\text{in.}}$).

10.2.3.3 Preservice Inspection

The preservice inspection program has the following features:

a. Rotor forgings are rough machined with minimum stock allowance prior to heat treatment

b. Each forging is subjected to 100 percent volumetric ultrasonic examinations. Ultrasonic testing is performed by a straight-beam examination in radial and axial directions and by an angle-beam examination in the center bore. Detectable flaw sizes are a radial sound beam direction of 1.5 mm(0.059 in) and an oblique axial sound beam direction of 1.3 mm(0.051 in). If the back reflection is less than 5 percent of the full height by ultrasonic, it is retested or considered not acceptable. Prior to assembly, inspection of all surfaces that would not be accessible after assembly is performed by magnetic particle inspection. The results of the above examinations are reported to the design engineering group for fracture analysis.

c. The fracture analysis is conservative. The result of the fracture analysis is acceptable when the fracture toughness is greater than the stress intensity factor of the maximum final growth crack or the critical crack size is greater than the maximum final growth size after the guaranteed lifespan. These criteria are more restrictive than the criteria for Class 1 components in ASME Section III and components in ASME Section V. The criteria include the requirement that subsurface ultrasonic indications be removed or evaluated to provide reasonable assurance that any cracks will not increase enough to compromise the integrity of the unit during its design life.

After final machining, all surfaces exposed to steam (i.e., all accessible surfaces except for shaft ends) are magnetic particle tested. Special attention is given to the areas of stress raisers.

Each fully bucketed turbine rotor assembly is spin tested for 3 minutes at 120 percent of the rated speed. This speed is greater than the maximum speed anticipated following a turbine trip from full load.

10.2.3.4 Turbine Rotor Design

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

a. The combined stresses of the turbine rotor at design overspeed resulting from centrifugal forces and thermal gradients does not exceed 0.75 of the minimum specified yield strength of the material.

b. Turbine shaft bearings are designed to withstand a turbine trip after a loss of a complete last stage blade together with its root. For this reason, the bearings are able to withstand any combination of normal operating loads and transients.

c. The multitude of natural critical frequencies of the turbine shaft assemblies existing between zero speed and 20 percent overspeed are controlled in the design to prevent distress to the unit during operation.

d. The turbine rotor assembly is designed and tested to withstand the stresses corresponding to an overspeed level of 120 percent of the rated speed. This speed is 10 percent above the maximum expected speed resulting from loss of load.

e. The turbine rotor design facilitates inservice inspection of high stress regions : (COL 10.2(1)).

10.2.3.5 Inservice Inspection

The inservice inspection program for the turbine assembly includes disassembly of the turbine's last two stages of blades in stages during plant shutdowns so the entire turbine is inspected within 10 years or less. The inspection includes a complete inspection of all normally inaccessible parts, such as couplings, coupling bolts, LP turbine rotors, LP turbine buckets, and HP turbine rotor. The inspection consists of visual, surface, and volumetric examinations.

The inservice inspection of MSVs, CVs, ISVs, and IVs includes the following description. At 3-year intervals, during refueling or maintenance shutdowns coinciding with the inservice inspection schedule required by ASME Section XI (Reference 11) for reactor components, at least one MSV, one CV, one ISV, and one IV are dismantled, and visual and surface examinations are conducted of valve seats, disks, and stems. If unacceptable flaws or excessive corrosion are found in a valve, all other valves of that type are dismantled and inspected. Valve bushings are inspected and cleaned, and bore diameters are checked for proper clearance. Non-return check valves are inspected by an inspection program in accordance with vendor recommendations.

The combined license (COL) applicant is to provide a description of the turbine and valve maintenance and inspection programs prior to fuel load.

10.2.4 Evaluation

The T/G and all related steam handling equipment are conventional with a typical proven design and have been used extensively in other nuclear power plants. This T/G automatically follows the electrical load requirements from the station auxiliary load to the turbine full load.

The T/G is located entirely in the turbine generator building. Thus, no safety-related system or portion of safety-related system is close enough to the T/G to be affected by the failure of a high or moderate energy line associated with the T/G or the LP turbine and condenser connection as described in Subsection 10.2.1.

The T/G and associated high and moderate energy piping, valves, and instruments are located entirely in the T/G building. There are no safety-related systems or components located within the T/G Building. Thus, no safety-related system or portion of safety related system is close enough to the T/G to be affected by the failure of a high or moderate energy line associated with the T/G or the LP turbine and condenser connection.

The probability of a destructive overspeed condition and missile generation, assuming the recommended inspection and test frequencies, is less than 1 x 10^{-5} per year in accordance with NUREG-0800 SRP, Subsection 3.5.1.3, turbine missiles. Additionally, the orientation of the T/G is favorable as shown in Figure 1.2 and Figure 3.5-1. These layout drawings show the general arrangement of the T/G and associated equipment in relation to essential safety-related SSCs. Failure of the T/G equipment does not preclude safe shutdown of the reactor. The T/G components and instrumentation associated with protecting the T/G from an overspeed condition are accessible under operating conditions.

The results of a failure analysis of the turbine speed control system are given in Table 10.2.4-1. The system is designed so that the single failure of any component or subsystem does not disable the turbine overspeed trip function.

Since the steam generated in the steam generators is not normally radioactive, no radiation shielding is provided for the T/G and associated components. During normal conditions, radiological considerations do not affect access to system components. In the event of a primary-to-secondary system leak due to tube leak in a steam generator, the steam possibly becomes contaminated. Appropriate radiological controls can be applied to steam systems in the event that such leakage occurs. Discussions of the radiological aspects of primary-to-secondary leakage are presented in Chapter 11.

10.2.5 Combined License Information

COL 10.2(1) The combined license (COL) applicant is to provide a description of the turbine and valve maintenance and inspection programs prior to fuel load.

10.2.6 References

1. NUREG-0800, “Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants,” Section 10.2, Rev. 3, U.S. Nuclear Regulatory Commission, March 2007

2. NUREG-0800, “Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants,” Section 10.2.3, Rev. 2, U.S. Nuclear Regulatory Commission, March 2007

3. 10 CFR 50, Appendix A, General Design Criterion 4, “Environmental and Dynamic Effects Design Bases.”

4. ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, “Rules for Construction of Pressure Vessels, ”American Society of Mechanical Engineers, 2004

5. IEEE Standard C50.13, 2005, “IEEE Standard for Cylindrical - Rotor, 50 Hz and 60 Hz Synchronous Generators Rated 10 MVA and Above,” IEEE Standards Association, 2005.

6. ASTM A470, “Standard Specification for Vacuum-Treated Carbon and Alloy Steel Forgings for Turbine Rotors and Shafts,” ASTM International, 2005.

7. ASTM A370, “Standard Test Methods and Definitions for Mechanical Testing of Steel Products,” ASTM International, 2005.

8. J.A. Begley and W.A. Logsdon, “Correlation of Fracture Toughness and Charpy Properties for Rotor Steels,” Scientific Paper 71-1E7-MSLRF-P1, Westinghouse Research Laboratories, Pittsburgh, Pennsylvania, July 26, 1971.

9. ASME Boiler and Pressure Vessel Code, Section III, “Rules for Construction of Nuclear Facility Components,” American Society of Mechanical Engineers, 2004.

10. ASME Boiler and Pressure Vessel Code, Section V, “Nondestructive Examination,” American Society of Mechanical Engineers, 2005.

11. ASME Boiler and Pressure Vessel Code, Section XI, “Inservice Inspection of Nuclear Power Plant Components,” American Society of Mechanical Engineers, 2004.

12. ASTM E399-90 (1997), “Standard Test Method for Plane-Strain Fracture Toughness of Metallic Materials,” ASTM International, 1997.

13. ASTM E1921-05, “Standard Test Method for Determination of Reference Temperature, $T_{o'}$, for Ferritic Steels in the Transition Range,” ASTM International, 2005.

14. A. Kaplan, J. Pepe, “Evaluation of Temper Embrittlement in Turbine Rotor Material,” GS-7145, Research Project 2481-2, EPRI, 1991.

Table 10.2.2-1

Source of Extraction Steam for Feedwater Heating

Extraction No.	Feedwater Heater No.	Extraction Source
1st Point	7	HP turbine 1st extraction
2nd Point	6	HP turbine 2nd extraction
3rd Point	5	HP turbine exhaust
4th Point	Deaerator	LP turbine 1st extraction
5th Point	3	LP turbine 2nd extraction
6th Point	2	LP turbine 3rd extraction
7th Point	1	LP turbine 4th extraction

Table 10.2.2-2

Turbine Valve Closure Times

Valve	Characteristic	Closure Time (seconds)
Main stop valves	The primary function is to quickly shut off steam flow to the turbine under emergency conditions. Hydraulic-actuated power actuator consists of a spring housing assembly and control package.	0.3
Control valves	The primary speed control acts as a first line against overspeed by closing on a proportional basis in response to a load rejection. Normal speed control should prevent the turbine from reaching the primary overspeed trip setpoint. The valves are opened by individual hydraulic cylinders.	0.3
Intermediate stop valves	The arrangement is welded directly to the cross–around pipe to locate the combined valve as close as possible to the turbine, thereby limiting the amount of uncontrolled cross-around steam that is available for overspeeding the turbine under emergency conditions. The valves are operated by individual hydraulic cylinders.	0.3
Intercept valves	The purpose of the intercept valve is to shut off steam flow from the cross around, which, because of its large storage capacity, could potentially drive the unit to a dangerous overspeed upon loss of generator load. The valves are operated by individual hydraulic cylinders.	0.3
Non-return check valves	The valves are employed to minimize potential to contribute to the turbine overspeed in the event of T/G trip. The valves are operated by air that is connected through air relay dump valve.	0.6

Table 10.2.2-3

Turbine Overspeed Protection Devices

Device	Function	Percent of Rated Speed (Approximate)
Speed Control System	CVs Control	100
Speed Control System	Valves Close	105
Mechanical Overspeed System	Trip	110
Electrical Overspeed System (2-out-of-3)	Trip	111.5

Table 10.2.2-4

Inspection and Test Requirement for Overspeed Trip Device

Test Item	Confirmation Item	Frequency
Mechanical Overspeed Trip Test	Operation of emergency trip valve	Weekly
Electrical Overspeed Trip Test	Operation of trip solenoid valves	Weekly
Turbine Valve Test	Operation of MSVs and CVs	Once / 3 months
	Operation of ISVs and IVs	Once / 3 months
	Operation of non-return check valves	Vendor’s recommendation
Hydraulic Control Fluid Sampling and Test	Items specified in manufacturer’s Standard	Vendor’s recommendation
Valves Inspection	Seat surface check of MSVs and CVs	Every 3 years during refueling or maintenance shutdown
	Seat surface check of non-return check valves	Every 3 years during refueling or maintenance shutdown
	Closure times of MSVs, CVs, ISVs and IVs	Every 3 years during refueling or maintenance shutdown

Table 10.2.3-1

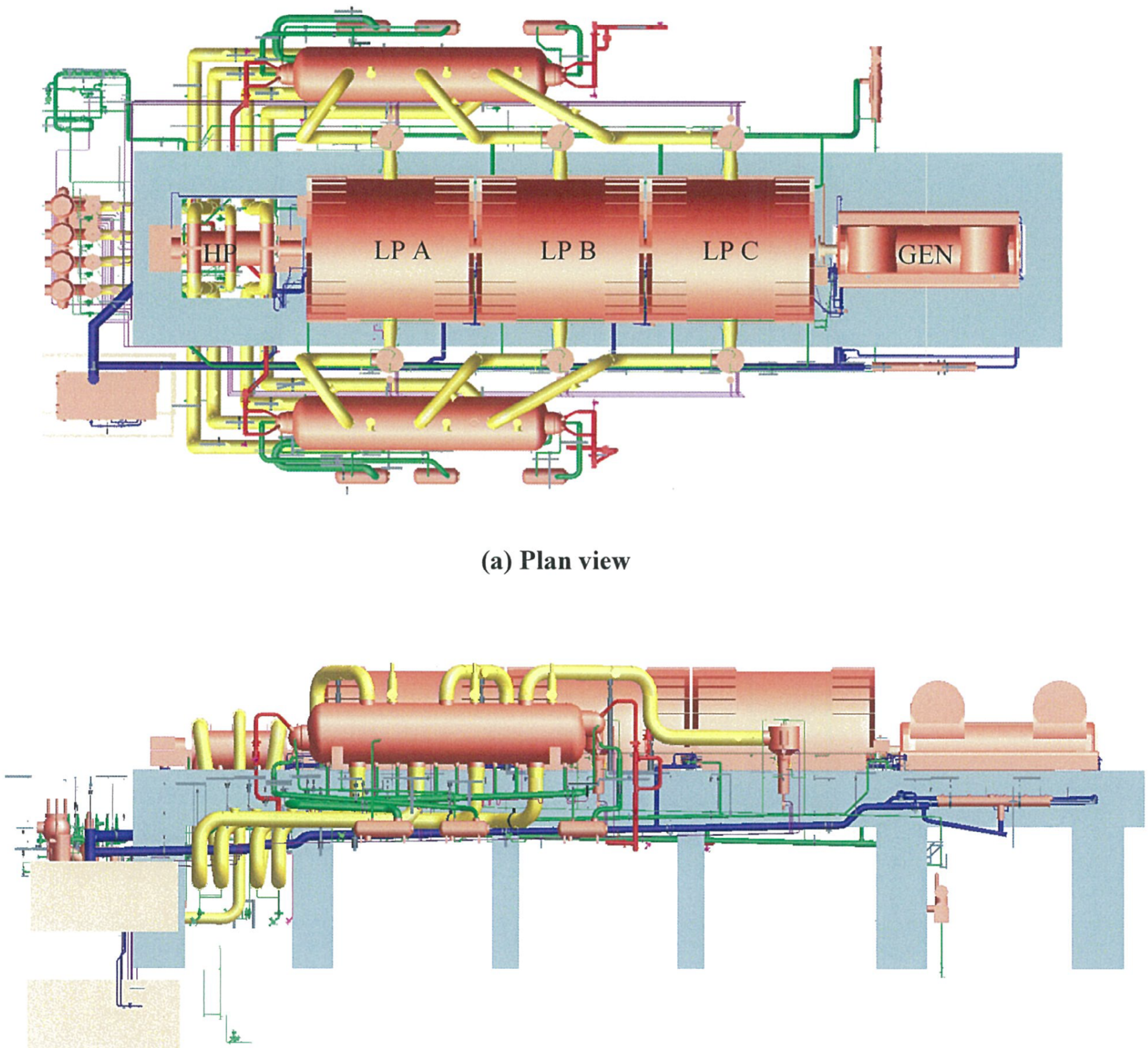
Chemical Composition for
Ni-Cr-Mo-V Alloy Material Designation

Element	Value (wt %)
C	0.22 – 0.30
Si	0.10 max.
Mn	0.20 – 0.45
P	0.012 max.
S	0.012 max.
Cr	1.5 – 2.0
Ni	3.25 – 4.00
Mo	0.25 – 0.50
V	0.07 – 0.15
Sn	0.010 max.

Table 10.2.4-1

Turbine Speed Control System Component Failure Analysis

Component	Malfunction	Overspeed Prevented By
Main control valves	Fail to close	Closure of main stop valve
Main stop valves	Fail to close	Closure of main control valve
Intercept valves	Fail to close	Closure of intermediate stop valves
Intermediate stop valves	Fail to close	Closure of intercept valve
Control processor 1	Fails	Control processors 2 and 3
Control processor 2	Fails	Control processors 1 and 3
Control processor 3	Fails	Control processors 1 and 2
Mechanical overspeed trip	Fails	Electronic overspeed trip
Electronic overspeed trip	Fails	Mechanical overspeed trip



(a) Plan view

(b) Side View

Figure 10.2.2-1 Turbine Generator Outline

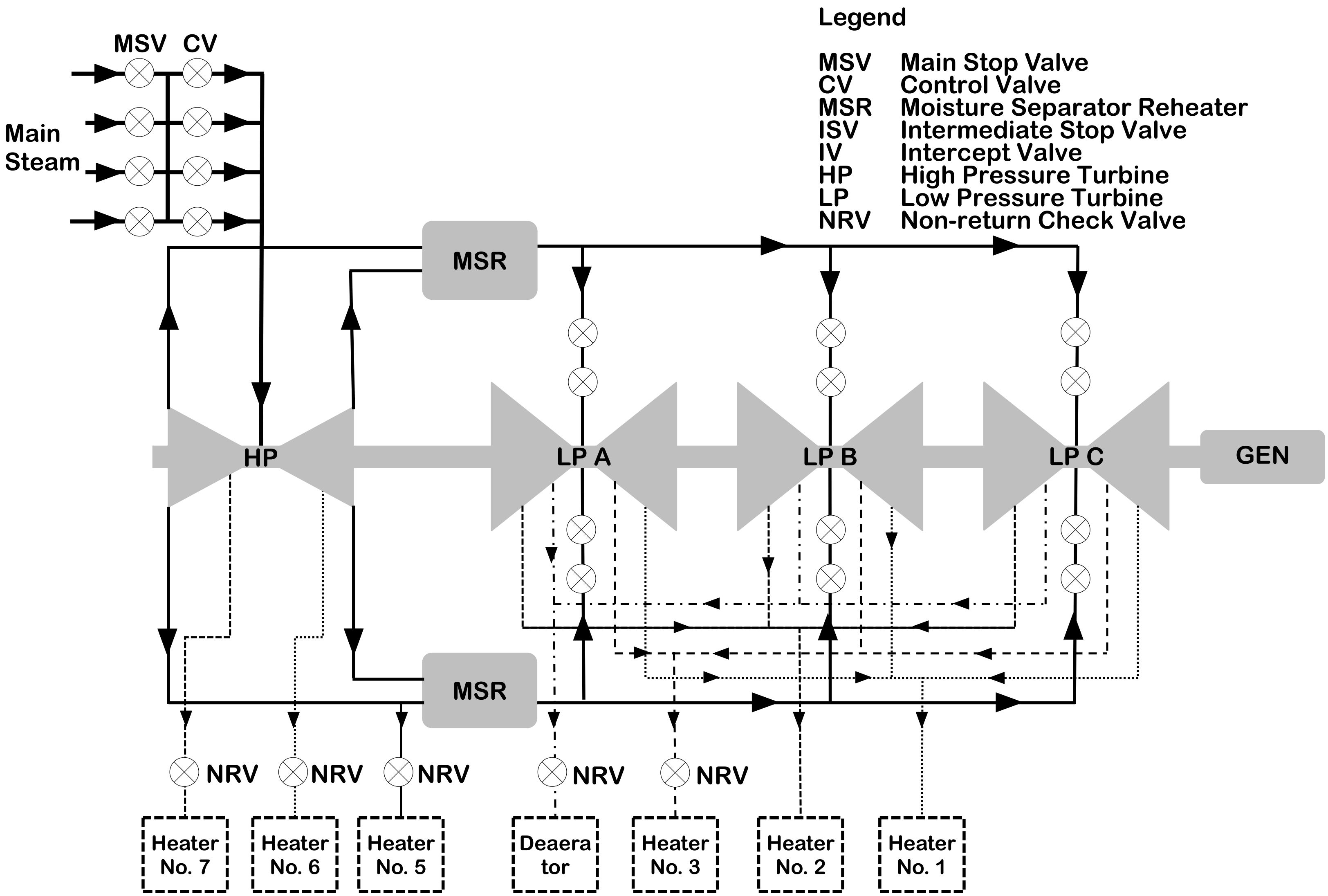


Figure 10.2.2-2 Typical Arrangement of T/G system

10.3 Main Steam System

The steam generated in the two steam generators (SGs) is supplied to the high-pressure turbine by the main steam system (MSS). The MSS consists of the components, piping, and equipment that transport steam to the power conversion system and various safety-related and non-safety-related auxiliaries.

The MSS extends from the connections to the secondary sides of the SGs up to the turbine stop valves and includes the following components:

a. Main steam isolation valves (MSIVs)

b. Main steam safety valves (MSSVs)

c. Main steam atmospheric dump valves (MSADVs)

d. Steam line to the auxiliary feedwater pump turbine

e. Turbine bypass valves (TBVs)

f. Connected piping of 6.4 cm (2.5 in) nominal diameter and larger

g. Up to and including the first valves that are either normally closed or capable of automatic closure during all modes of operation

10.3.1 Design Bases

The MSS is designed to:

a. Deliver steam from the SGs to the turbine-generator

b. Dissipate heat during the initial phase of plant cooldown

c. Dissipate heat from the reactor coolant system (RCS) following a turbine and reactor trip

d. Dissipate heat when the main condenser is not available

e. Provide steam for the following:

   Feedwater pump turbines, auxiliary feedwater pump turbines, the second stage reheater of the MSR, turbine steam seal system, auxiliary steam system, and process sampling system

f. Isolate the SGs from the non-safety related remainder of the MSS when necessary (including containment isolation and post-LOCA)

g. Provide adequate overpressure protection for the SGs and the MSS

h. Conform to applicable design codes

i. Permit visual inservice inspection

The safety-related portion of the MSS is the portion between the SG nozzle outlet to and including the main steam valve house (MSVH) penetration anchor wall.

The safety-related portions of the MSS are designed to perform their required functions during normal conditions, adverse environmental occurrences, and accident conditions, including a loss of offsite power (LOOP) with a single malfunction or failure of an active component.

The MSS meets the requirements of General Design Criteria (GDC) 2, GDC 4, GDC 5, and GDC 34 of Appendix A to 10 CFR 50 (Reference 13); 10 CFR 50.63 (Reference 14); and 1.155 (Reference 23), 1.115, 1.117, and 1.29 as follows:

a. GDC 2 – Safety-related portions of the MSS are designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunamis, and seiches without loss of capability to perform its safety functions. Refer to Sections 3.3, 3.4, and 3.7.

b. GDC 4 – Safety-related portion of the MSS are resistant to the effects of the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents, including LOCAs. Safety-related portions of the MSS are designed to withstand the effects of external missiles and internally generated missiles, pipe whip, and jet impingement forces associated with pipe breaks. Refer to Sections 3.5, 3.6, and 3.11.

c. GDC 5 – Safety-related portions of the MSS are not shared among nuclear power units. No safety-related equipment of the MSS is shared between units.

d. GDC 34 – The MSS is designed to provide sufficient cooldown capacity and suitable power supply and redundancy to provide reasonable assurance of functionality during a LOOP.

e. NRC RG 1.155 and 10 CFR 50.63 – Safety-related portions of the MSS are designed to provide decay heat removal capability necessary for core cooling and safe shutdown during a station blackout (SBO) event. A discussion of the SBO event and conformance with the guidance in NRC RG 1.155 is provided in Section 8.4. To cope with an SBO event and a loss of ac power, the APR1400 is provided with an AAC power source.

f. NRC RG 1.115 (Reference 8) – Safety-related portions of the MSS are designed to protect against low-trajectory turbine missiles. Refer to Section 3.5.

g. NRC RG 1.117 (Reference 9) – Safety-related portions of the MSS are designed to protect against tornadoes. Refer to Section 3.3.

h. NRC RG 1.29 – Safety-related portions of the MSS are classified as safety Class 2 and 3, quality group B and designed in accordance with ASME Section III (Reference 1) Class 2 and 3, seismic Category I. Refer to Section 3.2 and Table 3.2-1.

The main steam piping, its isolation valves and all associated supports from the SGs to the MSVH penetration anchor are seismic Category I and are designed in accordance with the

requirements of ASME Section III, Class 2 and 3. The remaining steam piping is in accordance with ANSI/ASME-B31.1 (Reference 3).

The MSS provides a means of discharging steam to remove reactor decay heat and reactor coolant pump heat during hot standby and emergency cooldown when the auxiliary feedwater system (AFWS) is in operation.

The MSS is provided with a main steam atmospheric dump valve (MSADV) on each of the four main steam lines to allow a controlled cooldown of the SGs when the MSIVs are closed or when the main condenser is not available as a heat sink.

In the combined event of a steam line break and the loss of normal ac power or an SG tube rupture and loss of normal ac power, manual operation of the intact MSADVs on the intact SG is possible because of its manual control provision.

The MSS delivers steam to the feedwater pump turbines during low load operation until hot reheat steam for the feedwater pump turbines is available.

Steam for the turbine-driven auxiliary feedwater pumps is taken from either of the two SGs from two of the four main steam lines outside the reactor containment building and upstream of the MSIVs.

The MSS is designed in accordance with ASME Section III, Class 2 and 3 to provide access to welds and in accordance with ASME Section XI (Reference 4) to have removable insulation in areas that require inservice inspection.

ASME Section III, Class 2, and 3 components are required to perform a specific function in shutting down the reactor to a safe-shutdown condition, in maintaining the safe-shutdown condition, or in mitigating the consequences of an accident. These components are subjected to inservice testing to assess and verify operational readiness as set forth in 10 CFR 50.55a(f) (Reference 15) and ASME OM Code. Descriptions of periodic inservice inspection and inservice testing of ASME Section III, Class 2 and 3 components are provided in Subsection 3.9.6 and Section 6.6. Preservice and inservice testing and inspection are further described in Chapter 14.

The MSSV and MSADV discharge piping are arranged and supported to minimize discharge loads so that the limiting loads are not exceeded for normal and relieving conditions. The MSS is designed to minimize the potential for steam hammer. The MSS is designed to accommodate steam hammer dynamic loads and relief valve discharge loads resulting from rapid closure of system valves and safety and relief valve operation without compromising safety functions.

10.3.2 System Description

10.3.2.1 General Description

The MSS delivers steam generated in the SGs to the HP turbine where the thermal energy of the steam is converted to mechanical energy to drive the main turbine generator. The MSS also provides steam to the feedwater pump turbines, auxiliary feedwater pump turbines, the second stage reheater of the MSR, turbine steam seal system, auxiliary steam system, and process sampling system.

The major components of the MSS are the main steam piping, MSIVs, main steam isolation valve bypass valves (MSIVBVs), MSSVs, MSADVs, turbine bypass valves (TBVs), and auxiliary feedwater pump turbine steam supply valves and warmup valves.

A flow diagram of the MSS is presented in Figure 10.3.2-1. The principal data for the MSS are provided in Table 10.3.2-1.

10.3.2.2 Component Description

10.3.2.2.1 Piping

The MSS delivers steam from the two SGs to the HP turbine during normal power operation. The MSS has four main steam lines from the two SGs to the main steam common header. The four main steam lines are designed to carry the rated steam flow of 8.14×10^6 kg/hr (17.95×10^6 lb/hr) from the two SGs to the main steam common header prior to the turbine main stop valves. The flow area of the main steam piping is sufficient to keep steam velocity below 45.72 m/sec (150 ft/sec). Main steam piping layouts that result in 90-degree elbows and miters are minimized.

The main steam piping and its supports and restraints are designed to withstand loads arising from the various operating and design bases events specified in Subsection 3.9.3. The attachment of the main steam piping to the SGs is designed so that the maximum permissible nozzle loadings are not exceeded.

Provisions are made for conveniently supporting the deadweight loads imposed during hydrostatic testing of the main steam piping.

Sampling connections are provided downstream of the MSIVs to monitor the steam chemistry. Low point drains are provided on the main steam piping for start-up operation and for prevention of turbine water induction. Low point drains upstream of the MSIVs are provided. Condensate from the low point is drained to the main condenser.

Adequate clearances are provided for inservice inspection of the ASME Section III, Class 2 portions of the main steam system piping, in accordance with the provisions of ASME Section XI.

Piping design data are provided in the Table 10.3.2-1.

10.3.2.2.2 Main Steam Isolation Valve and Main Steam Isolation Valve Bypass Valve

Each main steam line is provided with a main steam isolation valve (MSIV) for positive isolation against forward steam flow and isolation against reverse flow. Each MSIV is provided with a bypass around it for warm-up of the steam lines downstream of the isolation valves and pressure equalization prior to admitting steam to the turbine.

The MSIV is a fail-close valve, upon receipt of a main steam isolation signal (MSIS), the MSIV closes automatically. The MSIVs and MSIVBVs are interlocked to close upon initiation of an MSIS. The parameters that initiate an MSIS are given in Section 7.3. The stroke time from full open to full close of the MSIV under steam line break is five seconds or less upon receipt of an MSIS. For MSIVBVs, the full open to full close stroke time is ten seconds or less upon receipt of and MSIS.

Each MSIV and MSIVBV has a physically separate and electrically independent hydraulic actuator that provides redundancy of valve operation. An MSIS is provided to each redundant set of hydraulic actuators.

The provisions of GDC 57 (Reference 16) for containment isolation valves are met. The MSIVs are classified as active and conform to the design requirements of NUREG-0800, Section 10.3 (Reference 17).

The MSIV in each main steam line is remotely operated and is capable of maintaining tight shutoff under the main steam line pressure, temperature, and flow resulting from the transient conditions associated with a pipe break in either direction of the valves.

The MSIVs are supported so that the valve body and actuator do not distort to a degree that the valve cannot close or be displaced as a result of pipe break thrust loadings.

The MSIVs are designed, fabricated, and installed so that the requirements for inservice testing and inspection of ASME OM Subsection ISTC are met.

The MSIVs and their supports are designed to withstand loads arising from the various operating and design bases events, as specified in Subsection 3.9.3.

The following operator interfaces to the MSIV are provided locally, in the main control room (MCR), and the remote shutdown room (RSR).

a. Capability to manually open and close the valve

b. Capability to test the valve operation (MCR only)

c. Valve position indication (open/close indicating lights)

An electrical or mechanical malfunction of one circuit does not prevent the MSIV from closing. The MSIVBV control circuits are designed, or precautions are taken, so that no single electrical failure will result in the spurious opening of the valves.

No single failure of the control circuits prevents closure of the MSIVBV. The control circuit is designed to the applicable parts of IEEE Standard 308 (References 18, respectively).

The data for the MSIV and MSIVBV are provided in Table 10.3.2-1.

10.3.2.2.3 Main Steam Safety Valves

The primary purpose of the main steam safety valves (MSSVs) is to provide overpressure protection for the secondary system. The MSSVs also provide protection against overpressurizing the reactor coolant pressure boundary (RCPB). They provide a heat sink for the removal of energy from the reactor coolant system (RCS) when the preferred heat sink, provided by the condenser and circulating water system (CWS), is not available.

Five ASME spring-loaded main steam safety valves (MSSVs) are provided for each individual main steam line. Thus, total twenty MSSVs are provided for the four main steam lines from the two steam generators.

The total MSSV capacity is sufficient to pass 8.62×10^6 kg/hr (19×10^6 lb/hr) at 110 % of the steam generator design pressure.

The total relieving capacity of the 20 MSSVs is equally divided between the main steam lines and is based on the ASME Section III (see Table 10.3.2-1).

The maximum steam flow limit per one MSSV is no greater than 9.07×10^5 kg/hr (2.0×10^6 lb/hr) at 70.31 kg/cm^2A (1,000 psia).

Safety valve set pressure is calculated in accordance with Article NC-7000 of ASME Section III. The MSSVs are a proven design and consistently open fully at the set pressure within acceptable limits during operability tests.

The MSSVs and their supports are designed to withstand loads arising from various operating and design bases events, specified in Subsection 3.9.3. The piping and valve arrangement and design analysis are performed in accordance with ASME Section III, Division 1, Appendix O. The MSSVs are designed, fabricated, and installed so that the

requirements for inservice testing and inspection of ASME OM Subsection ISTC can be met.

The data for the MSSV are provided in Table 10.3.2-1.

10.3.2.2.4 Main Steam Atmospheric Dump Valves

One main steam atmospheric dump valve (MSADV) is provided on each main steam line upstream of the safety valves to allow cooldown of the SGs when the MSIVs are closed or when the main condenser is not available as a heat sink. The MSADVs are designed to maintain the steam pressure below the setting of the MSSVs during emergency shutdowns or plant hot standby conditions. Each valve is capable of holding the plant at hot standby, dissipating core decay and reactor coolant pump heat, and allowing controlled cooldown from hot standby to shutdown cooling system initiation conditions.

Each valve is sized to allow a controlled plant cooldown in the event of a line break or tube rupture, which renders one SG unavailable for heat removal, concurrent with a single active failure of one of the remaining two MSADVs. An MSADV with a saturated steam capacity of not less than 0.50×10^5 kg/hr (1.1×10^6 lb/hr) at 70.31 kg/cm^{2}A (1,000 psia) (critical flow assumed) satisfies the steam flow requirements over the range of the design inlet pressures. No single valve has a maximum capacity greater than 0.91×10^5 kg/hr (2.0×10^6 lb/hr) at 70.31 kg/cm^{2}A (1,000 psia). During pre-core hot functional testing (Refer to Subsection 14.2.1.1), the plant is maintained at standby conditions. To maintain the plant in standby conditions, each MSADV is capable of controlling flow at 28,576 kg/hr (63,000 lb/hr) at 77.34 kg/cm^{2}A (1,100 psia)

MSADVs are electro-hydraulically operated and include internal solenoid-operated pilot valves and electronic valve positioners. They are designed with a return spring that causes the valve to fail closed on loss of motive power or loss of control signal. Spurious opening of any one valve does not compromise reactor safety. MSADVs can be operated manually by a local manual control in the event of total loss of power.

The valves are connected to the main steam piping. The steam through the MSADV is discharged directly to the atmosphere, with a separate vertical vent stack provided for each valve. Isolation valves are provided in the steam line upstream of each MSADV. The

isolation valves are status controlled to the open position in the MCR and can be remotely positioned manually from the MCR or the RSR to isolate the MSADVs.

The MSADVs are designed, fabricated, and installed so the requirements for inservice testing and inspection of ASME OM, Subsection ISTC, can be met. The MSADVs are classified as active and conform to design requirements of NUREG-0800, Section 10.3.

Operator interface to the MSADV control system is provided in the MCR and RSR. The following are provided:

a. Capability to manually close and position the valve

b. Valve position indication (both analog position and open/close indication lights)

No single failure of the control circuits prevents operation of at least one MSADV on each SG. The control circuits are designed to the applicable provisions of IEEE Standard 279 and IEEE Standard 308.

The data for the MSADV are provided in Table 10.3.2-1.

10.3.2.3 System Arrangement

All valves in the main steam lines outside the containment up to and including the MSIVs are located as close to the containment wall as practicable. There are no isolation valves in the main steam lines between the SGs and the MSSVs.

The MSSVs are installed in accordance with the applicable provisions of ASME Section III, Division 1, nuclear power plant components (Subsection NC-Class 2 Components). The MSSV and MSADV discharge piping is arranged and supported to minimize discharge loads so that the limiting loads are not exceeded for normal and relieving conditions.

Auxiliary feedwater pump turbine steam supplies are taken off the main steam lines upstream of the MSIVs.

The MSSVs and MSADVs are arranged so that any condensate in the line between these valves and the main steam lines drains back to the main steam lines.

The main steam piping is arranged to minimize the number of low points.

The drainage system for main steam piping is designed to remove water prior to and during the initial rolling of the turbine and during shutdown.

a. A drain is located at each low point in the main steam piping system where water may be collected during startup, shutdown, or normal operation of a unit. Long runs of piping with no low point have a drain at the end of the piping. The low point drain consists of a drain pot with a minimum diameter of 0.31 m (12 in).

b. The routing of drain piping is downward, and the slope of all horizontal pipes in the direction of the flow is downward. MSS drains are routed to the condenser.

c. Two valves are installed in series in each drain line. One of these valves is pneumatically operated and arranged to fail open. The second valve is manual and locked open.

10.3.2.4 System Operation

10.3.2.4.1 System Startup

Prior to the startup of the MSS, the circulating water and the condensate and feedwater systems are in operation. Normal water level is established in the SGs. The SGs provide steam for the MSS warm-up using heat generated by reactor coolant pump, pressurizer heaters, and reactor.

All main steam line drain valves are opened to drain condensate. The main turbine stop valves are closed, and the stop valve seat drains are opened. The MSIVs remain closed while the MSIVBVs are opened for the MSS warm-up and pressure equalization across the MSIVs. The motor-operated globe valves downstream of the MSIVBVs are used to throttle warm steam into the MSS. When the pressure and temperature are equalized

across the MSIVs, the MSIVs can be opened and the MSIVBVs closed. The turbine is warmed and loaded.

After the MSS is warmed, main steam is supplied to the turbine gland seal for sealing the turbine shafts. If the main steam is not available, the auxiliary steam from either the auxiliary boiler source or the other plant's main steam source is supplied to the turbine gland seal.

During startup and low load operation, main steam from the cross-connection header is supplied to the auxiliary steam system.

During plant low load operation when hot reheat steam pressure is not high enough to drive the feedwater pump turbine at its required speed, main steam is introduced as a supplementary source to maintain the required feedwater pump turbine speeds.

10.3.2.4.2 Normal Operation

During normal plant operation, main steam is delivered to the high pressure turbine through the MSS and is automatically controlled by the turbine generator control system (TGCS). The MSS also supplies steam to the auxiliary steam system during all modes of operation. During normal operation, all MSIVs are opened, and all MSIVBVs, MSSVs, and MSADVs and TBVs are closed. Main steam is also supplied to the turbine steam seal system and the second stage reheater tube side.

The steam bypass control system (SBCS) provides control for the TBVs as necessary to remove excess energy from the NSSS. When the plant is at the normal operating mode, the SBCS is on standby and the TBVs are closed. During rapid load changes, if there are transient plant conditions where NSSS exceeds the turbine steam requirement, the SBCS provides modulation control of the valves to bypass steam and limit the pressure in the MSS.

10.3.2.4.3 Plant Shutdown

The SBCS accommodates load rejections of any magnitude including turbine trip from full power without tripping the reactor or opening the pressurizer pilot-operated safety relief valves (POSRVs) and/or MSSVs.

During the initial cooling period for plant shutdown, the main condenser removes decay heat from the RCS using the TBS. The bypassed steam is distributed over the condenser tubes by spray headers. The condenser design includes special provisions of the energy dispersion devices to prevent steam impingement on the tubes. In the event the TBS is not available for cooldown, MSADVs may be used. At the end of the cooldown period, the drain and vent valves are opened to drain any condensate formed in the piping, and the MSIVs are closed.

10.3.2.4.4 Abnormal Operation

The MSS delivers steam to the TBS to permit step load reductions from full load to house load, without turbine trip, reactor trip, or opening the POSRVs and/or MSSVs. The TBS provides a means of controlled cooldown of the RCS after a reactor trip by passing steam directly to the condenser.

The TBS takes steam from the main steam line upstream of the turbine stop valves and discharges it to the condenser. The TBS controls main steam pressure automatically, by the SBCS, thereby reactor coolant temperature is controlled to the shutdown cooling initiation condition. The TBVs are automatically closed or blocked from opening when the condenser is unavailable.

The MSSVs are opened to relieve steam in the event of condenser unavailability combined with a load rejection requiring steam release.

Steam from the MSS is automatically supplied to the auxiliary feedwater pump turbine when an auxiliary feedwater actuation signal (AFAS) occurs.

In the event that an MSIV fails to close all steam paths downstream of the MSIVs are isolated by their respective control systems following the main steam isolation signal

(MSIS) following a secondary line break. For an evaluation of a main steam line break (MSLB) and steam generator tube rupture (SGTR), refer to the section 15.0.

10.3.2.4.5 Water (Steam) Hammer Prevention

The MSS is designed to minimize the potential for steam hammer. The MSS is designed to accommodate steam hammer dynamic loads and relief valve discharge loads resulting from the rapid closure of system valves and safety/relief valve operation without compromising safety functions. Refer to Section 3.12 for a description of piping design and piping supports design. Loads from relief valve openings and sudden closure of valves are included in the piping analyses.

The MSS design includes protection against water entrainment. The protection against water entrainment includes provisions for drain pots, line sloping, and valve operation. The main steam nozzle vertical connection lines of the SGs are the highest point in the main steam piping, and all main steam lines slope away from the SGs.

Low point drains are provided on the main steam pipes for startup and for prevention of turbine water induction. Main steam drain valves are provided with position indications. Main steam drain valves can be manually controlled in the MCR and RSR. Main steam drain valves are automatically opened and closed by drip pot level switches. Level alarms are provided in the MCR and RSR to warn the operator of main steam line drain pot high-high level.

The COL applicant is to provide operating and maintenance procedures including adequate precautions to prevent water (steam) hammer and relief valve discharge loads and water entrainment effects in accordance with NUREG-0927 and a milestone schedule for implementation of the procedure (COL 10.3(1)).

10.3.2.4.6 Instrumentation and Control

The control system minimizes the number of instrumentation control functions and control loops required to perform the essential control functions.

Radiation monitors and alarms capable of detecting N-16 are incorporated in the main steam lines upstream of the MSIV and MSIVBVs. Two monitors per SG are provided. N-16 radiation monitors are described in Subsection 12.3.4.1.5.

Instrumentation and controls associated with the MSS are described in Chapter 7.

10.3.2.5 Design Features for Minimization of Contamination

The MSS is designed with specific features to meet the requirements of 10 CFR 20.1406 and NRC RG 4.21 (Reference 22). The basic principles of NRC RG 4.21, and the methods of control suggested in the regulations, are specifically delineated into four design objectives and two operational objectives discussed in Subsection 12.3.1.10. The following description summarizes the primary features to address the design and operational objectives for the MSS.

The MSS contains components that contain radiologically contaminated fluid resulting from steam generator tube leakage. In accordance with NRC RG 4.21, the MSS has been evaluated for leak identification from the SSCs that contain radioactive or potentially radioactive materials, the areas and pathways where leakage may occur, and the methods of leakage control incorporated in the design of the system. The leakage identification evaluation indicated that the MSS is designed to facilitate early leak detection and the prompt assessment and response to manage collected fluids. Unintended contamination to the facility and the environment is minimized and/or prevented by the SSC design, supplemented by operational procedures and programs and inspection and maintenance activities.

Prevention/Minimization of Unintended Contamination

The main steam lines are equipped with radiation monitors to detect radiological contamination and to provide alarms for operator notification. Following a steam generator tube rupture, the MSIVs for the affected steam generator are closed in order to isolate the affected steam generator. This design minimizes radiological cross-contamination and unintended contamination of the facility.

The main steam piping is sloped in the direction of steam flow to avoid water entrenchment and the collection of condensate drainage.

To minimize the possibility of water impingement into the main turbine, drain traps are provided at low points in the main steam piping where water may collect. Condensate from these drain traps is continuously removed with direct piping to the main condenser during normal plant power operation. This design approach prevents the spread of contamination within the facility.

Adequate and Early Leak Detection

Radiological monitoring of the MSS is provided continuously through N-16 gamma detection with a scintillation detector and microprocessor on each main steam line from the steam generator.

Radiation monitors are provided on the condenser vacuum pump exhaust line and the steam generator blowdown line to monitor contamination levels associated with the condensate and steam generator blowdown systems.

The radiation monitors are designed to provide indication of steam generator leakage and alert the operator of a steam generator tube leak condition during power operation, including the identification of the affected steam generator.

Reduction of Cross-Contamination, Decontamination, and Waste Generation

The safety-related portion of the main steam piping is designed to comply with the ASME Code Section III. The non-safety-related portion of the main steam piping is designed to ASME B31.1 for safe operation and the minimization of waste generation.

Main steam piping is designed to minimize the effects of erosion/corrosion, is adequately sized to limit velocities, and is routed with long radius elbows to minimize potential erosion and waste generation.

The SSCs are designed with life-cycle planning through the use of nuclear industry-proven materials compatible with the chemical, physical, and radiological environment, minimizing waste generation.

Process sampling connections are provided downstream of the MSIVs for monitoring of steam chemistry.

Decommissioning Planning

The main steam piping is designed for the full service life and is fabricated as individual segments for easy assembly and removal.

The main steam piping is designed with clean out capabilities. Design features, such as the utilized welding techniques, surface finishes, etc., are included to minimize the need for decontamination and resultant waste generation.

The MSS is designed without any embedded or buried piping, preventing contamination to the environment.

Operations and Documentation

The MSS piping and components are located in the reactor containment building, auxiliary building, and turbine generator building. Adequate space is provided around the equipment to enable prompt assessment and responses.

The COL applicant is to establish operational procedures and maintenance programs as related to leak detection and contamination control (COL 10.3(2)). Procedures and maintenance programs are to be completed before fuel is loaded for commissioning.

Site Radiological Environmental Monitoring

The MSS is part of the overall plant but does not have direct release points or contamination migration pathways to the environment during normal operation. Therefore, the MSS is not required to be included in the radiological environmental monitoring program.

10.3.3 Safety Evaluation

A rupture of any main steam line or malfunction of a valve in the system would not:

a. Reduce flow capability of the AFWS to below the minimum required flow

b. Prohibit function of an engineered safety feature

c. Initiate a loss of coolant accident

d. Cause uncontrolled flow from more than one SG

e. Jeopardize containment integrity

Safety-related portions of the MSS are contained in seismic Category I structures (RCB and main steam valve house in PAB) and are designed and located to protect against environmental hazards such as wind, earthquakes, tornadoes, hurricanes, floods, and missiles, as described in Chapter 3. Sections 3.3, 3.4, 3.5, 3.7, and 3.8 describe the bases of the structural design. High and moderate energy pipe break locations and evaluation effects are provided in Section 3.6. The MSIVs, MSSVs, and MSADVs are located in the seismic Category I designed main steam valve houses. The safety-related portion of the MSS is designed to remain functional after a safe shutdown earthquake.

MSS components are initially tested according to the program addressed in Chapter 14. Periodic inservice functional testing is done in accordance with Subsection 10.3.4. ISI for the Class 2 and 3 components of the safety-related portion is described in Section 6.6. Containment isolation adequacy and the containment leakage testing for MSS are addressed in Subsections 6.2.4 and 6.2.6, respectively.

The safety-related components of the MSS are qualified to function in accident environmental conditions. The environmental qualification program is addressed in Section 3.11.

Radioactive contamination of the MSS can occur by a primary-to-secondary side leak in the SGs. The radiological aspects of primary-to-secondary system leakage are addressed in Subsection 11.1.1.3.

Accident analyses of a main steam line break (MSLB) and steam generator tube rupture (SGTR) are addressed in Subsection 15.1.5 and 15.6.3 respectively.

Table 10.3.3-1 (MSS Failure modes and effects analysis) provides the results of a single failure analysis for the MSS. The analysis results demonstrate that no single failure, coincident with a LOOP event, compromises the ability to fulfill the system safety functions.

10.3.4 Inspection and Testing Requirements

10.3.4.1 Preoperational Testing

The components of the MSS are inspected and tested as part of the initial test program. The initial plant startup test program for the MSS is described in Subsections 14.2.12.1.29, 14.2.12.1.63, 14.2.12.1.64, 14.2.12.1.65, and 14.2.12.4.15.

10.3.4.2 Inservice Testing

ASME Section III, Class 2 piping is inspected and tested in accordance with ASME Sections III and XI. ANSI/ASME B31.1 piping is inspected and tested in accordance with ANSI/ASME B31.1 Code.

A description of periodic inservice inspection and inservice testing of ASME Section III, Class 2 and 3 components is provided in Subsection 3.9.6 and Section 6.6.

Safety-related active components in the MSS are designed to be tested during plant operation. Provisions are made to allow for inservice inspection of components at times that are consistent with those specified in ASME Section XI.

During the initial startup and periods of unit shutdown, the tripping mechanisms for the MSIVs are tested for proper operation in accordance with the Technical Specifications in

Chapter 16. The valves are periodically inservice tested for leakage and freedom of movement during plant operation in accordance with ASME OM, Subsection ISTC.

A test is conducted to verify MSIV response to a simulated MSIS, as follows:

a. The objective of the test is to verify the function of the MSIV and to confirm the closing time.

b. The test method consists of applying a simulated MSIS to the controls of the MSIV under test, and recording the temperature and pressure parameters upstream and downstream of the valve seat and the timing of the closure process from receipt of signal to the instance of valve closure as indicated by the valve stem travel indicator.

c. Acceptance criteria are the MSIV closes in accordance with Subsection 10.3.2.2.2.

Periodic testing to demonstrate the operability of the MSS components is performed as specified in the Technical Specifications in Chapter 16.

10.3.5 Secondary Water Chemistry

The principal function of the secondary water system is to provide high-purity, high-quality steam to the turbine. The term purity refers to the absence of chemical and physical contaminants. The term quality refers to the absence of entrained moisture.

It is required that chemistry throughout the secondary system be controlled by all volatile treatment (AVT). This zero solids concept has been selected as the best mode of operation to maintain the long-term integrity of the SG.

In order for the secondary system to fulfill its function of providing high-purity, high-quality steam to the turbine-generator system, secondary water chemistry is guided by the following objectives:

a. Minimization or elimination of secondary-side corrosion, and

b. Minimization of impurities in the steam.

These chemistry objectives are crucial elements of a program of prudent operation and preventive maintenance which seeks to maximize plant availability while maintaining long-term plant and component integrity. The secondary water chemistry program is based on the EPRI PWR Secondary Water Chemistry Guidelines (Reference 24).

10.3.5.1 Chemistry Control Basis

SG secondary side water chemistry control is accomplished by the following:

a. Close control of the feedwater to limit the amount of impurities that can be introduced into the SG

b. Continuous blowdown of the SG to reduce the concentrating effects of the SG

c. Chemical addition to establish and maintain an environment that minimizes system corrosion

d. Pre-operational cleaning of the feedwater system

e. Minimizing feedwater oxygen content prior to entry into the SG

Secondary water chemistry is based on the zero-solids treatment method. This method employs AVT method to maintain system pH and to scavenge dissolved oxygen that may be present in the feedwater. A neutralizing amine is added to establish and maintain alkaline conditions in the feed train. Neutralizing amines that can be used for pH control are ammonia or ethanolamine.

Hydrazine is added to scavenge dissolved oxygen that is present in the feedwater. Hydrazine also tends to promote the formation of a protective oxide layer on metal surfaces by keeping these layers in a reduced chemical state.

Both the pH agent and hydrazine are injected continuously downstream of the condensate pumps or condensate demineralizers. These chemicals are added for chemistry control and can also be added to the upper SG feed line.

Layup exists whenever the SGs are at a temperature of less than 99 °C (210 °F). The primary objective during any layup of the steam generators is to minimize corrosion by excluding and providing protection against oxygen, and maintaining a proper pH. In order to achieve this objective, the operator should prepare for layup as the plant is cooling down. The most effective means of excluding oxygen is to maintain an overpressure of steam or nitrogen in the steam generator. In order to provide reasonable assurance that oxygen is excluded, 0.35 kg/cm^2G (5 psig) is specified as the minimum steam generator pressure during normal layup. In addition, a positive nitrogen overpressure should be maintained during filling and draining operations to minimize oxygen ingress.

Sampling can be accomplished after pumping the contents from on SG to the other and back three times, assuming recirculation is available. The pumping operation should lower the water level in one SG from the can deck level to the low water level and raise the level in the other SG a corresponding amount. Adding chemicals, or reducing contaminant levels prior to or during wet layup, should be performed during the pumping operation. Otherwise, it should be necessary to drain the SGs partially to add chemicals. Should the latter be necessary, the amount of water drained should be minimized. If recirculation is not available, sufficient water should be drained to provide reasonable assurance that a representative sample is taken. Mixing should also be accomplished by sparging with nitrogen via the blowdown pipes.

The operating chemistry condition for secondary-side SG water, feedwater, and condensate are given in Tables 10.3.5-1, 10.3.5-2, and 10.3.5-3, respectively. Table's 10.3.5-4 and 10.3.5-5 show the recommended secondary sampling and laboratory analysis frequencies during normal operation and startup/wet layup, respectively.

The chemistry limits are divided into four groups: normal, Action Level 1, Action Level 2, and Action Level 3. The limits provide high-quality chemistry control and permit operating flexibility. The normal chemistry conditions can be maintained by any plant operation with little or no condenser leakage. The normal values are based on what is routinely achievable and will minimize the corrosion environments to achieve system reliability for the life of the plant.

Monitored parameters that are confirmed to be outside the normal operating values are assigned one of the three action levels, which indicate the need for remedial corrective action. The actions increase in severity from Action Level 1 through Action Level 3. Action levels and the associated chemistry limits are considered the minimum requirements for protection against secondary system and SG corrosion. Operating below Action Level 1 values, permits achievement of a design lifetime while avoiding corrosive conditions. Action Level 2 is instituted for conditions that have been shown to result in SG corrosion during extended full power (100 percent) operation. Action Level 3 is implemented for conditions exist that result in rapid SG corrosion, and continued operation is not advisable.

<u>Action Level 1</u>

Objective: To promptly identify and correct the cause of an out-of-normal value without power reduction.

Actions:

a. Corrective actions are implemented as soon as possible to return a parameter from the Action Level 1 condition.

b. If parameter remains in the Action Level 1 condition for more than 21 days following confirmation of excursion, the parameters with Action Level 2 values go to Action Level 2. If the Action Level 1 condition was entered as a result of increasing power above 30 percent power while sodium, chloride, or sulfate was above the Action Level 1 value and remained above that value for more than 24 hours after increasing above 30 percent power, parameters are restored to normal values within 20 days. The lack of progressive action criteria for many parameters is not intended to imply that remaining outside the normal range is satisfactory. In these cases, other chemical parameters, specifically associated with known corrosion conditions, are utilized for control.

c. For the parameters, that do not have an Action Level 2 value, an engineering justification is developed for operating above Action Level 1 for an extended period.

Action Level 2

Objective: To minimize corrosion by operating at reduced power while corrective actions are taken.

Actions:

a. Take immediate actions to reduce power to a plant specific level at 30 percent power and achieve that power level within 24 hours of entering Action Level 2, or as quickly as safe plant operation permits. The power level is governed by safe, automatic plant operational concerns and the need to reduce the heat flux (i.e., impurity concentration rate). Power de-escalation can be terminated when the parameter value is no longer in the Action Level 2 condition. Escalation to full power can be resumed once the parameter is no longer in the Action Level 1 condition.

b. If the parameter remains in the Action Level 1 or Action Level 2 condition for more than 300 hours after entering the Action Level 2 condition, go to Action Level 3 for those parameters having Action Level 3 values. If Action Level 2 is entered as a result of being in Action Level 1 for more than the allotted time, and the parameter value has not entered the Action Level 2 condition, operation at 30 percent power may continue. Escalation to full power can be resumed once the parameter is no longer in the Action Level 1 condition.

c. After an Action Level 2 excursion, excluding dissolved oxygen, consideration should be given to further reductions in power and low power or hot soak to promote removal of specific contaminant from the SG.

Action Level 3

Objective: To correct a condition which is expected to result in rapid steam generator corrosion during continued operation. Plant shutdown minimizes impurity ingress and eliminates further concentration of harmful impurities. Plant shutdown also reduces further damage to the steam generator by allowing cleanup of the impurities as a result of hideout return.

Actions:

a. Regardless of the duration of the excursion into Action Level 3, the plant is taken to less than 5 percent power as quickly as safe plant operation permits. Clean up by feed and bleed or drain and refill as appropriate until normal values are reached. The judgment on maintaining the steam generator in a hot condition or progressing to cold shutdown should be based on the corrosion concern imposed by the specific impurity and the most rapid means to effect cleanup.

10.3.5.2 Corrosion Control Effectiveness

Alkaline conditions in the feed train and the SG reduce general corrosion at elevated temperatures and tend to decrease the release of soluble corrosion products from metal surfaces. These conditions promote the formation of a protective metal oxide film and reduce the corrosion products released into the SG.

Hydrazine also promotes the formation of a metal oxide film by reducing ferric oxide to magnetite. Ferric oxide can be loosened from the metal surfaces and transported by the feedwater. Magnetite provides an adherent protective layer on carbon steel surfaces.

The removal of dissolved oxygen from secondary water is also essential in reducing corrosion. Oxygen dissolved in water causes general corrosion that can result in pitting of ferrous metals, particularly carbon steel. Dissolved oxygen is removed from the steam cycle condensate in the main condenser deaerating section and by the full-flow feedwater deaerator, which is located between the low-pressure and high-pressure feedwater trains. Additional oxygen protection is obtained by chemical injection of hydrazine into the condensate stream. Maintaining a residual level of hydrazine in the feedwater provides reasonable assurance that any dissolved oxygen that is not removed by the condensate system is scavenged before it can enter the SG.

The presence of free hydroxide (OH^-) can cause rapid corrosion if it is allowed to concentrate in a local area. Free hydroxide is avoided by maintaining proper pH control and by minimizing impurity ingress in the SG.

Zero-solids treatment is a control technique in which both soluble and insoluble solids are excluded from the SG. This is accomplished by maintaining strict surveillance over the possible sources of feed train contamination (e.g., main condenser cooling water leakage, air inleakage, subsequent corrosion product generation in the low pressure drain system). Solids are also excluded by injecting only volatile chemicals to establish conditions that reduce corrosion and therefore reduce the transport of corrosion products into the SG. Solids in the SG can also be reduced through the use of full-flow condensate demineralization.

In addition to minimizing the sources of contaminants entering the SG, continuous blowdown is used to minimize the concentration of the contaminants.

The condensate polishing, feedwater, and blowdown systems are addressed in Subsections 10.4.6, 10.4.7, and 10.4.8, respectively.

With low solid levels, which result from following the above procedures, the accumulation of corrosion deposits on SG heat transfer surfaces and internals is limited. Corrosion product formation can alter the thermal-hydraulic performance in local regions to an extent that deposits create a mechanism that allows impurities to concentrate to high levels and could cause corrosion. By limiting the ingress of solids into the SG, the effect of this type of corrosion is reduced.

Chemical additives do not concentrate in the SG and do not represent chemical impurities that can cause corrosion because they are volatile.

10.3.5.3 Primary-to-Secondary Leaks

Primary-to-secondary leaks result in two major problems. The first is general contamination of the secondary cycle because of the distribution and possible accumulation of both long- and short-lived radionuclides. The effects and monitoring methods for these radionuclides are described in the following sections. The second concern is the effect of boric acid from the reactor coolant on secondary system pH. The result of primary-to-secondary leaks is similar to a boric acid treatment of the secondary system.

10.3.5.3.1 Radioactivity Effects

Radioactivity in the secondary system is troublesome because of normal steam and water leaks throughout the plant and direct venting to the atmosphere. The limits in Subsection 3.4.15 of the Technical Specifications provide reasonable assurance that the health and safety of the general public at the site boundary is not affected if the limit is reached. In addition, primary-to-secondary leaks can result in contamination of components and increased radiation exposure of plant personnel. Because of these considerations, the radioactivity in the SGs is monitored and could result in a limiting condition for operation. Iodine 131 (^{131}I) has been selected because it is the most limiting nuclide. Additional discussion is presented in Chapter 11.

10.3.5.3.2 Monitoring

Several methods are used to monitor primary-to-secondary leakage. Analysis of the secondary water is required by Subsection 3.7.17 of the Technical Specifications. The surveillance requirement specifies that gross activity be analyzed once every 31 days.

Periodic radiochemical analyses do not provide sufficient warning if a substantial primary-to-secondary leak suddenly occurs. For this reason, plants rely on radiation monitors for initial indication. The monitors are located in the SG blowdown line (iodine activity), main steam line (noble gas activity), and the condenser vacuum exhaust (noble gas activity). During periods of low leak rates, or when noble gas activity is low, tritium activity in the secondary plant can be monitored. The measurement of noble gas activity from condenser vacuum exhaust appears to be the most sensitive method of detecting and quantifying primary-to-secondary leaks.

The secondary system radiation monitor alarm results in prompt action to analyze the SG water in order to determine the leak rate. The primary-to-secondary leak rate can be determined by performing a mass balance based on isotopic analyses of the SG and RCS water.

10.3.6 Steam and Feedwater System Materials

10.3.6.1 Fracture Toughness

The material specifications for pressure retaining components in the safety-related portion of the main steam and feedwater system meet the fracture toughness requirements of the ASME Section III, Articles NC-2300 (Class 2) for Quality Group B and ND-2300 (Class 3) for Quality Group C components.

10.3.6.2 Materials Selection and Fabrication

MSS and feedwater system piping materials used for ASME Section III, Class 2 and 3 components, defined in NRC RG 1.26 are provided in the Tables 10.3.2-2, 10.3.2-3, and 10.3.2-4. The APR1400 meets the regulatory requirements of 10 CFR 50.55a, GDC 1 of Appendix A to 10 CFR 50, and Appendix B to 10 CFR 50.

The material selection and fabrication methods used for Class 2 and 3 components conform to the following:

a. The materials that are used are included in Appendix I of the ASME Section III and conform to Parts A, Parts B, and Parts C of ASME Section II (Reference 2) and NRC RG 1.84 (Reference 12).

b. No austenitic stainless steel piping material is used in the main steam and feedwater systems.

c. The secondary system piping is designed to allow cleaning to remove foreign material and rust prior to operation and to prevent introduction of this material into the SG. Cleaning and acceptance criteria are based on the requirements of ASME NQA-1 (Reference 19) and recommendations of NRC RG 1.37 (Reference 20).

d. The control preheats temperatures for welding of low-alloy materials conform to the NRC RG 1.50 (Reference 10) for the MSS and feedwater system. Preheat temperature for carbon steel piping of the ASME Section III, Division 1, Class 2,

and 3 portions of the MSS and feedwater system conform to the ASME Section III, Appendix D, Article D-1000.

e. Welder performance qualification for areas of limited accessibility complies with the recommendations of NRC RG 1.71 (Reference 11) (i.e., assurance of the integrity of welds in locations of restricted direct physical and visual accessibility).

f. The nondestructive examination procedures and acceptance criteria for the examination of Class 2 and Class 3 materials of tubular products conform to the requirements of ASME Section III, NC/ND-2550 through NC/ND-2570.

g. A description of periodic inservice inspection and inservice testing of ASME Section III, Class 2 and 3 components is provided in Section 6.6 and Subsection 3.9.6. Preservice and inservice testing and inspection are addressed further in Chapter 14.

h. No copper alloys are used for components that are in contact with feedwater, steam, or condensate.

Oxygen-induced corrosion is minimized by providing the following component materials:

a. Steam reheater tubes are ferritic stainless steel or equivalent.

b. Feedwater heater tubes are type 304L stainless steel with carbon steel tube sheets.

c. Main steam piping, hot reheat piping, condensate piping, feedwater piping, and heater drain piping upstream of the drain control valves are carbon steel or equivalent.

10.3.6.3 Flow-Accelerated Corrosion

Flow-accelerated corrosion (FAC)-resistant alloy materials are selected for the FAC-susceptible piping of the secondary system. The water chemistry conditions of the secondary system are controlled to minimize corrosion, such as injecting amine for pH control and hydrazine for expediting formation of protective oxide film on material surface.

The piping layout is also considered to minimize the incidence of FAC or erosion/corrosion in piping.

Most of the piping on steam and feedwater systems is made of carbon steel. Materials for the piping portions that are extremely susceptible to FAC are installed using a FAC-resistant alloy such as Cr-Mo steel.

The following piping portions with potential for FAC are generally based on NSAC-202L-R3 (Reference 7) and NUREG-1344 (Reference 6) attached to GL 89-08 (References 5).

a. For other safety/non-safety carbon steel piping with relatively mild FAC degradation identified in NUREG-1344 attached to GL 89-08, NSAC-202L-R3 and through experience, the average thinning rates of 2.54×10^{-6} mm/hr (0.1×10^{-6} in/hr) in steam system and 4.35×10^{-6} mm/hr (0.17×10^{-6} in/hr) in water system are given based on the actual measurement records from Korea standard nuclear plants. The additional thickness of 0.889 mm (0.035 in) for the portion of steam system piping, and 1.524 mm (0.06 in) for the portion of water system piping in design are applied in consideration of the 40 years of design life.

b. As shown in Table 10.3.2-4, the main feedwater piping from the MFIV in the MSVH to SGs and the piping downstream of downcomer feedwater control valves are made of high content chrome-moly materials. This portion of the feedwater system is potentially susceptible to FAC, and the design specifications require FAC-resistant piping materials as described above. Other feedwater system piping is generally made of carbon steel with 1.524 mm (0.06 in) additional margin in design.

c. SG blowdown piping from SG to the blowdown flash tank are made of chrome-moly materials. FAC-susceptible portions are made of stainless steel; FAC-susceptible portions include wet lay-up recirculation lines, filters on upstream and downstream lines, and mixed bed demineralizer upstream and downstream lines. Other SG blowdown piping is made of carbon steel with 1.524 mm (0.06 in) additional margin in design.

d. Condensate piping from the deaerator inlet control valves to the deaerator is made of chrome-moly materials. Other condensate piping is made of carbon steel with a 1.524 mm (0.06 in) additional margin in the design.

e. As shown in Table 10.3.2-2 and Table 10.3.2-3, the entire portion of main steam system piping is made of carbon steel with a 0.889 mm (0.035 in) additional margin in design.

f. The entire portion of extraction steam piping is made of chrome-moly materials

g. Most feedwater heater drain piping is made of carbon steel with 1.524 mm (0.06 in) additional margin in design. FAC-susceptible portions such as downstream components of control valves are made of high content chrome-moly materials.

For safety/non-safety carbon steel piping with relatively mild potential for FAC degradation, the required design wall thickness is based on piping design pressure, design temperature, and allowable stress in accordance with ASME Section III NC/ND-3640 or ASME B31.1 Paragraph 104. The specified wall thickness (prior to fabrication) is a standardized wall thickness stipulated in ASME B36.10M (Reference 21). It is determined to exceed the required design wall thickness with consideration of minus tolerances of the thicknesses by the appropriate amount to account for the expected wall thickness loss during fabrication. The piping layout includes a consideration of several features for the various piping systems to minimize the incidence of FAC and erosion/corrosion in piping as follows:

a. Elimination of high turbulence points wherever possible (e.g., increasing the pipe length downstream of flow orifice, control valve)

b. Application of a suitable flow orifice to minimize cavitation possibilities (e.g., using the multi-plate orifice and multi-hole orifice)

c. Application of long radius elbows

d. Application of smooth transition at shop or field welds

e. Selection of pipe diameter to have velocities within industry-recommended values

For the safety/non-safety carbon steel piping with relatively mild FAC degradation, the FAC monitoring program is prepared and implemented using knowledge acquired from experience in pipe wall thinning management of the operating nuclear power plants in Korea. The FAC monitoring program includes preservice thickness measurements of as-built piping considered susceptible to FAC and erosion/corrosion. By performing this preservice measurement, the piping thickness margin that is used as a wall thinning margin is known. By combining the measurement with regular inspections, the frequency of the pipe replacement can be predicted. Reasonable assurance of the integrity and safety of plants is provided by conducting inspection and maintenance during the service life of the plant and replacing piping if necessary. The type of fluid, flow rates, fluid temperatures, and pressure of ASME Class 2 and 3 piping for steam and feedwater system are given in Table 10.3.2-5.

The COL applicant is to provide a description of the FAC monitoring program for carbon steel portions of the steam and power conversion systems that contain water or wet steam and are susceptible to erosion-corrosion damage. The description is to address consistency with GL 89-08 and NSAC-202L-R3 and provide a milestone schedule for implementation of the program (COL 10.3(3)).

10.3.7 Combined License Information

COL 10.3(1) The COL applicant is to provide operating and maintenance procedures including adequate precautions to prevent water (steam) hammer and relief valve discharge loads and water entrainment effects in accordance with NUREG–0927 and a milestone schedule for implementation of the procedure.

COL 10.3(2) The COL applicant is to establish operational procedures and maintenance programs as related to leak detection and contamination control.

COL 10.3(3) The COL applicant is to provide a description of the FAC monitoring program for carbon steel portions of the steam and power conversion systems that contain water or wet steam and are susceptible to erosion-corrosion damage. The description is to address consistency with GL 89-08 and NSAC-202L-R3 and provide a milestone schedule for implementation of the program.

10.3.8 References

1. ASME Boiler and Pressure Vessel Code, Section III, "Rules for Construction of Nuclear Facility Components," 2007 Edition with 2008 Addenda.
2. ASME Boiler and Pressure Vessel Code, Section II, "Materials," 2007 Edition with 2008 Addenda.
3. ANSI/ASME B31.1, "Power Piping," 2010.
4. ASME Boiler and Pressure Vessel Code, Section XI, "Rules for Inservice Inspection of Nuclear Power Plant Components," 2007 Edition with 2008 Addenda.
5. NRC Generic Letter 89-08, "Erosion/Corrosion-Induced Pipe Wall Thinning," May 2, 1989.
6. NUREG-1344, "Erosion/Corrosion-Induced Pipe Wall Thinning in U.S. Nuclear Power Plants," 1989.
7. EPRI NSAC-202L-R3, "Recommendations for an Effective Flow-Accelerated Corrosion Program," 2006.
8. NRC RG 1.115, "Protection Against Low-Trajectory Turbine Missiles," U.S. Nuclear Regulatory Commission, 2012.
9. NRC RG 1.117, "Tornado Design Classification," U.S. Nuclear Regulatory Commission, 1978.
10. NRC RG 1.50, "Control of Preheat Temperature for Welding of Low-Alloy Steel," 2011.
11. NRC RG 1.71, "Welder Qualification for Areas of Limited Accessibility," Rev. 1, 2007.
12. NRC RG 1.84, "Design and Fabrication Code Case Acceptability ASME Section III Division 1," 2010.
13. 10 CFR 50, Appendix A, "General Design Criteria for Nuclear Power Plants."
14. 10 CFR 50.63, "Loss of All Alternating Current Power."

15. 10 CFR 50.55a, “Codes and Standards,” March 2007.

16. General Design Criteria 57, “Closed Systems Isolation Valves,” 10 CFR 50, Appendix A.

17. NUREG-0800, “Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants,” Section 10.3 “Main Steam Supply System,” March 2007.

18. IEEE Std. 308, “IEEE Standard Criteria for Class 1E Power Systems for Nuclear Power Generating Stations,” 2012.

19. ASME NQA-1, “Quality Assurance Requirements for Nuclear Facility Applications,” 2008 Edition with 2009 Addenda.

20. NRC RG 1.37, “Quality Assurance Requirements for Cleaning of Fluid Systems and Associated Components of Water-Cooled Nuclear Power Plants,” Rev. 1, U.S. Nuclear Regulatory Commission, March 2007.

21. ASME B36.10M, “Welded and Seamless Wrought Steel Pipe,” 2004.

22. NRC RG 4.21, “Minimization of Contamination and Radioactive Waste Generation: Life-cycle Planning,” June 2008.

23. NRC RG 1.155, “Station Blackout,” August 1988.

24. EPRI PWR Secondary Water Chemistry Guidelines: Rev. 6, EPRI 1008224, December 2004 and Rev. 7, EPRI 1016555, February 2009.

Table 10.3.2-1 (1 of 2)

Main Steam System and Component Design Data

Main Steam System Design Data	
Description	Value
MSS design pressure/temperature	84.37 kg/cm^{2}A (1,200 psia) / 298.9 °C (570 °F)
MSS operating pressure/temperature (at steam generator steam nozzle outlets)	69.74 kg/cm^{2}A (992 psia) / 284.2 °C (543.6 °F)
Total main steam flow (MGR condition)	8.14 × 10^6 kg/hr (17.95 × 10^6 lb/hr)
Component Design Data	
Main Steam Piping	
Number of main steam lines	4
Steam flow, kg/hr (lb/hr)	8.14 × 10^6 (17.95 × 10^6)
Pipe size, I.D., m (in)	0.72662 (28.607)
Design pressure, kg/cm^{2}A (psia)	84.37 (1,200)
Pipe material	carbon steel
Design Code	ASME Section III, Class 2
Seismic Category	I
Main Steam Isolation Valves (MSIVs)	
Valve Type	EH (Electro-Hydraulic)
Valve Size, mm (in)	813 (32)
Number of MSSV per main steam line	1
Total number of MSSVs	4
Design Code	ASME Section III, Class 2
Seismic Category	I
Main Steam Isolation Valve Bypass Valves (MSIVBVs)	
Valve Type	EH (Electro-Hydraulic)
Valve Size, mm (in)	100 (4)
Number of MSIVBV per main steam line	1
Total number of MSIVBVs	4
Design Code	ASME Section III, Class 2
Seismic Category	I

Table 10.3.2-1 (2 of 2)

Main Steam Atmospheric Dump Valves (MSADVs)	
Valve Type	EH (Electro-Hydraulic), modulating
Valve Size, mm (in)	400(16)
Number of MSADV per main steam line	1
Total number MSADVs	4
Design relieving capacity per valve, 100 % open, kg/hr (lb/hr) (at 70.31 kg/cm^{2}A (1,000 psia))	498,952 (1,100,000)
Controllable capacity per valve, kg/hr (lb/hr) (at 77.34 kg/cm^{2}A (1,100 psia))	28,576 (63,000)
Design Code	ASME Section III, Class 2
Seismic Category	I
Main Steam Safety Valves (MSSVs)	
Valve Type	Spring loaded type
Valve Size, in and out, mm (in)	150 × 250 (6 × 10)
Number of MSSVs per main steam line	5
Total number of MSSVs	20
Set pressure, kg/cm^{2}G (psig)	
No. 1	82.54 (1,174)
No. 2	84.72 (1,205)
No. 3 ~ No. 5	86.48 (1,230)
Required minimum total relieving capacity of the 20 MSSVs at 110 % of SG design pressure, kg/hr (lb/hr)	8.62×10^6 (19×10^6)
Required minimum relieving capacity per one (1) valve at 110 % of SG design pressure, kg/hr (lb/hr)	4.31×10^5 (0.95×10^6)
Required maximum limit relieving capacity per one valve at 70.31 kg/cm^{2}A (1,000 psia), kg/hr (lb/hr)	9.07×10^5 (2.0×10^6)
Design Pressure, kg/cm^{2}G (psig)	86.48 (1230)
Design Temperature, °C (°F)	298.9 (570)
Design Code	ASME Section III, Class 2
Seismic Category	I

Table 10.3.2-2

Main Steam Piping Design Data

Segment	Material Specification	Nominal OD (mm (in))	ASME Class
SG to containment penetration	SA-106 Gr. C (seamless)	785.0 (30.907)	Section III, Class 2
Containment penetration to MSVH	SA-106 Gr. C (seamless)	785.0 (30.907) 820.7 (32.311)	Section III, Class 2
Fittings	SA-234 WPC	785.0 (30.907), 820.7 (32.311)	Section III, Class 2
Valves (gate)	SA-352 LCC	820.7 (32.311)	Section III, Class 2
MSVH to MS pipe enclosure	A-106 Gr. C (seamless)	802.8 (31.607)	B31.1
Fittings	A-234 WPC	Larger than 600 (24)	B31.1
MS pipe enclosure to main steam header	A-106 Gr. C (seamless)	802.8 (31.607)	B31.1
Main steam header	A-234 WPC	1517.7 (59.75)	
Main steam header to MSV	A-106 Gr. C (seamless)	732.8 (28.85)	
Fittings	A-234 WPC	Larger than 600 (24)	
Flanges	ASTM A-105	80 (3) and larger	
Valves (globe, gate, check)	ASTM A-105 or ASTM A-216 WCB	65 (2.5) ~ 650 (26)	

Table 10.3.2-3

Main Steam Branch Piping Design Data (2.5 Inches and Larger)

Segment	Material Specification	Nominal OD (mm (in))	ASME Class
Main steam piping to MSADV	SA106 Gr. C (seamless)	500 (20)	Section III, Class 2
MSADV discharge piping to silencer	A106 Gr. B (seamless)	400 (16)	B31.1
Main steam piping to MSSV	SA105	200 (8)	Section III, Class 2
MSSV discharge piping to vent stack	A106 Gr. B (seamless)	250 (10), 650 (26)	B31.1
Main steam piping to pipe chase	SA333 Gr. 6 (seamless)	200 (8)	Section III, Class 2
Pipe chase to AF pump turbine steam isolation valve	SA106 Gr. B (seamless)	200 (8)	Section III, Class 3
Fittings	ASTM (S)A-234 WPB	65 (2.5) and larger	Section III, Class 2
Flanges	SA350 LF2, ASTM A-105	65 (2.5) ~ 600 (24)	Section III, Class 2
Valves (globe, gate, check)	ASTM (S)A-216, WCB or WCC, A352 LCB	65 (2.5) and larger	Section III, Class 2
Main steam piping to moisture separator reheater	A106 Gr. B (seamless)	250 (10), 300 (12)	B31.1
Fittings	ASTM A-234, WPB	250 (10), 300 (12)	
Flanges	ASTM A-105	80 (3) and larger	
Valves (globe, gate, check)	ASTM A-216, WCB or WCC	65 (2.5) ~ 650 (26)	
HP turbine to moisture separator reheater	A588 Gr. C (welded)	1050 (42)	B31.1
Moisture separator reheater to LP turbine	A588 Gr. C (welded)	1050 (42)	B31.1
Fittings	ASTM A-234, WPB	1050 (42)	

Table 10.3.2-4 (1 of 2)

Feedwater Piping Design Data

Segment	Material Specification	Nominal OD (mm (in))	ASME Class
Feedwater pump to feedwater pump discharge header	A-106 Gr. B (seamless)	600 (24)	B31.1
Feedwater pump discharge header	A-672 Gr. B60 (welded)	762 (30)	
Feedwater pump discharge header to feedwater heaters 5/6/7	A-672 Gr. B60 (welded)	660.4 (26), 762 (30)	
Feedwater heaters 7 to feedwater heaters 7 discharge header	A-672 Gr. B60 (welded)	660.4 (26)	
Feedwater heaters 7 discharge header	A-672 Gr. B60 (welded)	812.8 (32)	
Fittings	A-234 WPB	600 (24), 660.4 (26), 762 (30), 812.8 (32)	
Flanges	ASTM A-105	80 (3) and larger	
Valves (globe, gate, check)	ASTM A-105 or ASTM A-216 WCB or WCC	65 (2.5) ~ 660.4 (26)	
Feedwater heaters 7 discharge header to MFIV	A-106 Gr. B (seamless, welded)	250 (10), 660.4 (24), 762 (26), 812.8 (32)	B31.1
Fittings	A-234 WPB	250 (10), 660.4 (24), 762 (26), 812.8 (32)	
Flanges	ASTM A-105	80 (3) and larger	
Valves (globe, gate, check)	ASTM A-105 or ASTM A-216 WCB or WCC	65 (2.5) ~ 660.4 (26)	

Table 10.3.2-4 (2 of 2)

Segment	Material Specification	Nominal OD (mm (in))	ASME Class
Downcomer feedwater control valve to main steam valve house (MSVH)	A335 Gr. P22 (seamless)	250 (10)	B31.1
Fittings	A-234 WP22	250 (10)	
Flanges	ASTM A-182 Gr. F22	—	
Valves (globe, gate, check)	ASTM A-182 Gr. F22 or ASTM A-217 Gr. WC9	—	
MFIV to SG	SA335 Gr. P22 (seamless)	150 (6), 250 (10), 350 (14), 600 (24)	Section III, Class 2
Fittings	SA420 WPL6, SA234 WP22	150 (6), 250 (10), 350 (14), 600 (24)	
Flanges	SA350 LF2, SA182 F22	150 (6) ~ 600 (24)	
Valves (globe, gate, check)	SA-182 F22 or SA-217 WC9, SA-350 LF2	150 (6) ~ 600 (24)	

Table 10.3.2-5

Main Steam and Feedwater Piping Fluid Data

Segment	Fluid	Flow Rate kg/hr (lb/hr)	Temperature ºC (ºF)	Pressure kg/cm²A(psia)
Main steam piping ASME Class 2	Steam	8.14×10^6 (17.95×10^6)	284.2 (543.6)	69.75 (992)
Feedwater piping ASME Class 2	Water	8.16×10^6 (17.99×10^6)	232.2 (450.0)	74.17 (1,055)

Table 10.3.3-1

Main Steam System Failure Modes and Effects Analysis

No.	Component Name	Component No.	Active Safety Function	Failure Mode (Actuation Signal)	Method of Failure Detection	Failure Effect on System Safety Function Capability
1.	Main Steam Safety Valves (MSSVs)	MS-V1301~1320	Protection of secondary circuit over-pressurization	Spurious opening or failure to reset after opening	Valve position indication in the MCR and RSR	No safety-related impact on plant. Refer to the Chapter 15 and 16. The impact about MSSV inadvertent opening and MSSV failure to close is analyzed in the Chap.15.
2.	Main Steam Isolation Valve (MSIV)	MS-V011~014	Isolation of reactor containment building.	Fails to close (MSIS)	Valve position indication in the MCR and RSR	No safety-related impact on plant. Refer to the Chapter 6, 15, and 16. The MSIV failure to close is analyzed in Chap. 6 and 15.
3	Main Steam Isolation Valve Bypass Valve (MSIVBV)	MS-V015~018	Isolation of reactor containment building.	Fails to close (MSIS)	Valve position indication in the MCR and RSR	No safety-related impact on plant. Refer to the Chapter 15. MSIVBVs are closed during plant normal operation and fail closed upon loss of power. Second isolation valve is provided near the MSIVBV in each MSIV bypass line.
4.	Main Steam Atmospheric Dump Valve (MSADV)	MS-V101~104	To cooldown the RCS through a controlled discharge of steam to the atmosphere	Fails to open or to close on demand	Valve position indication in the MCR and RSR	No safety-related impact on plant. Refer to the Chapter 15 and 16.
5	MSADV Isolation Valve (MSADVIV)	MS-V105~108	When MSADV fails to close, the MSADVIV isolate the MSADV	Fails to close	Valve position indication in the MCR and RSR	No safety-related impact on plant. Refer to the Chapter 15 and 16. MSADV Isolation valves are lock-opened during plant normal operation. When MSADV fails to close, the MSADVIV isolate the MSADV.
6	MS Line Drain Isolation Valve	MS-V090~093	Isolation of reactor containment building.	Fails to close (MSIS)	Valve position indication in the MCR and RSR	No safety-related impact on plant.

Table 10.3.5-1

Operating Chemistry Conditions for Secondary Steam Generator Water (1)

Variable	Wet Layup	Plant Startup (2)	Power Operation (4)			
			Normal (3) Specifications	Action Level		
				1	2	3
pH at 25 °C (77 °F)	≥ 9.8	—	—	—	—	—
Cation conductivity, µS/cm at 25 °C (77 °F)	—	≤ 2.0	≤ 1.0	—	> 1.0	> 4.0
Chloride, ppb	≤ 1,000	≤ 100	≤ 10	> 10	> 50	> 250
Sodium, ppb	≤ 1,000	≤ 100	≤ 5	> 5	> 50	> 250
Sulfate, ppb	≤ 1,000	≤ 100	≤ 10	> 10	> 50	> 250
Hydrazine, ppm	≥ 75	—	—	—	—	—
Dissolved oxygen, ppb	≤ 100 (5)	—	—	—	—	—

(1) The parameters and values are subject to change based on technical evaluation as water chemistry technology is developed.

(2) Plant startup values apply when the RCS temperature is greater than or equal to 99 °C (210 °F). The values are to be met prior to exceeding 5 percent reactor power.

(3) Normal specifications are those that are to be maintained by continuous SG blowdown during proper operation of secondary systems.

(4) This applies to greater than or equal to 30 percent reactor power.

(5) The oxygen value applies to SG fill source.

Table 10.3.5-2

Operating Chemistry Conditions for Feedwater [1]

Variable	Plant Startup [2]	Power Operation [4]		
		Normal [3]	Action Level 1	Action Level 2
Conductivity (intensified cation), [5] μS/cm	—	≤ 0.2	—	—
Hydrazine, ppm	≥ 8 × CPD [6] O_2 and ≥ 20	≥ 8 × CPD [6] O_2 and ≥ 20	< 8 × CPD [6] O_2 or < 20	[7]
Dissolved oxygen, ppb	≤ 100 [8]	≤ 5	> 5	> 10 [9]
Iron, ppb	—	≤ 5	> 5	—
Suspended solids, ppb	< 10 [10]	—	—	—
Sodium, ppb	—	≤ 3	—	—

(1) The parameters and values are subject to change based on technical evaluation as water chemistry technology is developed.

(2) Plant startup values apply when the RCS temperature is greater than 99 °C (210 °F), but reactor power is less than or equal to 5 percent.

(3) Normal specifications are those that are to be maintained during proper operation of secondary system.

(4) This applies to greater than or equal to 30 percent thermal power.

(5) Conductivity is a diagnostic parameter. This value is set as a means of addressing steam purity concerns. Lower values are needed to meet blowdown limitations in Table 10.3.5-1. Cation conductivity values less than or equal to 0.2 μS/cm are generally required to meet SG water quality.

(6) CPD means condensate polisher discharge.

(7) If the ratio of feedwater hydrazine to feedwater oxygen decreases to a value less than 2 and is not restored to a value greater than or equal to 2 within 8 hours, commence shutdown as quickly as safe plant operation permits.

(8) It may not be possible to control dissolved oxygen at this value before turbine steam seals can be established. However, this value is to be met prior to reaching 30 percent power.

(9) Reduction to 30 percent power may not be a proper response to this Action Level 2 situation because of decreased steam seal integrity.

(10) During operational hot and cold shutdowns, the normal value of suspended solids is less than or equal to 100 ppb. The suspended solids concentration for the hot standby to less than 30 percent power is less than or equal to 10 ppb.

Table 10.3.5-3

Operating Chemistry Conditions for Condensate

Variable	Normal [1]	Action Level 1
Dissolved oxygen, ppb	≤ 10	> 10

(1) Normal specifications are those that are to be maintained during proper operation of secondary systems at greater than 5 percent power.

Table 10.3.5-4

Secondary Sampling/Laboratory Analysis Frequencies During Normal Power Operation

Item	Sampling Frequency[1]		
	Steam Generator Secondary Water	Feedwater	Condensate
Cation conductivity	C	—	—
Specific conductivity	—	—	—
pH	C	C	C
Dissolved oxygen	—	C	C
Sodium	C	—	—
Hydrazine	—	C[2]	—
Chloride	D	—	—
Sulfate	D	—	—
Silica	—	—	—
Iron	—	W[3]	—
pH agent	—	D	—

(1) Frequencies:
C = Continuous
D = Daily
W = Weekly
Frequencies are to be increased if abnormal conditions are detected.

(2) Hydrazine analysis during normal operation is to be performed downstream of the normal chemical addition point.

(3) Analysis should be performed for the sample passed through filter and cation resin membrane.

Table 10.3.5-5

Secondary Sampling / Laboratory Analysis Frequencies
During Plant Startup and Wet Layup

Item	Sampling Frequency (1)		
	Steam Generator Water		Feedwater
	Plant Startup	Wet Layup	Plant Startup
Cation conductivity	C	—	—
pH	C	(2)	D
Dissolved oxygen	—	(2)	D
Sodium	C	(2)	—
Hydrazine	D (3)	(2)	D (3)
Chloride	D	(2)	—
Sulfate	D	(2)	—
Suspended solids	—	—	D (4)

(1) Frequencies:
C = Continuous
D = Daily
Frequencies are to be increased if abnormal conditions are detected.

(2) Analyze every other day until stable, then weekly.

(3) Hydrazine feed rate may be verified during startup if actual sampling is not possible.

(4) More frequently during transient operation.

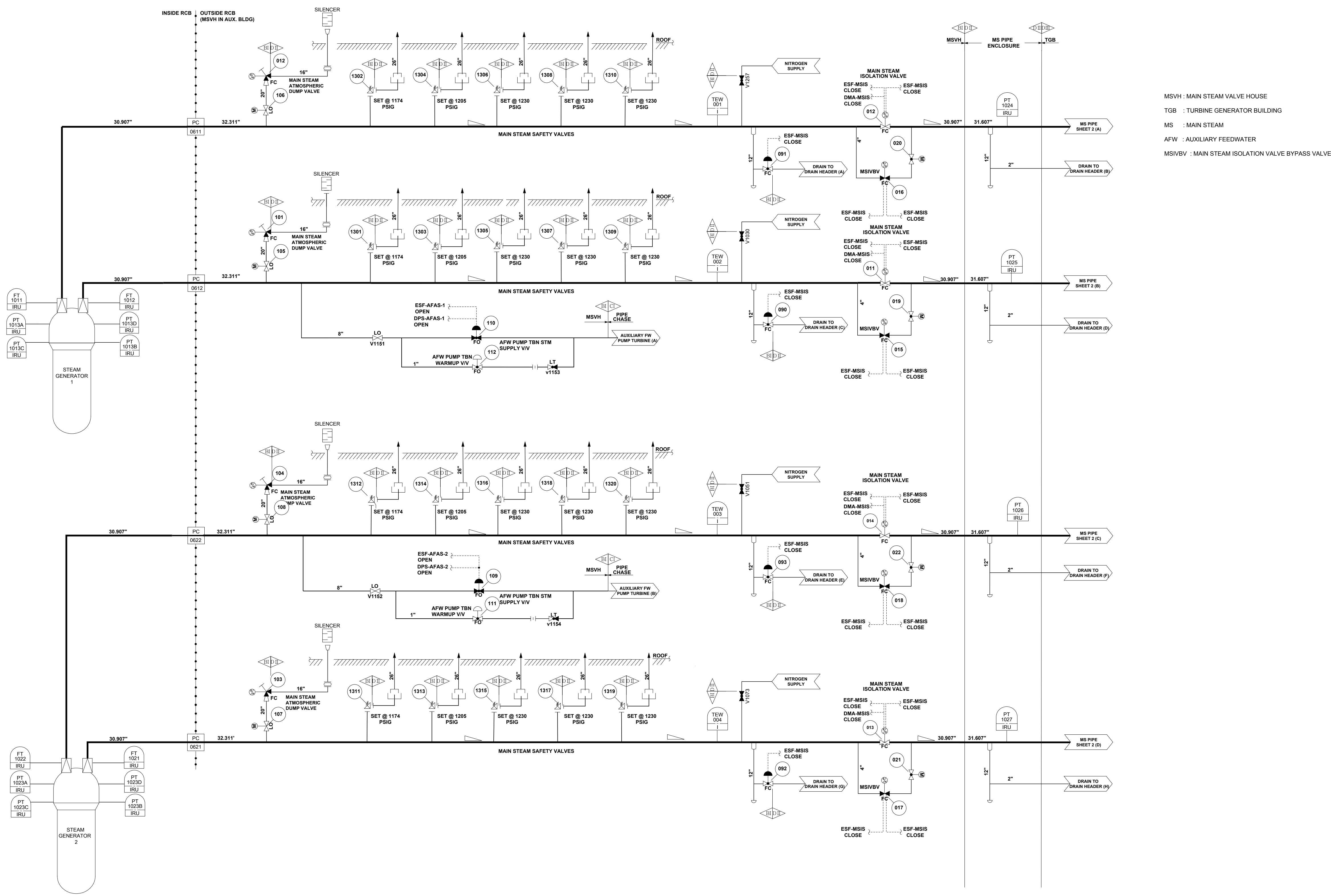


Figure 10.3.2-1 Main Steam System Flow Diagram (1 of 2)

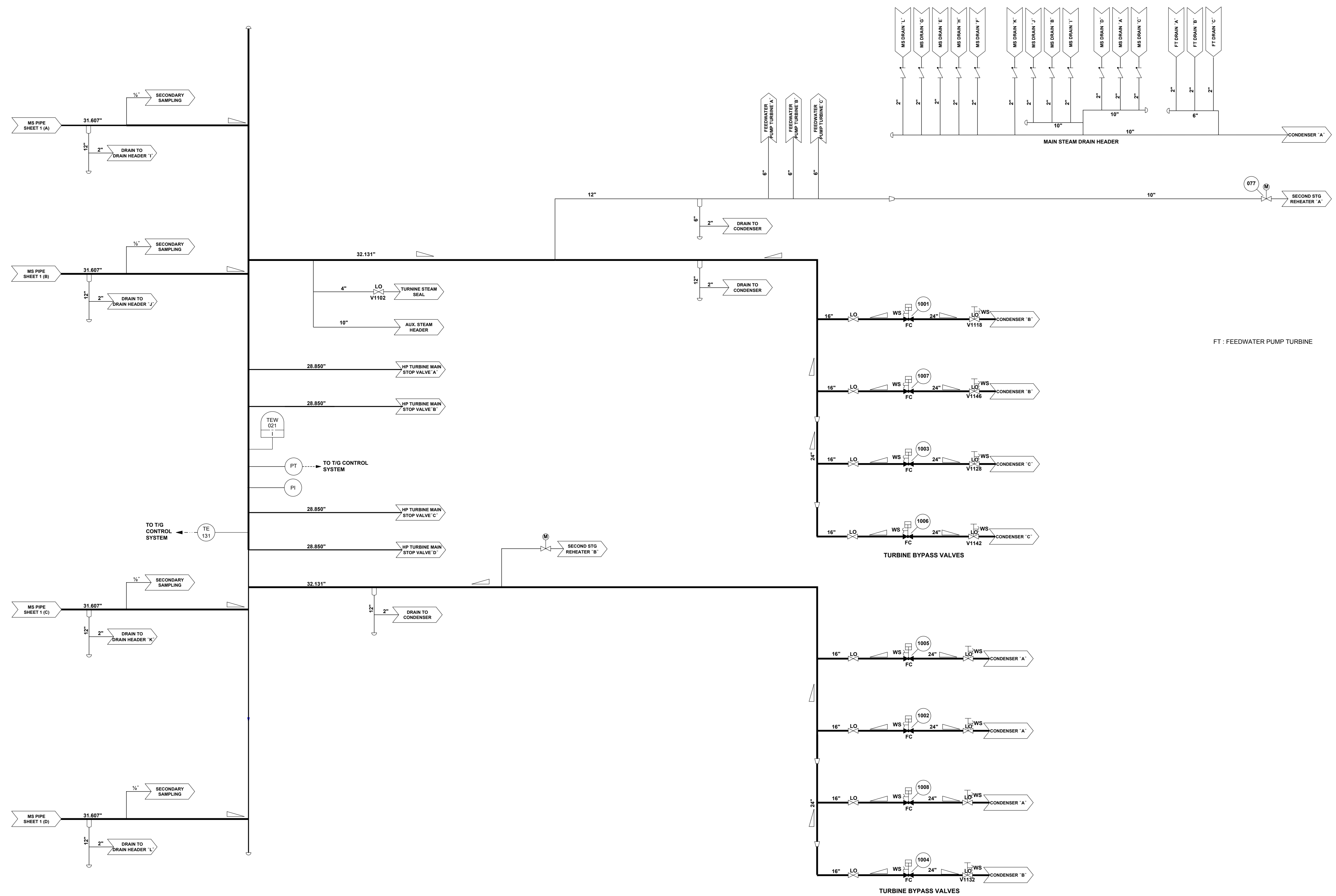


Figure 10.3.2-1 Main Steam System Flow Diagram (2 of 2)

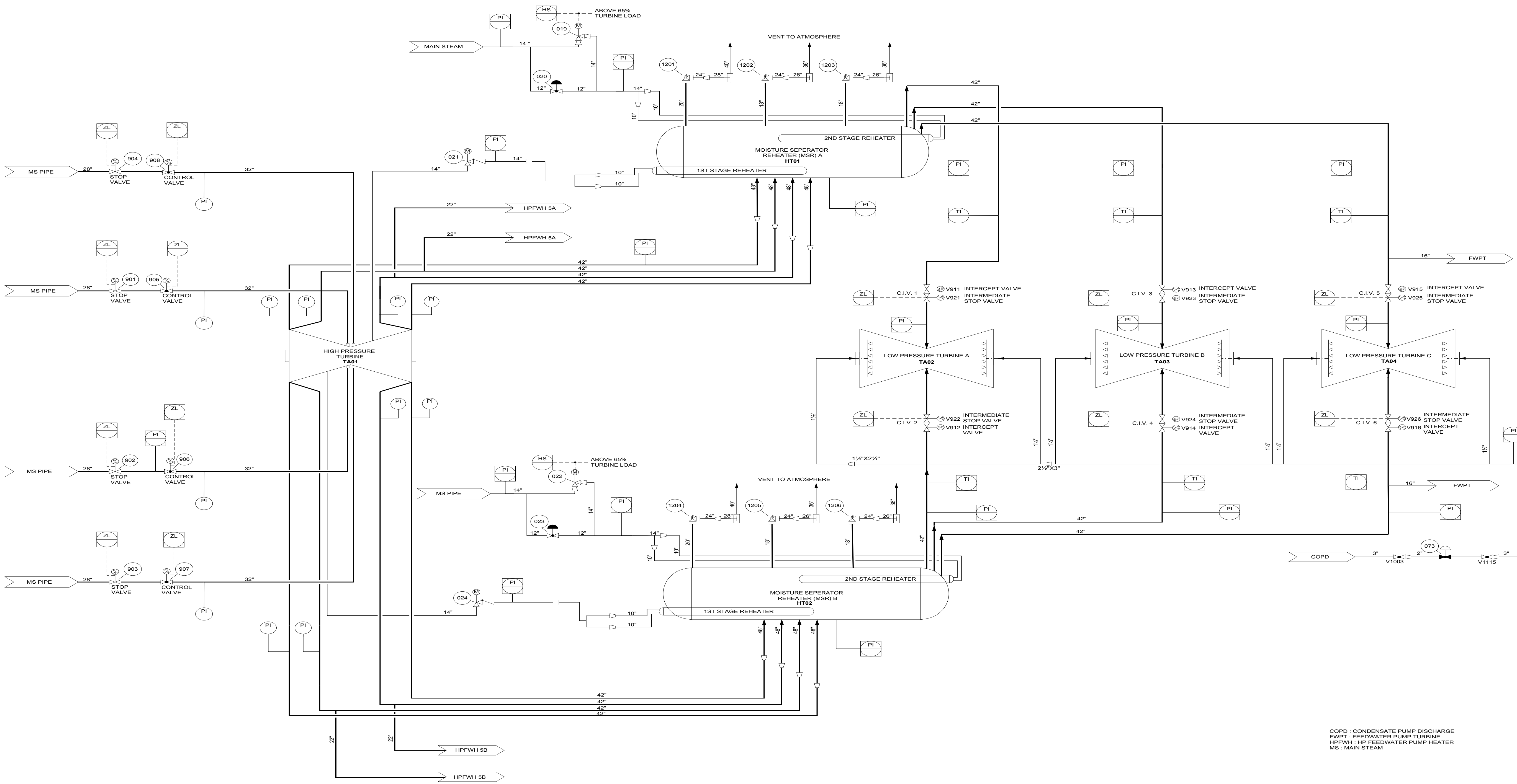


Figure 10.3.2-2 Turbine System Flow Diagram

10.4 Other Features of the Steam and Power Conversion System

10.4.1 Main Condensers

10.4.1.1 Design Bases

The main condenser is designed to condense the low-pressure turbine exhaust steam so that the condensate can be efficiently pumped through the steam cycle. The main condenser also serves as a collection point for the following:

a. Feedwater heater drains and vents

b. Miscellaneous equipment drains and vents

c. Feedwater pump turbine exhaust steam

The main condenser is also designed to condense up to 55 percent of the total full-power steam flow bypassed directly to the condenser by the turbine bypass system (TBS). The steam is bypassed to the condenser in case of a sudden load rejection of the turbine generator or a turbine trip, and at plant startup and shutdown as addressed in Subsection 10.4.4. The condenser is designed in accordance with the Heat Exchange Institute (HEI) (Reference 1). The condenser is a single-pressure, three-shell, and single-pass surface condenser. Each condenser shell consists of two parallel tube bundles to permit maintenance and cleaning during operation.

10.4.1.2 System Description

The main condenser is part of the condensate system. The condensate system is addressed in Subsection 10.4.7.

Classification of equipment and components is given in Section 3.2.

The following functional requirements of the main condenser are met to provide reasonable assurance of a reliable system:

a. The main condenser hotwells serve as storage reservoirs for the condensate and feedwater systems with sufficient volume to supply maximum condensate flow for 5 minutes.

b. The condenser vacuum system in the main condenser is designed to remove leaked air and non-condensable gases from condensing steam. The condenser vacuum system is described in Subsection 10.4.2.

c. The circulating water system is routed to each of three condenser shells in parallel configuration. Heat is removed from the main condenser by the circulating water system.

d. The condenser tube material is titanium and tube sheets are titanium-clad carbon steel, or equivalent material as specified in Table 10.4.1-1. The titanium material provides good corrosion and erosion resisting properties.

e. Condenser design precludes or minimizes steam impingement forces on the condenser tubes for normal operation and turbine bypass valve quick opening events. Tube support plates are designed to minimize tube vibrations.

f. Tube leak detection system is provided to permit sampling of the condensate in the condenser hotwell as discussed in Subsection 9.3.2. The tube leak detection system identifies which tube bundle has sustained the leakage if circulating water in-leakage occurs. The affected condenser hotwell is manually isolated by closing the motor-operated hotwell discharge valve when condenser tube leakage exceeds the design value for the condensate polishing system. Plant power is reduced as necessary. The water box is then drained and the affected tubes are either repaired or plugged.

g. The condenser is designed to deaerate the condensate during startup and normal operation. The design also deaerates any drains that enter the condenser.

h. In the event that the condenser tube leakage is beyond the design limit of the condensate polishing (CP) system, the condenser and circulating water system (CWS) are designed to permit isolation of a portion of the tubes (segmented

condenser) to permit repair of leaks while operating at reduced power (i.e., draining of water boxes and repairing or plugging the affected tubes)

i. The condenser is capable of being filled with water for a hydrostatic test. Provisions are made to allow draining and cleaning of the hotwell.

j. An expansion connection between the condenser neck and the turbine exhaust is provided.

k. Heater shells and piping installed in the condenser neck are located outside the turbine exhaust steam high-velocity regions. Internal piping is as short and straight as possible, and all steam-extraction piping slopes downward toward the heater shells.

l. The condenser shells are protected from the high internal pressure by using the relief diaphragm on the top of the low-pressure (LP) hood. If the pressure inside the LP hood exceeds atmospheric pressure, the relief diaphragm pops, and the steam inside the LP turbine is released to the air. The condenser shells have pressure transmitters to detect loss of the condenser vacuum. When the pressure from the pressure transmitters exceeds the setpoint, a turbine trip signal is generated.

m. The condensate polishing system is in full-flow operation or partial-flow operation when condensate purification is required under all load conditions. The design limit and operation period of the condensate polishing system against the condenser tube leakage without affecting the condensate/feedwater quality for safe reactor operation are addressed in Subsection 10.4.6.

10.4.1.3 <u>Safety Evaluation</u>

The condenser does not perform any safety related function and does not require safety evaluation.

The condenser is normally used to remove residual heat from the reactor coolant system during the initial cooling period after plant shutdown when the main steam is bypassed to

the condenser through the turbine bypass system. The condenser is also used to condense the main steam bypassed to the condenser in the event of sudden load rejection by the turbine generator or a turbine trip.

In the event of load rejection, the condenser condenses 55 percent of full-load main steam flow from the turbine bypass system without tripping the reactor. If the main condenser is not available during normal plant shutdown, sudden load rejection, or turbine trip, the spring-loaded main steam safety valves (MSSVs) can discharge full main steam flow to the atmosphere to protect the main steam system (MSS) from overpressure. Safe reactor shutdown can then be achieved by use of the main steam atmospheric dump valves (MSADVs). Non-availability of the main condenser considered here includes failure of the circulating water pumps to supply cooling water or loss of condenser vacuum for any reason.

During normal operation and shutdown, the main condenser does not have radioactive contaminants. Radioactive contaminants are only through primary-to-secondary system leakage due to steam generator (SG) tube leaks. The radiological aspects of primary-to-secondary leakage, including operating concentrations of radioactive contaminants, are addressed in Subsection 11.1.1.3. If high radiation is detected in the condenser vacuum system discharge, the off-gases are automatically diverted to containment drain sump area for removing the contaminants based on GDC 60. Detailed methods to preclude the accidental release of radioactive materials to the environment in excess of established limits are addressed in Subsection 10.4.2. There is no hydrogen buildup in non-condensable gas constituents in the main condenser. The noncondensable gases are removed by the mechanical vacuum pumps, which is addressed in Subsection 10.4.2. If there is a failure in one of the three vacuum pumps, a standby pump starts. The standby pump further decreases the buildup of hydrogen and explosive mixture in the main condenser shells.

Flooding due to failure of a condenser hotwell does not prevent safe shutdown of the reactor. Flooding from turbine generator building does not enter the safety-related building because the opening or access door between the turbine building and auxiliary building is located at a higher level than the basic grade of turbine building. Because the turbine generator building contains non-safety-related equipment and other buildings are not affected by turbine generator building flooding, the impact of internal flooding from the turbine generator building is limited to non-safety-related equipment in the turbine

generator building. Flood protection from internal sources is described in Subsection 3.4.1.

10.4.1.4 Inspection and Testing Requirements

The condenser is tested in accordance with the HEI for steam surface condensers. The condenser is designed to be capable of being filled with water for hydro tests. The condenser shells, hotwells, and waterboxes are provided with access openings to permit inspection and repairs; periodic visual inspections of and preventive maintenance on condenser components are conducted according to normal industrial practice.

10.4.1.5 Instrumentation Requirements

All of the instrumentation for the condenser is for the normal power operation, and is not required for safe shutdown of the reactor. Sufficient instrumentation is provided throughout the plant power generation systems to facilitate an accurate heat energy balance of the plant.

Hotwell level and pressure indications are provided locally, and associated alarms are provided in the main control room (MCR) for each condenser shell. The condensate level in the hotwell is maintained within proper limits by automatically transferring condensate to or from the condensate storage system. Condensate temperature (measured in the Condensate system), condenser pressure, circulating water temperature and pressure, and differential pressure from waterbox-to-waterbox are monitored and used to verify main condenser operation.

The condenser hotwell in each shell contains conductivity cells under each tube bundle to provide detection and location of condenser tube leaks.

Turbine trip is activated by pressure transmitters located in the condenser shells upon a loss of condenser vacuum when the condenser pressure reaches or exceeds the setpoint [[0.26 kg/cm^2 A(7.5 in HgA)]].

Refer to Subsection 7.7.1.1 for a description of the process component control system, which provides the applicable non-safety remote monitoring and controls from the MCR.

10.4.2 Condenser Vacuum System

10.4.2.1 Design Bases

The condenser vacuum system is designed to:

a. Remove air and non-condensable gases from the condenser

b. Maintain adequate condenser vacuum for proper turbine operation during startup and normal operation

The condenser vacuum system is designed to prevent an uncontrolled release of radioactive material to the environment. The condenser vacuum system vents the non-condensable gases to the environment in accordance with 10 CFR 50, Appendix A (Reference 2), General Design Criteria (GDC) 60 and 64. System components conform to the requirements of NRC Regulatory Guides (RGs) 1.26 and 1.28 (References 3 and 4, respectively) and HEI's "Standards for Steam Surface Condensers" (Reference 1).

All system components meet design code requirements that are consistent with the component quality group and seismic design classification, as described in Section 3.2.

System components in the turbine building are non-seismic and designed in accordance with NRC RG 1.26, Quality Group D. System components in the auxiliary building and]reactor containment building are seismic Category II and Quality Group D, except for the containment isolation portion, which is designed as seismic Category I and Quality Group B.

Piping and valves (Quality Group B and D) are designed in accordance with ASME Section III, Class 2, and ASME B31.1 (References 6 and 5, respectively).

10.4.2.2 System Description

10.4.2.2.1 General Description

The condenser vacuum system is shown in Figure 10.4.2-1.

The condenser vacuum system consists of four 33.33 percent capacity skid-mounted vacuum pumps and interconnecting piping, which are used to pull a vacuum on the condenser.

The vacuum pump capacity meets or exceeds the capacity recommended in HEI's "Standards for Steam Surface Condensers." The vacuum pumps remove the non-condensable gases from the condenser shells by hogging operation during startup, and by holding evacuation during normal plant operation.

Design parameters of the condenser vacuum pump are shown in Table 10.4.2-1.

10.4.2.2.2 System Operation

After the turbine steam seals are established, all vacuum pumps initially remove the air from the main condenser to draw down the pressure of the condenser and LP turbine casings. During normal operation, three vacuum pumps are continuously used. A standby vacuum pump is automatically activated in the event of excessive air inleakage resulting in the rise of condenser back pressure.

A high condenser pressure alarm annunciates in the MCR if the condenser pressure reaches the high pressure set point of [[0.17 kg/cm^{2}A (5 in HgA)]]. The turbine trips if the condenser vacuum system cannot maintain condenser operating pressure. The effects of a loss of condenser vacuum are described in Subsection 15.2.3.

The condenser vacuum system is also designed to remove non-condensable gases when the turbine bypass system is in operation, such as during hot shutdown. In the event that the condenser vacuum system malfunctions and the condenser becomes unavailable, the reactor coolant system heat rejection is accommodated by the MSADVs.

The non-condensable gases are not radioactively contaminated in normal operation. The radioactive materials are processed in this system only if there is a primary-to-secondary steam generator tube leak due to a steam generator tube rupture. If radioactivity in the exhaust flow exceeds acceptable level, the condenser vacuum pump vent effluent monitor actuates an alarm in the MCR and automatically diverts the exhaust flow from vacuum pumps to the containment drain sump area in reactor containment building, and then

adequate operating procedures are implemented to preclude significant release to the environment. The effluent monitor design, configuration, and its associated parameters are addressed in Subsections 11.5.2.1 and 11.5.2.2, respectively. The location of radiation detector is shown in Figure 11.5-1. The accumulated gas in the reactor containment building is exhausted to the atmosphere by low volume purge air cleaning unit of the reactor containment building purge system addressed in Subsection 9.4.6.2.2.

The exhausted non-condensable gases from the condenser vacuum pumps are controlled and monitored alarm set points in accordance with GDC 60 and 64. Conformance to GDC 60 and 64 is addressed in Subsections 3.1.51 and 3.1.55, respectively. The gaseous effluent radiological evaluation is provided in Section 11.3.

Thermal decomposition of hydrazine can be considered as source of hydrogen within condenser shells. However, a potential for hydrogen buildup within condenser shells does not exist because three vacuum pumps operate continuously during normal operation, and a standby vacuum starts when one vacuum pump fails. Condenser shells are considered to maintain the water vapor content above 58 percent by volume in noncondensable gases in compliance with NUREG-0800 SRP, Subsection 10.4.2 (Reference 40). The trace amounts of oxygen dissolved in the condensate and condenser hotwell inventory are considered negligible compared to the amounts of air evacuated by the vacuum pumps. Therefore, a potential for explosive mixtures within the condenser shells does not exist.

10.4.2.2.3 Design Features for Minimization of Contamination

a. The condenser vacuum system is designed with specific features to meet the requirements of 10 CFR 20.1406 (Reference 37) and Regulatory Guide 4.21 (Reference 38). The basic principles of NRC RG 4.21, and the methods of control suggested in the regulations, are specifically delineated into four design objectives and two operational objectives discussed in Subsection 12.3.1.10. The following description summarizes the primary features to address the design and operational objectives for the condenser vacuum system.

b. The condenser vacuum system has been evaluated for leakage identification from the SSCs that contain radioactive or potentially radioactive materials, the areas and pathways where leakage may occur, and the methods of leakage control incorporated in the design of the system. The leakage identification evaluation

indicated that the condenser vacuum system is designed to facilitate early leak detection and the prompt assessment and response to manage collected fluids. Unintended contamination to the facility and the environment is minimized and/or prevented by the SSC design and facility design, which is supplemented by operational procedures and programs, and inspection and maintenance activities.

Prevention/Minimization of Unintended Contamination

a. The condenser vacuum system components are located in an open area at the foundation level inside the turbine generator building. The components are designed to be skid mounted. The floors are sloped, coated with epoxy, and provided with drains that are routed to the local drain hubs. This design approach prevents the spread of contamination to the facility and the environment.

b. The condenser vacuum system is designed with sufficient capacity and redundancy to support normal operation, including anticipated operational occurrences. The components and piping are fabricated from carbon steel with welded construction for life-cycle planning, minimizing leakage, and unintended contamination of the facility and the environment.

Adequate and Early Leak Detection

c. The condenser vacuum system is designed with automated operation with manual initiation for the different modes of operation. Adequate instrumentation, including level and pressure elements and a radiation monitor, is provided to monitor the operations. Upon receipt of a high radiation signal, the vacuum discharge is diverted to the reactor containment building drain sump, and the vent from that sump is processed through the containment ventilation purge system. This design approach minimizes the spread of contamination and provides early detection.

Reduction of Cross-Contamination, Decontamination, and Waste Generation

a. The SSCs are designed with life-cycle planning through the use of nuclear industry-proven materials compatible with the chemical, physical, and radiological environment, thus minimizing waste generation.

b. The condenser vacuum system components are provided with seal water (demineralized water) for decontamination. Chilled water and other utilities are provided to facilitate operations. The utility connections are designed with a minimum of two barriers to prevent the contamination of clean systems.

Decommissioning Planning

a. The SSCs are designed for the full service life and are fabricated as individual assemblies for easy removal.

b. The SSCs are designed to facilitate decontamination. Design features, such as the welding techniques and surface finishes, are included to minimize the need for decontamination and therefore minimize waste generation.

c. The condenser vacuum system is designed without any embedded or buried piping, thus preventing unintended contamination to the environment and facilitating eventual decommissioning.

Operations and documentation

a. The condenser vacuum system is located in an open area inside the turbine generator building. Adequate space is provided around the equipment to enable prompt assessment and responses when required.

b. The COL applicant is to establish operational procedures and maintenance programs as related to leak detection and contamination control (COL 10.4 (7)). Procedures and maintenance programs are to be completed before fuel is loaded for commissioning.

c. The COL applicant is to maintain the complete documentation of system design, construction, design modifications, field changes, and operations (COL 10.4 (8)). Documentation requirements are included as a COL information item.

Site Radiological Environmental Monitoring

a. The condenser vacuum system is part of the overall plant and is included in the Site Radiological Environmental Monitoring Program, for monitoring of the release of non-condensable gases and the potential for environmental contamination. The Program includes air sampling and analysis and monitoring of meteorological conditions, hydro-geological parameters, and potential migration pathways of the radioactive contaminants. The Site Environmental Monitoring Program is included as a COL information item.

10.4.2.3 Safety Evaluation

The condenser vacuum system is designed as non-safety class with the exception of the containment isolation portion designed as safety Class 2. The condenser vacuum system is not required for safe shutdown of the plant.

10.4.2.4 Inspection and Testing Requirements

A performance test for each vacuum pump is performed in accordance with HEI "Performance Standard for Liquid Ring Vacuum Pumps" (Reference 41). The condenser vacuum system is fully tested and inspected before initial plant operation and is subject to periodic inspections after startup.

10.4.2.5 Instrumentation Requirements

The condenser vacuum system includes sufficient instrumentation to provide reasonable assurance of proper operation. All of the instrumentation for this system is for the normal power operation and none is required for safe shutdown of the reactor.

Radiation in the exhaust gases discharged to the atmosphere is continuously monitored by the effluent monitor and indicated in the MCR. The effluent monitor actuates an alarm in

the MCR upon receipt of a high radiation signal. Details on the process and effluent radiation monitoring and sampling systems are provided in Section 11.5.

10.4.3 Turbine Gland Sealing System

10.4.3.1 Design Basis

The turbine gland sealing system (TGSS) is designed to seal the annular openings where the turbine shaft penetrates the turbine casings to prevent steam out leakage and air inleakage along the turbine shaft. The TGSS also returns the air-steam mixture to the turbine gland steam-packing exhauster, condenses the steam, returns the drains to the main condenser, and exhausts the non-condensable gases to the atmosphere through blowers. The TGSS is designed to prevent uncontrolled release of radioactive material to the environment in accordance with GDC 60 and 64.

All system components are non-seismic and designed in accordance with NRC RG 1.26 (Reference 3), Quality Group D, as described in Section 3.2.

10.4.3.2 System Description

The TGSS consists of a steam-seal supply and exhaust header, a gland steam-seal feed valve, turbine steam seal control panel, a gland steam-packing exhauster with two motor-driven blowers, and the associated piping and valves. The TGSS serves both the main turbine and the feedwater pump turbines. For the system to function satisfactorily from startup to full load, a fixed positive pressure in the steam seal supply header and a fixed vacuum in the outer ends of all turbine glands are maintained at all loads. Steam is provided by the main, auxiliary, and extraction steam systems. The TGSS also receives steam-seal leak off from turbine control valves and main turbine stop valves. The TGSS is shown in Figure 10.4.3-1.

The steam discharge ends of all glands are routed to the gland steam packing exhauster that is maintained at a slight vacuum by the redundant motor-driven blowers. The gland steam packing exhauster is a shell-and-tube heat exchanger. Condensate from the condensate system is used to condense the steam from the mixture of air and steam drawn from the shaft packing. Drains from the gland steam packing exhauster are returned to the

condenser, and the non-condensable gases are vented to the atmosphere through the condenser vacuum system discharge line. The non-condensable gases discharged from the blowers are monitored for radioactivity as addressed in Section 11.5. The non-condensable gases are not radioactively contaminated in normal operation. The radioactive materials are processed in this system only if there is a primary-to-secondary steam generator tube leak due to a steam generator tube rupture. If radioactivity in the exhaust flow exceeds acceptable level, the condenser vacuum pump vent effluent monitor actuates an alarm in the MCR, and then adequate operating procedures are implemented to preclude significant release to the environment. Design and configuration for the effluent monitor, and the associated parameters are provided in Subsections 11.5.2.1 and 11.5.2.2, respectively. The location of radiation detector is shown in Figure 11.5-1.

During cold startup of the turbine generator, the sealing steam is provided by the auxiliary steam system. When the steam generator is brought up to full pressure, the auxiliary steam source is closed, and the main steam provides sealing. As the turbine is brought up to about 50 percent load, steam leakage from the high-pressure packing and the extraction steam system enters the steam-seal header. When this leakage is sufficient to maintain steam-seal header pressure, the main steam source valve is closed, and sealing steam to all turbine seals is supplied from the high-pressure packing and the extraction steam system. When the leakage from the high pressure packing is more than required by vacuum packing, the excess steam is discharged through the unloading valve to the main condenser.

10.4.3.3 Safety Evaluation

The TGSS has no safety function. The TGSS valves are arranged for fail-safe operation to protect the turbine.

10.4.3.4 Inspection and Testing Requirements

Tests and inspection of TGSS equipment are performed in accordance with applicable codes and standards. Hydrostatic tests for piping and valves are performed in accordance with ASME B31.1 (Reference 5) and ASME B16.34 (Reference 30), respectively. Non-destructive inspections are performed in accordance with ASME Section V (Reference 31). The TGSS is functionally tested during unit startup. Normal operating system performance monitoring detects any deterioration in the performance of system components.

10.4.3.5 Instrumentation Requirements

The indicating and alarm devices for steam-seal header pressure in local locations and the MCR are provided to monitor the system. A pressure controller is provided to maintain the steam-seal header pressure by signaling to the steam-seal header pressure control valves to discharge the excess steam into the main condenser by providing the signal to the unloading valve. All of the instrumentation of the TGSS is for the normal power operation, and not required for safe shutdown of the reactor.

10.4.4 Turbine Bypass System

The turbine bypass system (TBS) is part of the MSS. The TBS provides capability to flow the main steam from the SGs to the main condenser bypassing the main turbine by controlling to dissipate heat and to minimize transient effects on the reactor coolant system during startup, hot standby, cooldown and the generator step-load reduction.

10.4.4.1 Design Bases

The TBS performs no safety-related functions and therefore has no nuclear safety-related design basis. The TBS is located in the turbine generator building. The TBS takes steam from the main steam line upstream of the turbine stop valves and discharges steam to the condenser. The TBS is designed to accomplish the following functions:

a. Accommodate load rejections of any magnitude without tripping the reactor or opening the pressurizer pilot operated safety relief valves (POSRVs) and/or MSSVs. The TBS has the capacity to bypass 55 percent of the Maximum Steaming Rate to the main condenser.

b. Control nuclear steam supply system (NSSS) thermal conditions to prevent the opening of safety valves following a unit trip

c. Maintain the NSSS at no load conditions

d. Provide a means for manual control of reactor coolant system (RCS) temperature during NSSS heatup or cooldown

10.4.4.2 System Description

10.4.4.2.1 General Description

The TBS consists of the steam bypass control system (SBCS), the TBVs, and associated piping and instrumentation. The SBCS is described in Subsection 7.7.1.1.

The TBS discharges steam from the main steam line upstream of the turbine stop valves to the condenser. The TBS consists of eight TBVs located in two lines (four bypass valves per line) branching from the main steam header and connecting to the condensers. This arrangement is shown on Figure 10.3.2-1.

The TBS capacity, along with the NSSS control systems, provides the capability to meet the design requirements bases specified in Subsection 10.4.4.1. For power changes less than or equal to a 10 percent change in the electrical load or less than or equal to 5 percent per minute ramp load change, the TBS is not actuated.

10.4.4.2.2 Component Description

10.4.4.2.2.1 Turbine Bypass Valves

Turbine bypass lines are connected from the main steam header to eight TBVs. These valves discharge steam to the condensers. The total TBV capacity is 55 percent of the total full-power steam flow of saturated steam at normal full-power steam generator pressure. This relieving capacity, in conjunction with the steam bypass control system (SBCS) and reactor power cutback systems (RPCS), allows a turbine full-load rejection without causing a reactor trip or opening the POSRVs and/or MSSVs.

TBVs are normally controlled by the steam bypass control system but are capable of remote or local manual operation. The TBVs are equipped with handwheels to permit manual operation at the valve location. The TBVs are fail-close valves to prevent uncontrolled bypass of steam to the condenser.

10.4.4.2.3 System Operation

10.4.4.2.3.1 Normal Operation

During normal operation, the TBVs are under the control of the steam bypass control system, as described in Subsection 7.7.1.1.d. The SBCS provides control of the TBVs as necessary to remove excess energy from the NSSS. When the plant is in the normal operating mode, the SBCS is on standby and the TBVs are closed. During rapid load changes, if there are transient plant conditions in which NSSS exceeds the turbine steam requirement, the SBCS provides modulation control of the valves to bypass steam and limit the pressure in the MSS.

10.4.4.2.3.2 Shutdown

During hot shutdown or cooldown, the TBVs may be actuated individually from the MCR to regulate steam generator pressure and reactor coolant temperature.

The SBCS accommodates load rejections of any magnitude including turbine trip from full power without tripping the reactor or opening the POSRVs and/or MSSVs.

During the initial cooling period after plant shutdown, the main condenser removes decay heat from the RCS through the TBS. In the event the TBS is not available for cooldown, MSADVs may be used.

10.4.4.2.3.3 Abnormal Operation

Sudden Reduction of Turbine Load

In conjunction with the reactor power cutback system (RPCS) and reactor regulating system (RRS), the SBCS dissipates excess energy in the NSSS by regulating steam flow through the TBVs following the load rejection of any magnitude including a turbine trip from 100 percent power without a reactor trip or opening the POSRVs and/or MSSVs.

Closure of Turbine Stop Valves

When a rapid reduction of steam flow occurs resulting from a sudden closure of the turbine stop valves, the SBCS immediately generates the quick open signal of the TBVs.

Large Reduction in Steam Flow

If a reduction in steam flow is large enough (due to a sudden reduction in turbine load or a turbine trip), a signal is sent to the RPCS, rapidly reducing the reactor power.

10.4.4.3 Safety Evaluation

The TBS has no safety-related function and is not required to operate during or after an accident.

The design of the TBS satisfies GDC 34, relating to providing a system of heat removal that has the capability of shutting down the plant during normal operation.

The total TBV capacity is a minimum of 55 percent of the Maximum Steaming Rate (8.142×10^6 kg/hr (17.95×10^6 lb/hr) of saturated steam) at the normal full power SG pressure of 70.31 kg/cm^2A (1,000 psia).

This relieving capacity, in conjunction with the SBCS and reactor power cutback system (RPCS), allows a turbine full load rejection without causing a reactor trip or lifting the Pilot Operated safety relief valves (POSRVs) and/or MSSVs.

No single TBV have a maximum capacity greater than 9.07×10^5 kg/hr (2.0×10^6 lb/hr) of saturated steam at a SG pressure of 70.31 kg/cm^2A (1,000 psia).

The TBVs fail closed upon loss of motive air or electric signal. This is to prevent the possibility of the primary side of the plant from over cooling. In the unlikely event that one of the TBVs opens inadvertently, the maximum steam flow through one valve at full load main steam pressure is less than the maximum permissible flow to limit a reactor transient.

The design of the TBS satisfies GDC 4, regarding the environmental effects of a TBS failure on essential equipment. The equipment and high energy lines of the TBS are located in the turbine building. TBS piping failures would not affect any safety-related equipment because turbine building has no safety-related equipment in the vicinity of the TBS. Because there are no safety-related systems to be affected by a TBS pipe-break, NUREG-0800 BTP 3-3 and BTP 3-4 (References 16 and 17, respectively) are not applicable to the TBS. Pipe failures are addressed in Subsections 3.6.1 and 3.6.2.

The TBS includes energy dispersion devices of a sufficient pressure reduction stage with de-superheating spraying. Energy dispersion devices are installed to protect the condenser tubes, feedwater heaters located in the condenser neck, and other condenser components from turbine bypass steam entering the condenser shell. Energy dispersion devices distribute the steam turbine bypass flows to remove any kinetic energy without causing undue impingement on tubing or condenser structure.

10.4.4.4 Inspection and Testing Requirements

Preoperational and startup tests conform to the recommendations of NRC RG 1.68 (Reference 18). A test is conducted to verify opening of the TBVs in response to a signal simulating turbine bypass from the SBCS. Additional descriptions of inspection and tests are provided in Subsection 14.2.12.1.29.

10.4.4.5 Instrumentation Requirements

Instrumentation for the TBS is described in Subsection 7.7.1.1.d. Controls are provided in the MCR. Pressure, flow, valve position indication, and alarms are provided in the MCR and RSR.

10.4.5 Circulating Water System

The circulating water (CW) system supplies cooling water to the condenser and the turbine generator building open cooling water system (TGBOCWS). The CW discharged from the condenser and the TGBCCW heat exchanger is [[returned to the cooling tower where the heat is dissipated to the environment as a heat sink.]] [[The system configuration is

site-specific. The mechanical draft cooling tower is used as a heat sink.]] The TGBOCWS is described in Subsection 9.2.9.

10.4.5.1 Design Bases

The design bases are as follows:

a. The CW system supplies cooling water at a flow rate sufficient to remove heat from the main condenser under all conditions of power plant loading.

b. The CW system is designed to supply the condenser with an adequate amount of cooling water to maintain condenser backpressure within the design limits.

c. The CW pumps are manually tripped in the event of gross leakage into the condenser pit to prevent flooding of the turbine generator building.

d. [[The cooling towers are designed to wind resistance.]]

e. Each waterbox is designed to be isolated and drained individually during operation in the event of tube leakage.

f. Pressure surges resulting from a hydraulic transient during startup, shutdown, and accidental loss of one or more CW pumps are minimized and would not damage system components.

g. The CW system is designed to meet the requirements of GDC 4, "Environmental and Dynamic Effects Design Bases," by including design provisions so the intended safety function of a system or component will not be precluded by the effects of discharging water that may result from a failure of a component or piping in the CW system.

10.4.5.2 System Description

The CW system consists of the [[CW pumps, cooling towers,]] condenser and piping, valves, and instrumentation with the following auxiliary systems:

a. Condenser tube cleaning system

b. CW pump bearing lubrication system

c. [[Cooling water makeup and blowdown system]]

d. [[Cooling tower chemical injection system]]

The CW pumps [[located in the CW pump house take CW from the cooling tower basin]] and supply the six condenser waterboxes through the individual supply conduits. The CW passes along the condenser tubes and then discharged back to [[the cooling towers]] through the common discharge conduit. [[The cooling water is then distributed to the cooling towers and is returned to the cooling tower basin.]]

The COL applicant is to provide the location and design of the cooling tower, basin, and the CW pump house, if used (COL 10.4(1)).

CW system flow diagrams are presented in Figure 10.4.5-1. The system design parameters based on the site-specific design parameters given in Table 2.0-1, Section 2.0, are listed in Table 10.4.5-1.

10.4.5.2.1 Circulating Water Pumps

The [[six]] CW pumps are vertical, wet-pit type, single-stage pumps driven by electric motors. [[Each CW pump has a capacity for 16.66 percent of the design flow for the condenser plus 25 percent of the design flow for the TGBCCW heat exchanger.]] As the cooling water temperature decreases, the number of CW pumps in operation can be reduced.

Motor-operated butterfly valves are provided at each CW pump discharge to permit isolation of the pump when it is out of service and at the condenser shell inlet and outlet to allow isolation of line faults or maintenance.

The CW pump discharge butterfly valves are programmed for sequential opening and closing during startup and shutdown of the CW system to prevent pump damage and the initiation of water hammer.

10.4.5.2.2 Condenser Tube Cleaning System

The condenser tube cleaning system maintains condenser efficiency at design levels. The condenser tube cleaning system removes biofouling, sediment, corrosion products, and scaling with sponge rubber balls.

10.4.5.2.3 [[Cooling Towers and Auxiliaries]]

[[The conceptual design of the cooling tower is based on the mechanical draft cooling tower and consist of 56 cells in two rows with fans, motors, and components such as drift eliminators, fills, water distribution, and risers.]] [[The cooling towers have a sufficient capacity to dissipate the heat rejected from main condenser and TGBCCW heat exchanger to the environment in plant normal operation.]]

[[A basin screen is provided to prevent clogging of the CW system. The screen mesh size is selected to prevent flow blockage of the pump inlets and to limit ingestion of biofouling organics and debris.]]

[[During normal plant operation, the cooling tower chemical injection system intermittently adds chemicals including biocides. The cooling tower chemical injection system controls the water chemistry. The chemical injection pumps add biocide, algicide, pH adjuster, dispersant, corrosion, and scale inhibitor to the cooling water. Biocides are used to control biological growth inside the condenser tubes and the growth of organisms in the basin.]]

[[The cooling water makeup system provides the raw water in order to compensate for the loss of water by evaporation, wind drift and blowdown. Three 50 percent cooling water makeup pump supplies makeup water to the cooling tower basin.]]

[[The blowdown system controls the concentration of dissolved solids. Three blowdown pumps have 50 percent capacity each and take cooling water from the cooling tower basin and discharges when the conductivity that is proportional to the concentration of dissolved solid of the water is reached the preset value. Blowdown water is treated before discharge to meet regulations or requirements as necessary.]]

10.4.5.2.4 Circulating Water Pumps Bearing Lubrication

Each CW pump is supplied with an independent CW pump bearing lubrication consisting of a lube water booster pump, filtering equipment, piping, and valves. Provisions are included for fresh water lubrication during startup and shutdown.

10.4.5.2.5 System Operation

The CW system operating modes of start-up, shutdown, normal, and abnormal operations correspond to the same operation modes for the plant.

During plant start-up, the CW pumps start sequentially and manually after initial filling.

During normal plant operation, CW pumps circulate cooling water through the condenser waterboxes. [[Then the cooling water is distributed to the cooling towers and is returned to the cooling tower basin.]] [[Each cooling tower fan or CW pump is removed from service as the ambient wet bulb temperature or/and cooling load of the plant becomes lower than the design point as condenser vacuum conditions allow.]] Each CW pump is supplied with an independent CW pump lube water system. Lube water drawn from the discharge nozzle of each CW pump is supplied continuously to the individual pump by a lube water booster pump. [[CW bypasses the cooling tower and is delivered directly to the basin through the bypass line if required.]]

[[The cooling tower chemical injection system]] and condenser tube cleaning system operate during normal plant operation. [[The cooling tower chemical injection system adds chemicals to the CW to minimize fouling.]] Ball recirculation pumps inject sponge rubber balls upstream of each waterbox. After passing through the condenser tubes, the balls are collected in the strainer section and recirculated.

[[The cooling water makeup system and blowdown system operate continuously during normal operation. The operation of cooling water makeup system is interlocked with the water level of cooling tower basin.]]

CW system is not required to operate during plant shutdown, AOO, accident conditions such as LOOP. However, the CW system may operate until the power and condenser are

available during shutdown. [[The cooling tower chemical injection system is removed from service automatically when the CW pumps are not in operation.]]

The design of the CW system satisfies GDC 4 in regard to the design provisions that are implemented to accommodate the effects of discharging water that could result from a malfunction or failure of a component or piping in the system.

If flooding in the yard area occurs due to a failure in a portion of the CW system, the yard is sloped to drain the water away from the auxiliary building and compound building, and [[the cooling towers are located sufficiently far from equipment or structures important to nuclear safety.]] The safe shutdown capability would therefore not be compromised by flooding in the yard area. The COL applicant is to provide elevation drawings (COL 10.4(2)).

A postulated failure in the CW system in the turbine generator building would flood the turbine generator building basement floor. The only access to the auxiliary building from the turbine generator building is sufficiently above the turbine generator building grade elevation, and the floodwater would therefore not enter the auxiliary building. Because there is no safety-related equipment in the turbine generator building, no safety-related equipment is affected.

A CW line leak is detected with high-high condenser pit water level switches in the condenser pit sump. In the event of gross leakage into the condenser pit, the condenser pit alarm is initiated and the CW pumps are manually stopped to prevent flooding of the turbine generator building. When CW inleakage to the main condenser exceeds the design value, the respective CW supply is isolated. The plant may operate at a reduced capacity when either a condenser water box or a CW pump is isolated from the CW system.

10.4.5.2.6 Design Features for Minimization of Contamination

The CW system is designed with features to meet the requirements of 10 CFR 20.1406 and NRC RG 4.21. The basic principles of NRC RG 4.21, and the methods of control suggested in the regulations, are specifically delineated into four design objectives and two operational objectives discussed in Subsection 12.3.1.10. The following evaluation

summarizes the primary features to address the design and operational objectives for the Circulating Water System.

The CW system contains chemically treated water for cooling purposes but can become radioactively contaminated as a result of leakage in the condenser heat exchange tubes. In accordance with NRC RG 4.21, the CW system has been evaluated for leakage identification from the system components, primarily the tubes containing circulating water in the condensers, which may become contaminated from the potentially radioactive steam and condensate, the areas and pathways where leakage may occur, and the methods of leakage control incorporated in the design of the system. The leak identification evaluation indicated that the Circulating Water System is designed to facilitate early leak detection and the prompt assessment and response to manage collected fluids. Thus unintended contamination to the facility and the environment is minimized and/or prevented by the design, supplemented by operational procedures and programs and inspection and maintenance activities. Evaporative cooling in mechanical cooling towers is used for the rejection of heat in the circulating water system. The design of the cooling towers is site-specific. The COL applicant is to address design features of the prevention of contamination (COL 10.4(9)).

Prevention/Minimization of Unintended Contamination

a The system components, including the piping and heat exchangers, are designed with corrosion and erosion resistant materials for life-cycle planning. The piping and tubes are designed with hydraulic features to maintain heat transfer performance and tube integrity, thus minimizes fouling that may result in corrosion and the spread of contaminated material.

b. The CW system is sampled and analyzed periodically to assess the water quality including the level of radiological contamination. In the event that contamination is detected, inspection, and repair of the heat exchanger tubes are performed as corrective actions. This design approach minimizes leakage and unintended contamination of the facility and the environment.

Adequate and Early Leak Detection

a. The CW system is designed in conjunction with the Turbine Generator Building Drain System. The sumps in the Turbine Generator Building Drain System are used to collect above ground piping leakages and are equipped with dual level instruments to provide reasonable assurance of the detection of liquid level, thus minimizing the spread of contamination and waste generation.

b. A CW system leakage is detected by sampling and analysis of the circulating water in the piping and through measured fluid levels in the Turbine Generator Building Drain System sumps followed by sample analysis and piping inspection. This approach is consistent with the operating requirements of RG 4.21 and nuclear industry practices.

Reduction of Cross-Contamination, Decontamination, and Waste Generation

a. The SSCs are designed with life-cycle planning through the use of nuclear industry-proven materials compatible with the chemical, physical, and radiological environment, thus minimizing waste generation.

b. The CW system is designed to operate at a higher pressure than the condenser. This design approach minimizes infiltration of condensate into the circulating water, which reduces the potential for contamination.

c. The areas in which the circulating water system SSCs are housed are designed with sloped floors, epoxy coating to provide drainage and cleanable surfaces, and local sumps to collect leakage and overflows. Cubicle curbs are provided to reduce the spread of contamination to other plant areas.

Decommissioning Planning

a. The Circulating Water System may contain some buried piping in the yard related to the site-specific cooling tower design. Circulating water is sampled and analyzed periodically to assess water quality and contamination levels. When contamination is detected, the piping segment is isolated for inspection and repair. This design approach minimizes unintended contamination of the facility and the environment and facilitates decommissioning.

Operations and documentation

a. The Circulating Water System is designed for automated operations with manual initiation for the different modes of operation.

b. Adequate space is provided around the equipment to enable prompt assessment and responses when required.

c. The COL applicant is to establish operational procedures and maintenance programs as related to leak detection and contamination control (COL 10.4(7)). Procedures and maintenance programs are to be completed before fuel is loaded for commissioning.

d. The COL applicant is to maintain complete documentation of the system design, construction, design modifications, field changes, and operations (COL 10.4(8)). Documentation requirements are included as a COL Information item.

Site Radiological Environmental Monitoring

a. The circulating water system is designed to be a generally nonradioactive system with the potential to have low levels of contamination through leakage in the condenser tubes. Through monitoring, inspection, and lessons learned from industry experiences the integrity of the circulating water is well maintained, resulting in minimal levels of contamination of the facility. Continuous cooling tower blowdown is used to provide reasonable assurance that the water quality is maintained. Hence, inclusion in the Site Radiological Environmental Monitoring Program is not required for this system.

10.4.5.3 Safety Evaluation

The CW system is non-safety related and is not required for safe shutdown of the plant.

10.4.5.4 Inspection and Testing Requirements

The performance test for CW pumps is performed at least every 20 months in accordance with the HI standards (Reference 14) or applicable alternate test methods. Performance, hydrostatic, and leakage tests are performed on the butterfly valves in accordance with ANSI/AWWA C504 (Reference 15). [[The performance test for cooling towers is performed in accordance with ASME PTC 23 (Reference 33). The blowdown pumps and cooling water makeup pumps are also tested according to the HI standards or applicable alternate test method.]]

10.4.5.5 Instrumentation Requirements

CW pumps are controlled from the MCR where pump status is indicated. A CW pump trip is annunciated in the MCR.

CW pump discharge valves, the condenser inlet, and outlet valves are also controlled from the MCR where the valve status is indicated. CW pumps are interlocked to start only after their discharge valves have opened at least 20 percent. The CW pump discharge valve automatically closes when the pump stops.

CW pressures and temperatures at the condenser inlet and outlet are indicated locally and in the MCR. Pressure differential through condenser tubes are indicated locally. [[The water level of the cooling tower basin is indicated, and a low level is annunciated in the MCR.]]

[[Cooling water in the basin is periodically sampled to control the operation of the cooling tower chemical injection system and blowdown system. The conductivity of cooling water in the basin is measured to monitor the concentration of total dissolved solids and to control the operation of the blowdown system manually or automatically.]]

[[The cooling water makeup pump is interlocked with the level of cooling tower basin and operates when the water level is lower than predetermined level. The makeup and blowdown flow of cooling water are indicated locally.]]

Level switches installed in the condenser pit sump monitor flooding conditions.

10.4.6 Condensate Polishing System

10.4.6.1 Design Bases

The condensate polishing (CP) system is classified as non-safety related, non-class 1E, and seismic Category III.

The CP system removes dissolved and suspended impurities from the condensate.

The CP system maintains water quality as described in Subsection 10.3.5, as it relates to GDC 14.

The CP system is designed to continuously treat the full condensate flow supplied from the condensate pumps. The CP System may be operated in either full flow operation or partial flow operation when condensate purification is required under all load conditions including start-up and power operation. The CP system can also be bypassed when condensate purification is not required.

The CP system follows the ALARA design and operational approach described in Sections 12.1 and 12.3 in accordance with NRC RG 8.8 (Reference 36). The CP system demineralizers are located in a shielded area in order to reduce ORE.

10.4.6.2 System Description

10.4.6.2.1 General Description

The CP system consists of seven pairs of cation bed ion exchanger vessels (CBVs) and mixed bed ion exchanger vessels (MBVs) to remove the dissolved and suspended impurities from condensate under all load conditions including start-up and power operation.

The CP system is shown schematically in Figure 10.4.6-1.

The CP System processes approximately 16 to 100 percent of the condensate flow during the normal plant operation. When operating in a partial flow, a bypass flow around the

vessels is automatically controlled by the differential pressure across the condensate polisher.

The CP system is located in the second floor of the turbine generator building.

10.4.6.2.2 Component Description

Major component data are provided in Table 10.4.6-1.

Seven CBVs and seven MBVs are provided in the CP system to remove the dissolved and suspended impurities from the condensate. During the normal plant operation, the CP system has the capability to polish 100 percent of condensate through six CBVs and MBVs. The seventh CBV and MBV are isolated for standby service. All CBVs and MBVs are fabricated from stainless steel with rubber lining.

A resin trap and a resin collection tank are furnished downstream of each CBV and MBV to remove discharge of resin from each vessel to be permeated into the condensate and feedwater system in the event of failure of the outlet distributor inside each vessel.

Two recycle pumps are furnished to stabilize the effluent quality during each vessel startup in the recirculation line to the main header of the CBV and MBV.

Two spent resin holding tanks are provided for both the CBVs and MBVs. Each tank holds spent resin from each vessel until it is transported to the offsite. Spent resin holding tanks are fabricated from carbon steel with a rubber lining.

One resin holding tank holds fresh cation resin for charging to the CBV. The resin holding tank is fabricated from carbon steel with rubber lining.

One resin mixing and holding tank holds fresh mixed (cation and anion) resin for charging to the MBV. The resin mixing and holding tank is fabricated from carbon steel with rubber lining.

Resin addition equipment is provided to fill the fresh resin in the CP system.

Two sluice water pumps are provided to transfer and fill the resin.

A sampling system is provided for monitoring polishing demineralizer effluent chemistry. The sampling system includes a sample sink with instruments for measuring sodium, chloride, conductivity, hydrazine and pH, as well as provisions for collecting grab samples.

10.4.6.2.3 System Operation

A pair of the CBV and MBV processes approximately 16 percent of the condensate flow. One set of the vessels is maintained on standby condition. As a result, the CP system remains in continuous operation without reducing processing capability.

An individual vessel is manually removed from service when the level of impurities in the effluent or the differential pressure exceeds the specified limits or after a specified amount of fluid has been processed.

The CP system design provides assurance that a condensate polishing vessel is always on standby. The exhausted resin is transferred by sluice water pumps to one of the spent resin holding tanks commensurate with resin, and the fresh resin in the resin holding tank and/or resin mixing and holding tank is immediately returned to each ion exchanger vessel. The spent resin holding tanks hold spent resin until it is sampled and prepared for transport offsite. Spent resin is normally non-radioactive, so it does not normally require any special handling method. When the resin is radioactively contaminated in a vessel, temporary shielding is installed, if required. Radioactive resin is transferred from the spent resin holding tank to the radwaste treatment area for waste management.

Tube leak detection system is provided to permit sampling of the condensate in the condenser hotwell as discussed in Subsection 9.3.2. If circulating water in-leakage occurs, these design features identify which tube bundle has sustained the leakage. When condenser tube leakage exceeds the design value for the condensate polishing system, the affected condenser hotwell is manually isolated by closing the motor-operated hotwell discharge valve. Plant power is reduced as necessary. The water box is then drained and the affected tubes are either repaired or plugged.

10.4.6.2.4 Design Features for Minimization of Contamination

The CP system is designed with specific features to meet the requirements of 10 CFR 20.1406 (Reference 37) and NRC RG 4.21 (Reference 38). The basic principles of NRC RG 4.21, and the methods of control suggested in the regulations, are specifically delineated into four design objectives and two operational objectives discussed in Subsection 12.3.1.10. The following evaluation summarizes the primary features to address the design and operational objectives for the CP system.

The CP system contains components that handle radiologically contaminated fluid resulting from steam generator leakage. In accordance with NRC RG 4.21, the CP system has been evaluated for leakage identification from the SSCs that contain radioactive or potentially radioactive materials, the areas and pathways where leakage may occur, and the methods of leakage control incorporated in the design of the system. The leak identification evaluation indicated that the CP system is designed to facilitate early leak detection and the prompt assessment and response to manage collected fluids. Unintended contamination to the facility and the environment is minimized and/or prevented by the SSC design and supplemented by operational procedures and programs, and the inspection and maintenance activities.

Prevention/Minimization of Unintended Contamination

a. The system components, including the polishing cation and mixed bed demineralizer columns, are designed to be constructed of carbon steel material with rubber linings and welded construction for life-cycle planning, thus minimizing leakage and unintended contamination of the facility and the environment.

b. The CP tanks are designed with ellipsoidal bottoms. The tanks have polished internal surfaces to minimize crud traps.

Adequate and Early Leak Detection

a. The CP tanks are designed to include pressure and level instrumentation to provide reasonable assurance of safe operation of the SSCs including the associated piping, and provide alarms for operator notification in the event of high content levels.

b. The CP tank area is designed with trenches to drain leakage to the nearest sump for collection and containment. The sump is equipped with a level switch, which provides an alarm signal to the MCR in the event of high liquid level detection. This design prevents the spread of contamination to the facility and the environment and allows for prompt leak detection.

Reduction of Cross-Contamination, Decontamination, and Waste Generation

a. The SSCs are designed with life-cycle planning through the use of nuclear industry-proven materials compatible with the chemical, physical, and radiological environment, minimizing waste generation.

b. The condensate is collected in the provided sump with leak collection trenches. The trenches are sloped and epoxy coated to enhance drainage and facilitate cleaning. This design approach minimizes the spread of contamination and waste generation.

c. The CP system is designed to operate in total, partial, and bypass flow modes to meet secondary side chemistry requirements. The system is designed with on-line specific conductivity instruments, pH indicators, and other process instrumentation for automated operation with manual initiation. Sampling and analyses are implemented to determine optimum operational requirements.

d. The process piping containing contaminated solids is properly sized to facilitate easier flow with sufficient velocities to prevent the settling of solids. The piping is designed to reduce fluid traps, thus reducing the need for decontamination and the resultant waste generation.

e. Utility connections (sluice water and service air) are designed with a minimum of two barriers to prevent the contamination of clean systems.

<u>Decommissioning Planning</u>

a. The SSCs are designed for the full service life and are fabricated as individual assemblies for easy removal.

b. The CP system is designed with minimum embedded or buried piping. Piping between buildings is equipped with piping sleeves with leakage directed back to the compound building for collection, thus preventing unintended contamination.

<u>Operations and documentation</u>

a. The CP operation is designed for automated operation with manual initiation for the different modes of operation. Adequate instrumentation, including conductivity, level, flow rate, and pressure elements, is provided to monitor the process to prevent undue interruption.

b. Adequate space is provided in the vicinity of the sumps to enable prompt assessment and responses.

c. Operational procedures and maintenance programs as related to leak detection and contamination control is to be prepared by the COL applicant. Procedures and maintenance programs are to be completed before fuel is loaded for commissioning.

d. Complete documentation of system design, construction, design modifications, field changes, and operations is to be maintained by the COL applicant. Documentation requirements are included as a COL information item.

<u>Site Radiological Environmental Monitoring</u>

a. The CP system is expected to have low levels of contamination as a result of leakage in the steam generator. Due to the containment of leakage from the system within the Turbine Generator Building sumps, inclusion in the Site Radiological Environmental Monitoring Program is not required for this system.

10.4.6.3 Safety Evaluation

The CP system is a non-safety related system and is not required for the safe shutdown of the plant.

10.4.6.4 Inspection and Testing Requirements

All equipment is inspected and tested in accordance with the equipment specifications and codes.

10.4.6.5 Instrumentation Requirement

A local control panel (LCP) is provided for monitoring and controlling the CP system. Condensate flow to each CBV and MBV is indicated on the LCP. CBV and MBV outlet conductivity is monitored online on the LCP.

The CP system provides adequate process and chemistry instrumentation to keep operators apprised of system performance. The following instruments are included as a minimum: pressure indicators, pressure differential indicators, flow totalizers, flow indicators, and recorders for specific conductivity, cation conductivity, sodium, and pH.

Differential pressure transmitters are provided across each vessel, each bank of vessels and across the entire CP system. Associated indication and high alarm is provided at the control panel.

The flow totalizer is provided to measure outlet flow from each vessel. The flow rate and total volume processed are indicated on the control panel. An alarm at the control panel sounds when the vessel has reached its limit of volume processed.

The system effluent quality including specific conductivity, cation conductivity, and sodium is also monitored continuously by the process sampling system as addressed in Subsection 9.3.2.

A CP system common trouble alarm is provided in the main control room (MCR) and in the remote shutdown room (RSR), a plant operator is required to investigate the alarm condition.

10.4.7 Condensate and Feedwater System

The condensate and feedwater system delivers feedwater from the condenser to the steam generator (SG) at the required pressure, temperature, flow rate, and water chemistry. The boundary of the condensate system is from the condenser hotwell outlet to the deaerator, and the feedwater system is from the outlet of the deaerator to the inlet of the SGs. Condensate is pumped from the condenser hotwell by the condensate pumps, passes through the low pressure (LP) feedwater heaters to the deaerator storage tank. Feedwater is pumped from the deaerator storage tank by the feedwater booster pumps and main feedwater pumps through the high pressure (HP) feedwater heaters to the SGs. The condensate and feedwater system is shown on Figure 10.4.7-1.

10.4.7.1 Design Bases

The entire condensate system is non-safety-related. The portion of the feedwater system that is required to mitigate the consequences of an accident and allow safe shutdown of the reactor is safety-related. The safety-related portion is required to function following a design basis accident to provide containment and feedwater isolation. Structures, systems, and components (SSCs) from the main steam valve house (MSVH) to the SG are designed as ASME Section III (Reference 6), Class 2, and seismic Category I. All other portions are designed as non-nuclear safety (NNS) and seismic Category III in conformance with NRC RG 1.29. Table 3.2-1, Section 3.2 provides the classification of SSCs in the feedwater and condensate system in conformance with NRC RG 1.29.

The safety-related portion of the feedwater system is designed as follows:

a. In conformance with GDC 2, the safety-related portion is designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, and tsunami without loss of capability to perform its safety function.

   Refer to the Section 3.3, 3.4, and 3.7.

b. In conformance with GDC 4, the safety-related portion is designed to accommodate the effects of the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents, including LOCAs.

   The design includes the protection against the dynamic effects, including internally generated missiles, pipe whipping, and discharging fluids due to equipment malfunctions. The system is protected from water hammer by complying with the following requirements:

   1) Guidance contained in Branch Technical Position 10-2 (Reference 19) for reducing the potential for water hammers in SGs

   2) Guidance for water hammer prevention and mitigation in NUREG-0927, Rev. 1 (Reference 20)

   Refer to the Sections 3.5, 3.6, 3.11, and Subsection 10.4.7.6.

c. In conformance with GDC 5, no equipment in the condensate and feedwater system is shared between units.

d. In conformance with GDC 44, the portion is designed to provide:

   1) Capability to transfer heat loads from the reactor system to a heat sink under normal operating and accident conditions

   2) Redundancy of components so that under accident conditions, the component's safety functions can be performed assuming a single, active component failure

   3) Capability to isolate components, subsystems, or piping if required so that the system safety function is maintained

e. The condensate and feedwater system is designed to permit appropriate periodic inservice inspection of important components in conformance with GDC 45.

f. In conformance with GDC 46, the condensate and feedwater system is designed to permit appropriate functional testing of the system and components to provide reasonable assurance of structural integrity and leak-tightness, operability, and performance of active components, and the capability of the integrated system to function as intended during normal, shutdown, and accident conditions.

g. The portion is designed to withstand loads arising from the various specified normal operating and design basis events (DBEs).

10.4.7.2 System Description

10.4.7.2.1 General Description

The condensate and feedwater system delivers feedwater from condenser hotwells to the SGs at the required temperature, pressure, and flow rate. Condensate and feedwater is heated through the LP feedwater heaters and HP feedwater heaters. The condensate and feedwater system is composed of a condensate system and feedwater system.

The condensate system consists of three condensate pumps, three stages of three parallel LP heaters, a deaerator, and two deaerator storage tanks. Three 50 percent capacity motor-driven condensate pumps (two operating and one standby) deliver condensate from the condenser hotwell to the deaerator through the condensate polisher, a steam packing exhauster, and three stages of LP feedwater heaters. Condensate is provided to the SG blowdown regenerative heat exchanger for cooling.

The deaerator storage tank level is controlled by two pneumatic valves. The condenser hotwell level is maintained by directing condensate flow to and from the condensate storage tank using makeup lines.

Drains from the LP feedwater heaters are cascaded to the next lower pressure feedwater heaters with drains from the lowest pressure feedwater heaters draining to the condenser.

The feedwater system consists of three main feedwater pumps, three feedwater booster pumps, a startup pump, three stages of two parallel HP heaters, main feedwater isolation valves (MFIVs), feedwater check valves, and feedwater control valves.

During normal power operation, three motor-driven feedwater booster pumps and three turbine-driven feedwater pumps provide the required feedwater flow to the SGs. Each combination of feedwater booster pump and feedwater pump can provide a maximum of 55 percent of the flow requirements for the feedwater system. Feedwater booster pumps deliver condensate from the deaerator storage tank to the suction of the main feedwater pumps. Main feedwater pumps deliver feedwater through three stages of two parallel HP feedwater heaters to each SG.

Drains from the HP feedwater heaters are cascaded to the next lower pressure heaters with drains from the lowest HP feedwater heaters draining to the deaerator.

The manner in which the feedwater flow is delivered to the SG varies with reactor power, as follows:

a. When reactor power is from 0 percent to 20 percent of full power, all feedwater is delivered to the SG through the downcomer line.

b. When the reactor power is above 20 percent of full power, the feedwater flow is split so that 10 percent of the full power feedwater flow goes to the downcomer while the remainder of the feedwater flow goes to the economizer.

10.4.7.2.2 Component Description

Major components design parameters are given in Table 10.4.7-1.

Piping and Valves

The valves, piping, and associated supports and restraints of the main feedwater system from and including the MSVH to the SG feedwater nozzles are seismic Category I and designed to ASME Section III, Class 2 requirements.

ASME Section III, Class 2 main feedwater system piping is capable of being inspected and tested in accordance with ASME Section III and Section XI (Reference 7).

All ASME Section III, Class 2 valves are capable of being periodically inservice tested for structural integrity and leakage in accordance with ASME Section XI.

The design of the main feedwater piping and its supports and restraints accommodates the loads arising from the various normal operating and DBEs that are specified in Subsection 3.9.3.

Feedwater system materials are covered in Subsection 10.3.6.

Main Feedwater Isolation Valves

The MFIVs and associated supports and restraints are ASME Section III, Class 2, and seismic Category I, and are designed to withstand loads arising from the various normal operating and DBEs as specified in Subsection 3.9.3.

Two redundant and fail closed type MFIVs in series are installed in the economizer feedwater lines and downcomer feedwater lines. The MFIVs are located in the MSVH outside the reactor containment building as close to the containment wall as possible.

The MFIVs provide complete termination of feedwater flow to the SGs after receipt of a main steam isolation signal (MSIS) even after the effects of a single failure are imposed.

The MFIVs in each main feedwater line are remotely operated and capable of maintaining a tight shut off of the transient conditions associated with a postulated pipe break in either direction of the valves.

Each MFIV actuator is physically and electrically independent of the other in series so that failure of one does not cause the failure of the other.

The safety analysis of these valves is described in Chapter 15.

Feedwater Check Valves

The feedwater check valves and associated supports and restraints are ASME Section III, Class 2, and seismic Category I and are designed to withstand loads arising from the various normal operating and DBEs as specified in Subsection 3.9.3.

Two check valves in series are located in the downcomer feedwater lines and economizer feedwater lines to preclude blowdown of both SGs following a pipe rupture upstream of the check valves. In the economizer line, there is one check valve outside the containment and two check valves in parallel inside the containment. The economizer check valves inside the containment are located as close to the SG as possible to minimize the possibility of backflow from the SG.

The total reverse leakage rate of the feedwater check valves from each SG does not exceed the limitation of MSS SP-61 (Reference 21).

Feedwater Control Valves

The feedwater control valves are installed in the economizer feedwater lines and downcomer feedwater lines. The feedwater control valves are automatically controlled by the feedwater control system as described in Subsection 7.7.1.1.c to maintain the proper SG level.

The feedwater control valve and controller are designed to minimize the potential for oscillation instability, vibrations, and water hammer. This design is verified to be stable and compatible with all final designed operating conditions of the system. Precautions to avoid the potential for water hammer occurrences are described in plant operating and maintenance procedures.

Main Condenser

The main condenser is described in Subsection 10.4.1.

Condensate Pumps

Three 50 percent capacity condensate pumps are vertical, multistage, centrifugal, and motor-driven and operate in parallel. During normal operation, two pumps are running. The third pump is prepared as a standby and starts automatically on the loss of one of the two operating pumps, allowing the plant to remain at 100 percent power.

Startup Feedwater Pump

During shutdown and startup, a motor-driven startup feedwater pump provides feedwater from the deaerator storage tank to the SGs. The startup feedwater pump is capable of providing 5 percent of the feedwater flow to both SGs in addition to pump recirculation flow.

Feedwater Booster Pumps

Three 55 percent capacity feedwater booster pumps are horizontal, single stage, centrifugal, and motor-driven with identical characteristics and operate in parallel. Each of the three feedwater booster pumps takes suction from the deaerator storage tank and discharge to its associated main feedwater pump. There are no isolation valves or check valves between the booster pumps and the main feedwater pumps.

Main Feedwater Pumps

Three 55 percent capacity main feedwater pumps are horizontal, single stage, centrifugal, and turbine-driven with identical characteristics and operate in parallel. Each of the three main feedwater pumps takes suction from the individual feedwater booster pump and discharges to the SGs through the HP feedwater heaters. In order to reduce the incidence of low suction pressure trips during the transient period, main feedwater pumps are capable of operating in a "dry run" condition for at least 3 minutes.

Low Pressure Feedwater Heaters

Three parallel LP feedwater heater trains are provided. Each LP train (A, B, and C) consists of feedwater heaters Nos. 1, 2, and 3. LP heaters No. 1 and 2 are located within

the condenser neck. Each LP feedwater heater train handles one third of the condensate system design flow with all three trains running during normal operation. However, each heater train is designed to handle a maximum of 50 percent of the design system flow; thus, when one train is out of service, the remaining two trains handle 100 percent of the condensate system design flow.

The LP feedwater heater train bypass line is also designed to handle at least 50 percent of condensate system design flow when two of the three LP feedwater heater trains are out of service or required for startup flushing. The LP feedwater heater trains are isolated by closing the motor-operated inlet and outlet isolation valves provided for each train to prevent water induction into the LP turbine resulting from increasing the shell side water level of the No. 1 or No. 2 LP feedwater heater due to tube rupture or drain control malfunction.

High Pressure Feedwater Heaters

Two parallel HP feedwater heater trains are provided. Each HP heater train (A and B) consists of feedwater heaters Nos. 5, 6, and 7.

Each closed-type HP feedwater heater train handles 50 percent of the feedwater system design flow during normal operation. However, each parallel train is designed to pass approximately 75 percent of the feedwater flow, and the bypass valve passes approximately 25 percent of the feedwater flow. Each HP feedwater heater train has motor-operated inlet and outlet isolation valves.

Deaerator and Storage Tanks

The deaerator (feedwater heater No. 4) is located between the LP and HP feedwater heater trains. The deaerator is a spray tray type, single horizontal cylindrical, direct contact heater. Condensate enters the deaerator from the top and heating steam flows from the bottom up. The heating steam is condensed and raises the temperature of the condensate to near saturation, liberating dissolved gases from the condensate. The condensate drains from the deaerator into the storage tank. Noncondensable gases are vented from the top of the deaerator and flow through an orifice and valve assembly to the atmosphere.

During the cleanup/recirculation mode and low load condition, auxiliary steam from the auxiliary steam supply system is supplied to the deaerator and maintains the pressure in the tank at 1.41 kg/cm^{2}A (20 psia). The steam heats the condensate for removal of any dissolved gases present in the condensate.

During normal operation, extraction steam from the LP turbines is supplied to the deaerator for condensate heating and is also used to remove any dissolved gases present in the condensate.

During large load rejection or turbine trip, main steam through the auxiliary steam header is also automatically supplied to the deaerator to maintain deaerator pressure above 1.41 kg/cm^{2}A (20 psia).

10.4.7.2.3 System Operation

System Startup

The condensate system is filled with condensate from the condensate storage tanks, and the feedwater system filling is provided from the deaerator storage tank. The condensate storage tank capacity is provided in Table 9.2.6-1, Subsection 9.2.6.

After the system filling, initial recirculation for the hotwell cleanup is performed through the condensate recirculation line from downstream of the steam packing exhauster to the condenser. The other recirculation line from the suction line of the feedwater booster pump to the condenser is used to cleanup the entire condensate system.

One of the three feedwater booster pumps is manually started and recirculates feedwater through the recirculation line from downstream of HP feedwater heaters to the condenser.

When the feedwater booster pump is stopped upon completion of cleanup/recirculation operation, the startup feedwater pump is manually started. Feedwater can then be introduced into the S/G by using the startup feedwater pump and the downcomer feedwater line.

Before the reactor power level reaches 5 percent, one feedwater booster pump is manually started. After the feedwater booster pump reaches normal operating speed, the turbine-driven feedwater pump is started using the feedwater pump turbine control system.

After startup of the first feedwater pump/feedwater booster pump train is completed and the train is in minimum recirculation, the startup feedwater pump is then manually shutdown.

When the feedwater control system (FWCS) supplies feedwater automatically to the SG and the reactor power level is below 40 percent, the second combination of the feedwater booster pump and main feedwater pump is started using the same procedure. When the reactor power level is between 40 percent and 80 percent, the third combination of the feedwater booster pump and main feedwater pump is started.

System Shutdown

On normal shutdown, the FWCS maintains automatic control of feedwater flow down to 0 percent reactor power level.

When the reactor power level is reduced to anywhere between 40 percent and 80 percent, one of the three operating feedwater pumps is manually shutdown. Further, when the reactor power level is reduced to less than 40 percent, the second operating feedwater pump is manually shutdown. The feedwater booster pump is interlocked to stop automatically when the associated feedwater pump is shutdown.

When reactor power is reduced to approximately 5 percent, the startup feedwater pump is manually started by the control in the MCR and RSR.

When the startup feedwater pump is in normal operation, the operating feedwater pump is manually shutdown. The S/G level is automatically controlled by the downcomer feedwater control valve continuously until the reactor power level is reduced to 0 percent.

Normal Operation

During full power operation, two out of three condensate pumps discharge condensate to the polishing demineralizers. The condensate polishing demineralizers remove suspended

and dissolved solids from the condensate. The condensate polisher bypass flow is automatically controlled by the differential pressure across the condensate polisher.

After passing through the LP feedwater heaters Nos. 1, 2, and 3, the condensate flow to the deaerator is regulated by the deaerator storage tank level control valves, which maintain an essentially constant deaerator storage tank water level at all plant operating conditions.

The deaerator, which is a direct contact type deaerating heater, mixes and heats the condensate with extraction steam from the LP turbine. The deaerator removes entrained oxygen and noncondensable gases. The heated and deaerated condensate is stored in the deaerator storage tanks.

A separate FWCS is provided for each SG to control the SG water level. Each FWCS regulates the feedwater flow rate to the corresponding SG by adjusting the position of the economizer and downcomer feedwater control valves and the speed of the main feedwater pumps.

During low reactor power level operations (below 20 percent), the downcomer feedwater control valves regulate the feedwater flow to the SG. In this control mode, the economizer feedwater control valves are closed and the feedwater pump speed setpoint is at its programmed minimum speed.

During high reactor power level operation (above 20 percent), the downcomer feedwater control valves receive a bias signal that positions the valves to pass approximately 10 percent of total feedwater flow, and the economizer feedwater control valves position and the feedwater pump speed are adjusted to regulate the feedwater flow rate.

The speed of the feedwater pump turbine is controlled by changing the position of the feedwater pump turbine control valves. During plant high power operation when hot reheat steam pressure is high enough to drive the turbine at its demand speed, the equally sized LP steam control valves pass hot reheat steam to the turbine. During plant low power operation when hot reheat steam pressure is not high enough to drive the turbine at its required speed, main steam is automatically introduced through the HP steam control valve as a supplementary source to maintain the required turbine speed.

The HP steam control valve is opened only after all LP steam control valves are fully opened. During these periods of operation, a mixture of hot reheat steam and main steam is supplied to the first stage of the turbine.

During normal plant operation, the startup feedwater pump is maintained in hot standby to minimize startup time in the event that all feedwater pumps trip.

The FWCS also provides manual control capability of the feedwater flow rate to each SG from 0 percent to 100 percent reactor power.

Abnormal Operation

a. Loss of one feedwater pump or one feedwater booster pump

   Loss of a feedwater booster pump is interlocked to trip the associated feedwater pump, and the loss of a feedwater pump is interlocked to trip the associated feedwater booster pump and close the motor-operated stop check valve downstream of the associated feedwater pump.

   Upon loss of any one of the three operating feedwater pumps, the FWCS provides a pump speed setpoint demand signal to the remaining two feedwater pumps, and these pumps can supply feedwater automatically to the SGs at 110 percent system rated flow without reactor trip.

b. Loss of two of the three operating feedwater pumps or one of the two operating feedwater pumps

   Two of the three operating feedwater pumps or one of the two operating feedwater pumps trip signal causes the actuation of reactor power cutback system (RPCS) to reduce the plant power to a level based on fuel burnup and reactor power.

c. Isolation of one train of high pressure feedwater heaters

   Each HP feedwater heater train has motor-operated inlet and outlet isolation valves. The heater trains have a common bypass line provided with a motor-operated

isolation valve. An entire train is isolated to repair any heater in the train. The feedwater heater bypass valve is manually opened when one train of the HP heaters is removed from service. The remaining heater train passes approximately 75 percent of the feedwater flow, and the bypass valve passes approximately 25 percent of the feedwater flow.

d. Isolation of feedwater system on main steam isolation signal

After receipt of main steam isolation signal (MSIS), redundant main feedwater isolation valves provided in both the economizer and downcomer feedwater lines are automatically closed within limits, and the operating pumps (combination of feedwater/feedwater booster pumps and/or startup feedwater pump) are automatically tripped.

10.4.7.2.4 Design Features for Minimization of Contamination

The condensate and feedwater system is designed with specific features to meet the requirements of 10 CFR 20.1406 and NRC RG 4.21. The basic principles of NRC RG 4.21, and the methods of control are delineated into four design objectives and two operational objectives discussed in Subsection 12.3.1.10. The following evaluation summarizes the primary features to address the design and operational objectives for the condensate and feedwater system.

The condensate and feedwater system has been evaluated for leakage identification from the SSCs that contain radioactive or potentially radioactive materials, the areas and pathways where leakage may occur, and the methods of leakage control incorporated in the design of the system. The leak identification evaluation indicated that the condensate and feedwater system is designed to facilitate early leak detection and the prompt assessment and response to manage collected fluids. Unintended contamination to the facility and the environment is minimized and/or prevented by the SSC design, supplemented by operational procedures and programs and inspection and maintenance activities.

Prevention/Minimization of Unintended Contamination

a. The condensate and feedwater system components are located in elevated cubicles inside the turbine building (TB). The cubicle floors are sloped, coated with epoxy, and provided with drains that are routed to the local drain hubs. This design approach prevents the spread of contamination through the facility and to the environment.

b. The condensate and feedwater system is designed with sufficient capacities to accommodate different modes of operation. The piping is adequately sized to prevent blockage; primary process piping is sloped to facilitate drainage and prevent fluid accumulation and crud buildup.

c. The condenser hotwell in each shell contains conductivity cells under each tube bundle to provide for the detection and location determination of condenser tube leaks.

d. The condenser is designed to the HEI Standard and manufactured using high grade austenitic stainless steel.

e. The LP and HP feedwater heater is constructed of carbon steel and is welded for life-cycle planning, thus minimizing leakage and unintended contamination of the facility and the environment.

f. The heat exchangers are designed such that tube side pressure is higher than shell side pressure to protect against leakage from the potentially contaminated steam to the clean circulating water system.

g. The feedwater pump turbine system is designed with casing leaking (exhausting) from the turbine directly to the condenser pit sump through the equipment drain and the floor drain.

h. Unintended contamination to the facility is minimized/prevented by the floor drainage design, the elevated location, and regular inspection.

Adequate and Early Leak Detection

a. The condensate and feedwater system is designed with automated operation with manual initiation for the different modes of operation. Adequate instrumentation, including level, flow rate, temperature, and pressure elements, is provided to monitor and control the operations to prevent undue interruption. This design approach minimizes the spread of contamination and waste generation.

b. Leak detection trays are included at all tube-to-tube sheet interfaces. Provisions for early leak detection are provided for the tube sheet trays and in each hotwell section.

Reduction of Cross-Contamination, Decontamination, and Waste Generation

a. The SSCs are designed with life-cycle planning through the use of nuclear industry-proven materials compatible with the chemical, physical, and radiological environment, minimizing the spread of contamination and waste generation.

b. Normal and emergency drains are routed to the condenser and are forwarded to the condensate polishers for treatment, minimizing the spread of contamination.

c. If leakage occurs from the condensate and feedwater system equipment, the water is drained to local drain hubs by gravity and transferred to the turbine generator building drain system sump for collection.

Decommissioning Planning

a. The SSCs are designed for the full service life and are fabricated as individual assemblies for easy removal.

b. The SSCs are designed with decontamination capabilities. Design features, such as the utilized welding techniques, surface finishes are included to minimize the need for decontamination and waste generation.

c. The condensate and feedwater system is designed without any embedded or buried piping. Piping between buildings is equipped with piping sleeves with leakage directed back to the TB for collection, preventing unintended contamination.

Operations and Documentation

a. The condensate and feedwater system is located in an open area inside the TB. Adequate space is provided around the equipment to enable prompt assessment and responses.

b. The COL applicant is to provide operational procedures and maintenance programs as related to leak detection and contamination control (COL 10.4(7)). Procedures and maintenance programs are to be completed before fuel is loaded for commissioning.

c. The COL applicant is to maintain complete documentation of the system design, construction, design modifications, field changes, and operations (COL 10.4(8)). Documentation requirements are included as a COL information item.

Site Radiological Environmental Monitoring

a. The condensate and feedwater system is located inside the TB and drainage is collected and treated before release. The condensate and feedwater system is not required to be directly monitored for environmental contamination.

10.4.7.3 Safety Evaluation

The safety-related portion of the feedwater system is designed in accordance with the design bases addressed in Subsection 10.4.7.1. Failure in the non-safety class portions of the condensate and feedwater system does not prevent safe shutdown of the reactor.

Safety-related portions of the feedwater system are located in seismic Category I structures and are designed to protect against environmental hazards such as wind, tornadoes, hurricanes, floods, and missiles and against the effects of high- and moderate-energy pipe rupture, as described in Sections 3.3, 3.4, 3.5, and 3.6.

SG overfill due to a feedwater system malfunction is prevented by automatic closure of the feedwater isolation valves upon receiving an MSIS, which is generated when the high SG water level setpoint is reached.

The effects of feedwater system equipment malfunction on the reactor coolant system are presented in Subsections 15.1.1, 15.1.2, 15.2.7, and 15.2.8..

The design consideration of water hammer prevention is described in Subsection 10.4.7.6.

Release of radioactivity to the environment in the event of line break is negligible because of the minimal amount of radioactivity in the system.

The results of condensate and feedwater system failure mode and effects analysis are shown in Table 10.4.7-2.

10.4.7.4 Inspection and Testing Requirements

The condensate and feedwater system testing includes functional testing of the systems and components to provide reasonable assurance of structural integrity, leaktightness, operability and performance of active components, and testing of the capability of the integrated system to function as intended during normal, shutdown, and accident conditions.

ASME Section III piping is inspected and tested in accordance with ASME Sections III and XI. ASME Section III, Class 2 valves are periodically inservice tested for exercising and leakage in accordance with ASME OM (Reference 22).

The MFIVs are inservice tested in accordance with ASME Section XI.

10.4.7.5 Instrumentation Requirements

Sufficient instrumentation and controls are provided to adequately monitor and control the condensate and feedwater system.

Alarms are installed for low NPSH of feedwater booster pump and main feedwater pump and high pressure of the main feedwater pump discharge header. Instrumentation and controls

are installed for maintaining minimum pump recirculation flow in order to prevent pump damage. Upon loss of one of two operating condensate pumps, the standby pump is started automatically.

The MCR and RSR have feedwater flow, condensate flow, deaerator pressure and deaerator storage tank level indications. The MCR and RSR have SG narrow range and wide range level indications and alarms.

MFIVs automatically close on receipt of a main steam isolation signal (MSIS) and also can be manually controlled in the MCR and RSR.

Feedwater control system is described in Subsection 7.7.1.1.c.

10.4.7.6 Water Hammer Prevention

The feedwater system design minimizes the potential for a water hammer and its effects. The SG design features, including a feedring for water hammer prevention, are described in Subsection 5.4.2.1.2.1. The design features avoid the formation of a steam pocket in the feedwater piping that when collapsed, could create water hammer. The feedwater connection to each SG is the highest point of each feedwater line downstream of the MFIV. The feedwater lines contain no steam pockets that could trap steam and lead to a water hammer.

Feedwater piping analysis considers the following factors and events in the evaluation:

a. Rapid closure of the main feedwater check valve due to line breaks

b. Pump trips

c. Spurious MFIV trip

d. Feedwater piping, anchors, supports, and snubbers as applicable

Water hammer prevention and mitigation are implemented in accordance with the following, as specified in NUREG-0927 and BTP 10-2:

a. The horizontal length of feedwater piping between the SG and the vertical run of piping is minimized by providing downward turning elbows immediately upstream of feedwater nozzles

b. The top feedwater lines are maintained full at all times

c. The design consideration of the main feedwater control valve in terms of oversizing and instability reduce the frequency and severity of a water hammer.

d. A check valve is provided upstream of the auxiliary feedwater connection to the top feedwater line.

e. Operator training and operational and maintenance procedures (e.g., warm-up of line, adequate valve operation, vent/drain, and removal of void) reduce the frequency and severity of a water hammer.

f. For a water hammer anticipated by intended system operation (or steam hammer), the generated load is considered for piping and support designs.

Check valves are installed in each feedwater line outside the containment. During normal and abnormal conditions, the main feedwater check valve prevents reverse flow from the SG when the feedwater pumps are tripped. In addition, the closure of the valves prevents SG from blowing down in the event of a feedwater pipe break. The main feedwater check valve is designed to limit blowdown from the SG and to prevent a slam resulting in potentially severe pressure surges due to a water hammer. The valves are designed to withstand the closure forces encountered during the normal and abnormal conditions. Rapid closure associated with a feedwater line break does not impose unacceptable loads on the SG.

The COL applicant is to provide operating and maintenance procedures in accordance with NUREG-0927 and a milestone schedule for implementation of the procedure (COL 10.4(4)). The procedures are to address:

a. Prevention of rapid valve motion

b. Introduction of voids into water-filled lines and components

c. Proper filling and venting of water-filled lines and components

d. Introduction of steam or heated water that can flash into water-filled lines and components

e. Introduction of water into steam-filled lines or components

f. Proper warm up of steam-filled lines

g. Proper drainage of steam-filled lines

h. Effects of valve alignments on line conditions

10.4.7.7 Flow-Accelerated Corrosion

The condensate and feedwater system is designed to avoid FAC and erosion/corrosion damage. The methods described in Subsection 10.3.6 are used to minimize FAC and erosion/corrosion degradation based on GL 89-08 (Reference 39).

10.4.8 Steam Generator Blowdown System

The steam generator blowdown system (SGBS) consists of two subsystems, the blowdown subsystem (BDS) and wet layup subsystem (WLS). The SGBS assists in maintaining the chemical characteristics of the secondary side water, within permissible limits, during normal plant operation and anticipated operational occurrences (AOOs), due to main condenser tube leak or SG primary-to-secondary tube leakage. The SGBS is designed to remove impurities concentrated in SGs by continuous blowdown (CBD), periodical high capacity blowdown (HCBD), and emergency blowdown (EBD).

10.4.8.1 Design Bases

10.4.8.1.1 Safety Design Bases

The following safety-related functions of the SGBS are performed following a design basis accident (DBA):

a. Steam generator shell pressure boundary

b. Containment isolation

The SGBS has the following design basis requirements and criteria:

a. The safety-related function of the SGBS is performed against a single active component failure associated with a loss of offsite power(LOOP).

b. Air operated valves (AOVs) for containment isolation have an active safety-related function under loss of electric power to the valve actuating solenoid or pneumatic pressure to the valves.

c. All components, piping, and their associated supports from the SG blowdown nozzles to the outermost containment isolation valves are safety Class 2 (refer to Subsection 3.2.2) and are designed according to ASME Section III (Reference 6), Class 2 and seismic Category I requirements. The SG blowdown system piping, supports, and restraints are designed to withstand the loads arising from the various normal operating and DBA.

d. The safety-related portion of the SGBS is designed to function during normal operation and following a DBA, and is protected against earthquakes, wind, tornadoes, hurricanes, floods, and missiles (GDC 2).

e. The safety-related piping, supports, and restraints of the SGBS are designed to withstand dynamic loads related to the postulated rupture of piping as described in Section 3.6.

10.4.8.1.2 Non-Safety Power Generation Design Bases

The non-safety-related functions and design basis requirements of the SGBS are as follows:

a. Remove non-volatile materials generated from condenser tube leaks, primary-to-secondary tube leaks, and corrosion that would otherwise become more concentrated in the shell side of the SGs, in order to help maintain SG shell side water chemistry as specified in Table 10.3.5 (GDC 13)

b. Enable blowdown concurrent with SG tube leak to remove radioactive materials from the secondary side without release of radioactivity to the environment

c. Sample blowdown water for chemistry analysis and monitor the SG primary-to-secondary tube leakage with SG blowdown water radiation monitor (GDC 14)

d. Establish and maintain wet and dry layup of the steam during plant shutdown

e. Drain the secondary water of the SG for maintenance

f. Control the blowdown water temperature to protect the demineralizer resin from high temperatures

g. Monitor the radiation level at the downstream of the post-filter

All components, piping, and their associated supports downstream of the outermost containment isolation valves of the SGBS are non-safety and meet the following intents of the quality standards of Position C.1.1, C.4, and C.7 of NRC RG 1.143 (Reference 23).

a. Table 10.4.8-3 details the equipment codes for design and construction as required in Table 1 of NRC RG 1.143. The structure, system, and components (SSCs) of the SGBS classified as RW-IIc are designed in compliance with applicable codes and standards, and guidelines provided in NRC RG 1.143.

b. The quality assurance (QA) program for the design, installation, procurement, and fabrication of SGBS components complies with Regulatory Position C.7 of NRC RG 1.143.

c. The SGBS is designed and tested to the codes and standards listed in Table 10.4.8-3 in accordance with Regulatory Positions C.1.1.1 and C.4 of NRC RG 1.143.

The SGBS follows the ALARA design and operational approach described in Sections 12.1 and 12.3 in accordance with NRC RG 8.8 (Reference 36). The SGBS' demineralizers are located in a shielded area in order to reduce the Occupational Radiation Exposures (ORE).

10.4.8.2 System Description

10.4.8.2.1 General Description

SGBS schematic diagrams are shown in Figure 10.4.8-1. Classification of equipment and components in the SGBS is shown in Section 3.2.

The blowdown subsystem (BDS) consists of blowdown piping connected to each SG, a blowdown flash tank, a regenerative heat exchanger, two pre-filters, two demineralizers, a post-filter, and control valves. The wet layup subsystem (WLS) consists of two recirculation trains (one for each steam generator) and shares filters and demineralizers with the BDS.

10.4.8.2.2 Component Description

Component design parameters are shown in Table 10.4.8-1.

a. SG blowdown flash tank

   The blowdown flash tank is a vertical pressure vessel with level, pressure, and temperature instruments and is designed to accommodate CBD, HCBD, and EBD rates and to send them to the regenerative heat exchanger. The pressure of the blowdown flash tank is controlled by one of two control valves located in the blowdown flash tank steam vent line. The blowdown flash tank is equipped with

blowdown inlet and outlet nozzles, a safety relief valve nozzle, a steam vent nozzle, fill and drain nozzles, and instrument nozzles.

b. SG blowdown regenerative heat exchangers

The regenerative heat exchanger is a shell-tube type. The hot blowdown water from the SG flows to the shell side, and the condensate from the downstream of condensate polisher flows to the tube side so that thermal energy is regenerated. The blowdown water temperature at the exits of the regenerative heat exchanger is controlled by regulating condensate flow.

c. SG blowdown filters

There are two pre-filters and a post-filter. The pre-filters remove undissolved solid particles in order to prevent the blocking of the demineralizer. The post-filter is installed downstream of the demineralizer to filter resin particles escaped from the demineralizer vessels.

d. SG blowdown demineralizers

Two demineralizers are provided to purify the blowdown to a water quality that is sufficient to return it to the condensate system. Both demineralizers are normally used in series during blowdown. One demineralizer is used while the other is in standby. The two demineralizers can be aligned in parallel.

e. Wet layup recirculation pump

The centrifugal wet layup recirculation pump recirculates the SG secondary side water through filters and demineralizers during wet layup of the SG. The pumps are also used to drain and fill the SG secondary side.

10.4.8.2.3 System Operation

10.4.8.2.3.1 Plant Startup

The steam generators are maintained in the wet lay-up by the WLS when the plant is expected to be shut down for a long period. After the WLS operation is ceased, the water in the steam generator is transferred to either the [[wastewater treatment facility]] or the liquid radwaste system. If the steam generator water is non-radioactive, it is drained to the [[wastewater treatment facility]] by gravity or by using the wet lay-up recirculation pump until the required water quality is met and the desired water level is achieved. If the steam generator water is radioactive, it is drained to the liquid radwaste system by gravity or by using the wet lay-up recirculation pump until the required water quality is met and the desired water level is achieved.

The abnormal blowdown (ABD) is started following feedwater pump start-up operation.

The ABD of 1 percent of steam generator's maximum steaming rate (SGMSR) is maintained until the water quality is within the normal limits.

10.4.8.2.3.2 Normal Operation

During normal power operation, the CBD that flows from each SG is maintained in order to keep the SG secondary side water chemistry within the specified limits. The CBD flow rate is 0.2 percent in normal blowdown or 1 percent in ABD.

The blowdown system cools the blowdown water with regenerative heat exchanger to a temperature that is acceptable for processing filters and demineralizers.

The blowdown water returns to the secondary system after being filtered and demineralized meets the applicable chemistry requirements to return the water to the main condenser.

The blowdown system removes suspended and dissolved impurities that are concentrated in the secondary side liquid of the SG using the CBD.

Each SG has two branch lines connected respectively to the hot leg and the economizer regions of the SG shell side. The blowdown is directed independently into the blowdown flash tank where the flashed steam is returned to the cycle through the high pressure feedwater heaters. The liquid portion flows to the regenerative heat exchanger where it is cooled by the condensate system and then directed through one of two parallel blowdown pre-filter where the major portion of the suspended solids is removed. After filtration, the blowdown fluid is processed by the blowdown demineralizers and returned to the condenser using a common discharge line.

The blowdown water temperature at the exit of the regenerative heat exchanger is maintained at 57.2 °C (135 °F) by controlling the condensate flow rate to the regenerative heat exchanger. The temperature controller at the exit of the regenerative heat exchanger automatically controls the condensate control valve. When the blowdown water is unacceptable for use or contaminated with radioactive materials, the water is directed to the wastewater treatment system or the liquid radwaste system.

When the CBD is operated, the blowdown flash tank level controller is set to automatic mode, and the level control valve located downstream of the post-filter maintains the water level in the blowdown flash tank. Before the HCBD or EBD is opened, the blowdown flash tank level controller is set to manual mode, and the level control valve is manually set to the Normal Blowdown (NBD) or ABD opening. When the HCBD or EBD is operated, the water level in the blowdown flash tank increases. After the HCBD or EBD operation is stopped, the water level on the blowdown flash tank is returned to the normal level manually by setting the level control valve to the ABD opening. Each CBD (normal blowdown or ABD) flow is controlled by remotely opening and closing a corresponding CBD isolation valves in series with a flow regulation valve.

The APR1400 SG's utilize a "central" blowdown system arrangement. In this arrangement, blowdown holes are drilled from the lower part of blowdown pipe where it is installed at the top of tube sheet. This arrangement is shown as Figure 10.4.8-3 and facilitates effective sludge removal from the tube sheet. The blowdown from each SG is depressurized by the pressure control valves located in the vent line of the blowdown flash tank where water and flashing vapor are separated. The vented steam is discharged to the high pressure feedwater heater. When the high pressure feedwater heater is unavailable, the vent pass is diverted to condenser.

10.4.8.2.3.3 Plant Shutdown

During long-term shutdown periods, the WLS is used to control the water chemistry in the SG. Following draining or dry layup, the WLS refills the SGs.

10.4.8.2.3.4 Steam Generator Drain

The SGBS is used to drain the SGs for maintenance or for a refueling shutdown. In this mode, the blowdown drain water is directed to the liquid radwaste system only when radioactivity is detected, otherwise drained to [[the wastewater treatment system (WWTS)]]. The COL applicant is to describe the nitrogen or equivalent system design for the SG drain.

10.4.8.2.3.5 Abnormal Operation

a. Condenser tube leakage

   In the event of a main condenser tube leakage and concurrent high sodium concentration downstream of the demineralizers and filters treating impurities, the blowdown water is discharged to [[the WWTS]].

b. Containment isolation signals

   The containment isolation valves are automatically isolated at the following signals:

   1) Main steam isolation signal

   2) Diverse protection system auxiliary feedwater actuation signal

   3) Containment isolation actuation signal

   4) Auxiliary Feedwater Actuation Signal

The outermost containment isolation valves in the blowdown lines are interlocked to close automatically on a high radiation signal from the radiation monitor installed at the outlet of the post-filter.

c. Abnormal water chemistry condition

When the radioactivity level at the outlet of the SG blowdown demineralizers exceeds the predetermined limit, blowdown water is discharged to the liquid radwaste treatment system. When the sodium concentration exceeds the specified limit, blowdown water is discharged to the WWTS.

d. SG Tube Leakage

In the case of steam generator primary to secondary tube leakage within tube leak rate as specified in the plant technical specifications, blowdown water continues to be purified with SG blowdown demineralizers to remove the radioactivity entering from leaking SG tube (s).

e. Malfunction in SGBS component

The following conditions indicate respectively the potential malfunctions of the blowdown flash tank vent line, the regenerative heat exchanger, and blowdown flash tank:

- High pressure alarm for the blowdown flash tank
- High temperature alarm at the exit of the regenerative heat exchanger
- High level alarms for the blowdown flash tank

The malfunctions of the above SGBS components isolate the SGBS lines and after those conditions are restored, the SGBS is in service.

10.4.8.2.3.6 Multiple Steam Generator Tube Rupture

In the event of a main steam generator tube rupture (MSGTR) that is beyond the design basis accident, the EBD is operated to reduce the SG water generator water level using HCBD valve and piping.

10.4.8.2.4 Design Features for Minimization of Contamination

The SGBS is designed with specific features to meet the requirements of 10 CFR 20.1406 (Reference 37) and Regulatory Guide 4.21 (Reference 38). The basic principles of NRC RG 4.21, and the methods of control are delineated into four design objectives and two operational objectives discussed in Subsection 12.3.1.10. The following evaluation summarizes the primary features to address the design and operational objectives for the SGBS.

The SGBS has been evaluated for leak identification from the SSCs that contain radioactive or potentially radioactive materials, the areas and pathways where leakage may occur, and the methods of leakage control incorporated in the design of the system. The leak identification evaluation indicated that the SGBS is designed to facilitate early leak detection and the prompt assessment and response to manage collected fluids. Unintended contamination to the facility and the environment is minimized and/or prevented by the SSC design, supplemented by operational procedures and programs and inspection and maintenance activities.

Prevention/Minimization of Unintended Contamination

a. The SGBS components are located in elevated cubicles inside the Auxiliary Building. The cubicle floors are sloped, coated with epoxy, and provided with drains that are routed to the local drain hubs. This design approach prevents the spread of contamination through the facility and to the environment.

b. The SGBS is designed with sufficient capacity for different modes of operation, including CBD, ABD, HCBD, and emergency BD. The system piping is adequately sized to prevent blockage and is sloped to facilitate drainage and prevent crud buildup.

c. The flash tank is constructed of carbon steel material; other components, including the heat exchangers, filters, demineralizers, and the wetted parts of the WLS recirculation pumps are fabricated from stainless steel material and utilize welded construction for life-cycle planning, thus minimizing leakage and unintended contamination of the facility and the environment.

Adequate and Early Leak Detection

a. The SGBS is designed with automated operation with manual initiation for the different modes of operation. Adequate instrumentation, including level, flow rate, temperature, and pressure elements, and a process radiation monitor, are provided to monitor the system operation in order to prevent undue interruption.

Reduction of Cross-Contamination, Decontamination, and Waste Generation

a. The SSCs are designed with life-cycle planning through the use of nuclear industry-proven materials compatible with the chemical, physical, and radiological environment, thus minimizing waste generation.

b. The SGBS components are provided with demineralized water for decontamination purposes. Nitrogen and other utilities are provided to facilitate operations. The utility connections are designed with a minimum of two barriers to prevent the contamination of clean systems.

c. Process sampling connections are provided to determine the levels of contamination, treatment requirements, and confirmation of the continual radiation monitoring output. Continuous process radiation monitoring is provided on the outlet line of the treated blowdown water. The detection of high radiation levels initiates automatic valve closure for isolation and operator actions, minimizing cross-contamination.

Decommissioning Planning

a. The SSCs are designed for the full service life and are fabricated as individual assemblies for easy removal to the maximum extent possible.

b. The SSCs are designed in order to facilitate decontamination. Design features, such as the utilized welding techniques, surface finishes, are included to minimize the need for decontamination and the resultant waste generation.

c. The SGBS is designed without any embedded or buried piping. Piping between buildings is equipped with piping sleeves with leakage directed back to the AB for collection, thus preventing contamination of the environment.

Operations and Documentation

a. The removal and packaging of spent filter elements and spent resin is designed for remote manual operation. Adequate space is provided around the equipment to enable prompt assessment and responses.

b. Operational procedures and maintenance programs as related to leak detection and contamination control is to be prepared by the COL applicant. Procedures and maintenance programs are to be completed before fuel is loaded for commissioning.

c. Complete documentation of system design, construction, design modifications, field changes, and operations is to be maintained by the COL applicant. Documentation requirements are included as a COL information item.

Site Radiological Environmental Monitoring

a. The SGBS is part of the overall plant and is included in the Site Radiological Environmental Monitoring Program for monitoring the potential for environmental contamination. The program includes sampling and analysis of waste samples, meteorological conditions, hydrogeological parameters, and potential migration pathways of the radioactive contaminants. The program is included as a COL information item.

10.4.8.3 Safety Evaluation

a. The design of the SGBS satisfies GDC 1 as it relates to the system components being designed, fabricated, erected, and tested for quality standards.

b. Seismic, design and fabrication codes, and quality group classifications of the SGBS components are provided in Section 3.2.

c. The power and control function related to the safety functions of the system is Class 1E.

d. The portion of SG secondary side pressure boundary inside the containment and the portion used as containment isolation are designed as safety Class 2.

e. The safety-related portions of the SGBS are located in the containment and the auxiliary building. These buildings are designed to withstand the effects of earthquakes, tornadoes, hurricanes, floods, external missiles, and other natural phenomena.

f. The safety-related portion of the SGBS is designed to remain functional during and after a safe shutdown earthquake.

g. The safety-related components of the SGBS are qualified to function in normal and accident environmental conditions. The environmental qualification program is described in Section 3.11.

h. The SGBS maintains the secondary water chemistry within specified limits (GDC 13). The blowdown system is sampled continuously to monitor the secondary water chemistry. The sampling system is described further in Subsection 9.3.2.

i. The SGBS maintains the secondary water chemistry in the SGs within specific limits through the CBD (GDC 14). The secondary water chemistry program and the associated limits are described in Subsection 10.3.5. The SGBS meets the intents of NUREG-0800 Branch Technical Position (BTP) 5-1 (Reference 35).

j. Controls are provided to prohibit SGBS demineralizer resin damage from high temperatures. The single failure criterion is applied to the containment isolation valves. Subsections 6.2.4 and 6.2.6 describe the system containment isolation arrangement and containment leakage testing.

k. The results of the failure modes and effects analysis, as shown in Table 10.4.8-2, are that safety-related equipment remains functional considering a single failure coincident with a LOOP. The results of the failure modes and effects analysis for SGBS sampling isolation valve is described Table 9.3.2-5, considering a single failure coincident with a LOOP.

10.4.8.4 Inspection and Testing Requirements

The SGBS and components are inspected and tested during plant startup using the test program. The SGBS lines within the containment and up to the second isolation valve outside the containment are inspected in accordance with ASME Sections III (Reference 6) and XI (Reference 7) during preservice and inservice inspections. SGBS components are designed and located to permit preservice and inservice inspections to the extent practicable.

Inspection and tests are described further in Section 14.2.

10.4.8.5 Instrumentation Requirements

Pressure, level, flow, temperature, differential pressure, and radiation instrumentation monitor and control the system operation.

The blowdown flash tank is provided with a level and pressure instrument.

Flow elements downstream of the isolation valves measure and indicate blowdown flow from each SG.

The blowdown water temperature instrumentation monitor at the exit of the regenerative heat exchanger controls the condensate flow rate to the regenerative heat exchanger to maintain the temperature below approximately 57.2 °C (135 °F).

The differential pressure indicators display locally the differential pressure across the pre-filters, demineralizers, and post-filters.

The SG blowdown water radiation monitor, located in the downstream of the post-filter detects the radioactivity in the SG blowdown water.

10.4.9 Auxiliary Feedwater System

10.4.9.1 Design Bases

10.4.9.1.1 Functional Requirements

a. The auxiliary feedwater system (AFWS) provides an independent safety-related means of supplying auxiliary feedwater (AFW) to the SG(s) for the following events whenever the reactor coolant temperature is above the cut-in temperature for shutdown cooling system initiation and the main feedwater system is inoperable. The AFWS and supporting systems are designed to provide the required flow to the SG(s) with a loss of offsite power (LOOP) event, assuming a single active failure.

   1) Loss of normal feedwater

   2) Main steam line break (MSLB) or feedwater line breaks (FLB)

   3) Steam generator tube rupture (SGTR)

   4) Transient conditions or postulated accidents such as reactor trip

   5) Any incident that results in station blackout (SBO)

   6) Small break loss-of-coolant accident (SBLOCA)

   7) Anticipated transients without scram (ATWS)

b. Following the above events, the AFWS supplies AFW inventory in the SG(s) for residual heat removal and is capable of maintaining hot standby and facilitating a plant cooldown (at the maximum administratively controlled rate of 41.7 °C/hr (75 °F/hr) from hot standby to shutdown cooling system initiation.

c. The AFWS is also designed to be initiated with operator action following a primary-side LOCA to keep the steam generator tubes covered for the long-term to enhance the closed-system containment boundary.

d. Each AFW pump is capable of providing the required minimum flow of 2,461 L/min (650 gpm) under the following conditions:

    1) The maximum steam generator downcomer nozzle pressure is 87.2 kg/cm^{2}A (1,240 psia), which accounts for the SG design pressure, safety valve uncertainty and feed nozzle losses from the downcomer nozzle to the SG steam space.

    2) Pump suction is at the minimum suction pressure.

e. The AFWS is capable of providing the required minimum flow to the intact SG without isolation of the depressurized SG, assuming a postulated pipe failure concurrent with a single active component failure, in accordance with the steam generator makeup flow requirement.

f. The AFWS is designed to restrict the maximum AFW flow by a cavitating venturi to provide reasonable assurance that the containment is not overpressurized and that the steam generator is not overfilled following a main steam line break without operator action to modulate or terminate the AFW flow for 30 minutes after AFWS actuation. The AFW flow can be terminated by operator action within 30 minutes to close the AFW isolation valves and/or shutoff the associated AFW pumps if the SG is faulted (i.e., the main feedwater or main steam line breaks).

g. The AFWS has two 100 percent capacity auxiliary feedwater storage tanks (AFWSTs). Each tank has a minimum usable safety-related water volume of 1,514,165 L (400,000 gal) to achieve a safe cold shutdown based on the following:

   1) eight hours of operation at hot-standby conditions

   2) Subsequent cooldown of RCS within six hours to conditions that permit operation of the shutdown cooling system

   3) A feedwater line breaks without isolation of auxiliary feedwater to the affected steam generator for 30 minutes in accordance with NUREG-0611 and NUREG-0635 (References 25 and 26, respectively)

   The safety-related water volume provides reasonable assurance of sufficient feedwater to allow an orderly plant cooldown to shutdown-cooling entry conditions following the above events.

h. The AFWS consists of two 100 percent capacity motor-driven pumps, two 100 percent capacity turbine-driven pumps, two 100 percent auxiliary feedwater storage tanks (AFWSTs), valves, two cavitating flow-limiting venturis, and instrumentations. One motor-driven pump and one turbine-driven pump are configured into one mechanical division.

i. The AFWS is an ASME Section III (Reference 6), Class 2 and 3, seismic Category I, redundant system with 1E electric components. The AFW is designed to remain functional after a safe shutdown earthquake (SSE).

10.4.9.1.2 Design Criteria

a. The AFWS components are located in auxiliary building designed as seismic Category I, which protect the AFWS components from external environmental hazards such as wind, tornado, hurricane, flood, and earthquake, as described in Sections 3.3, 3.4, and 3.7. Each redundant and diverse AFW line is physically separated from the others within these structures to protect the AFWS components

from the effects of internally and externally generated missiles as described in Section 3.5.

b. All mechanical components and piping up to the AFW isolation valves are safety Class 3 and designed to ASME Section III requirements. All components and piping from and including the containment isolation valves to the SGs are safety Class 2 and designed to ASME Section III requirements. All components and piping essential to the safety function are designed to seismic Category I requirements, as described in Section 3.7. The seismic category and safety and quality classification of the AFWS components are listed in Table 3.2-1, Section 3.2.

c. The safety-related portions of the AFWS are appropriately protected against the possible effects of postulated high- or moderate-energy pipe failure including pipe whip or jet impingement, as described in Section 3.6.

d. A failure of a non-essential equipment or component does not affect the AFWS safety functions.

e. The AFWS components are provided with emergency power and adequate redundancy, diversity, and separation to perform design basis functions in the event of an SBO coincident with the following:

    1) A single active mechanical component failure

    2) A single active electrical component failure

    3) The effects of a high- or moderate-energy pipe rupture

f. The AFWS is provided with diverse power sources so that either of the power sources (AC or DC) meets the AFWS performance requirements.

g. The AFWS provides double isolation valves from the main feedwater system with one check valve and one Class-1E, DC-powered AFW isolation valve in normal open position.

h. The AFWS is designed to preclude water hammer by complying with the following requirements:

   1) Guidance contained in Branch Technical Position (BTP) 10-2 (Reference 19) for reducing the potential for water hammers in SGs.

   2) Guidance for water hammer prevention and mitigation in NUREG-0927, Rev. 1 (Reference 20).

i. Suitable flood protection during abnormally high water levels is provided to the building where the AFWS components are located, as addressed in Section 3.4.

j. The equipment and floor drainage system is provided with collection and detection of AFWS leakage, which may originate in each AFW pump room, in each AFWST, and areas containing AFWS piping where a moderate- or high-energy pipe rupture is postulated, as defined in Section 3.6.

k. Means are provided to permit periodic surveillance testing of AFW pumps and valves and functional testing of the integrated operation of the system in accordance with the Technical Specifications, Subsection 3.7.5, providing limiting conditions for operation and the surveillance testing requirements for the system to provide reasonable assurance of continued system reliability during plant operation.

l. Adequate instrumentation and controls are provided to verify that the AFWS is correctly operating in each mode.

m. The automatic initiation signals and circuits are designed so that their failure does not result in the loss of the ability to be manually initiated from the MCR in accordance with NRC RG 1.62 (Reference 10). Details of the engineered safety features system are provided in Section 7.3.

n. The AFWS meets the recommendations identified in NUREG-0635.

o. An AFWS reliability analysis is performed in accordance with TMI Action Item II.E.1.1 of NUREG-0737. The AFWS is designed to have unavailability from 10^{-5} to 10^{-4} per demand as described in Chapter 19.

p. The AFWS design meets the provision of TMI Action Plan Item II.E.1.2 of NUREG-0737 (Reference 24) and 10 CFR 50.62(c)(1) (Reference 8). The AFWS can be either manually actuated or automatically actuated by an auxiliary feedwater actuation signal (AFAS) from the engineered safety feature actuation system (ESFAS) described in Section 7.3 or the diverse protection system (DPS) described in Subsection 7.8.1.1.

q. In conformance with guidance in 10 CFR 50.63 and NRC RG 1.155 (References 9 and 32, respectively), the APR1400 is provided with an AAC power source to cope with an SBO event as described in Section 8.4.

r. The AFWS piping, associated supports, and restraints are designed so that the following do not occur as a result of a single event, such as a ruptured auxiliary feedwater line or a closed isolation valve:

   1) Initiating a LOCA

   2) Causing failure of the other SG's safety class steam and feedwater lines, MSIVs, MFIVs, SG blowdown isolation valves, or MSADVs

   3) Reducing the capability of any of the engineered safety feature actuation systems or the plant protection system

   4) Transmitting excessive loads to the containment pressure boundary

   5) Compromising the function of the MCR

   6) Precluding an orderly cooldown of the RCS

s. Each turbine-driven pump is supplied with steam from a single SG (i.e., the one to which it supplies AFW).

t. The AFW is delivered to the downcomer nozzles of the steam generators.

u. A non-safety-grade source of condensate from the condensate storage tank (by gravity feed) can be aligned if the safety-related source is exceeded before shutdown cooling system entry conditions are reached.

v. The principal AFWS pressure retaining materials are shown in Table 10.4.9-5.

w. The recommendations of NRC RG 1.37 (Reference 34) are applied during fabrication of the AFWS, and preheat guidelines in ASME Section III, Appendix D, Article D-1000 for carbon steel are applied to the AFWS components.

10.4.9.2 System Description

10.4.9.2.1 General Description

The AFWS is shown in Figures 10.4.9-1, 10.4.9-2, and 10.4.9-3. The AFWS consists of two 100 percent capacity motor-driven pumps, two 100 percent capacity turbine-driven pumps, two 100 percent auxiliary feedwater storage tanks (AFWSTs), valves, two cavitating flow-limiting venturis, and instrumentations. Steam generator makeup flow requirement is given in Table 10.4.9-6.

Each pump takes suction from a respective AFWST and has a respective discharge header. Each pump discharge header contains a pump discharge check valve, flow modulating valve, AFW isolation valve, and SG isolation check valve. One motor-driven pump and one turbine-driven pump are configured into one mechanical division and joined together inside containment to feed their respective steam generator through a common auxiliary feedwater (AFW) header, which connects to the steam generator downcomer feedwater line. Each common AFW header contains a cavitating venturi to restrict the maximum AFW flow rate to each steam generator.

A cross connection is provided between each AFWST so that either tank can supply either division of the AFWS. Each of the safety Class 3, seismic Category I AFWSTs contains 100 percent of the total volume specified in Subsection 10.4.9.1.1. A manually operated isolation valve is provided for each AFWST to provide separation. The line connected to

non-safety sources can be manually aligned for gravity feed to either of the AFW pump suction if the AFWSTs reach low levels before shutdown cooling system entry conditions are reached.

A flow recirculation line is provided downstream of each pump discharge to allow for the following:

a. A continuous recirculation to the AFWST for pump

b. Full or minimum recirculation flow testing of the pumps

A multi-stage flow-restrictive orifice restricts the flow to the minimum required for pump protection.

A non-condensing AFW pump turbine with an atmospheric discharge line is provided for each turbine-driven pump. Each turbine is supplied with the driving steam from its respective SG upstream of the main steam isolation valves (MSIVs) in the main steam system. Each supply line contains an air-operated steam isolation valve.

The turbine exhaust steam is discharged to atmosphere through a seismic Category I vent line routed through the roof.

10.4.9.2.2 Component Description

A summary of design parameters and codes for the major AFWS components is given in Table 10.4.9-1.

10.4.9.2.2.1 Auxiliary Feedwater Pumps

The AFWS pumps are horizontal, multi-stage, centrifugal pumps. Each pump is capable of delivering the system design flow of 2,461 L/min (650 gpm) to the SG(s) over the entire range of steam generator pressure of 6.3 through 87.2 kg/cm^{2}A (90 through 1,240 psia).

Each pump has adequate flow capacity to provide the required design basis flow to the SGs plus the capacity to continuously recirculate this flow. The recirculation lines are

adequately sized so that full pump flow can be recirculated through the bypass provided around the flow restrictive orifice for full flow pump testing during power operation. The bypass line contains a manual flow control valve in order to vary the pump flow for performance testing.

10.4.9.2.2.2 Turbine-Driven Auxiliary Feedwater Pump Turbines

Each turbine is supplied with a hydraulic governor valve and a turbine trip and throttle valve with reset capability. The turbine speed is automatically controlled by the governor valve and is maintained to provide the required AFW flow. The turbine can be stopped by remotely closing the turbine trip and throttle valve using a trip switch located in the MCR, RSR, or local control panel.

Each AFW pump turbine is capable of being started and put on line very quickly from a cold condition. The steam supply line up to AFW pump turbine steam isolation valve is pressurized at near operating temperature during normal power operation to implement fast turbine start and to prevent thermal shock. A low point drain, located upstream of the AFW pump turbine steam isolation valve, provides a continuous blowdown through a pressure reducing orifice to prevent water slugs from entering the turbine.

10.4.9.2.2.3 Auxiliary Feedwater Storage Tanks

Two AFWSTs (one tank in division 1 and one tank in division 2) provide a primary source for the AFW. Each tank contains 100 percent of the required water volume given in Subsection 10.4.9.1.1. A common tie line with two normally closed manual valves connects the two AFWSTs.

Each tank, which consists of a stainless-steel-lined, reinforced concrete enclosure, is an integral part of the safety-related, seismic Category I auxiliary building and is protected against environmental hazards. The provisions are provided so that a failure or leak of the tank does not adversely affect other essential components.

Periodic grab sampling is performed to provide reasonable assurance that the suspended solids do not exceed 0.1 ppm. Any excess in the suspended solids is corrected by operator actions utilizing feed and bleed method. The AFWS are supplied with makeup water from

the demineralized water storage tank. The minimum and maximum temperatures of the condensate supplied or stored in each tank are 4.4 °C (40 °F) and 48.9 °C (120 °F), respectively. The design temperature of the AFWST is 60 °C (140 °F).

A non-safety-related back up water source by gravity feed to AFW pump suction is also available from the condensate storage tank and raw water storage tank.

10.4.9.2.2.4 Auxiliary Feedwater Cavitating Venturis

A cavitating venturi is located in the common AFW supply line to each SG. Each cavitating venturi limits the maximum AFW flow that can be supplied to a SG.

10.4.9.2.2.5 Valves

The following valves are required to maintain their functional capability during a safe plant shutdown.

a. Auxiliary feedwater isolation valves

   The auxiliary feedwater isolation valves are normally open during normal plant operations. These valves, in series with check valves provide containment double isolations. These valves are automatically closed by the engineered safety features actuation system (ESFAS) signal at a steam generator level higher than the normal operation water level. These valves can be individually opened or closed remotely from the MCR and at the RSR. The valves are provided with motor operators and with manual handwheels.

b. Auxiliary feedwater modulating valves

   The auxiliary feedwater modulation valves are normally open when the system is in standby. These valves have a close/modulating control mode. When the valves are in modulating mode, the associated steam generator level signal controls the valves to the desired position or closes the valves. The valve control switches and position indicators are provided on the MCR and RSR. The valves

can be controlled manually and are provided with solenoid operators. The failure mode of these valves is 'fail-open'.

c. Auxiliary feedwater pump turbine steam isolation valves

The auxiliary feedwater pump turbine steam isolation valves isolate the steam supply to the AFW pump turbines. Opening of these valves supplies steam to the turbines and starts governor control of the steam flow to the turbines. These valves are automatically opened on an AFAS from the ESFAS or DPS. These valves can be remotely opened and closed from the MCR and at the RSR.

10.4.9.2.3 Electrical Power Supply

Each AFW line receives power from an associated Class 1E emergency power system. In the event of LOOP, power is supplied by emergency diesel generators. In accordance with NUREG-0611 and NUREG-0635, all instrumentation, controls, and valves that are essential to the operation of the turbine-driven AFW pump lines are supplied from battery-backed Class 1E power supplies for 16 hours. Battery-backed power is also available for the governor speed control of the AFW pump turbine. An AAC source of standby power is provided for the operation of the motor-driven pump lines during an extended SBO. The emergency power train designations for the motor-driven AFW pumps, power-operated valves, instrumentation, and controls are given in Table 10.4.9-2. A more detailed description of the onsite power systems is provided in Section 8.3.

10.4.9.2.4 Auxiliary Feedwater System Operation and Control

The AFWS is normally in standby mode, available for operation during normal power operation and during plant transients and accidents. The AFWS is not used during plant startup and normal plant shutdown. The AFWS supply capacity is adequate for makeup to the SGs during hot standby and cooldown conditions following a transient or accident condition. The AFWS can be manually or automatically actuated by an AFAS from the ESFAS described in Section 7.3 or the DPS described in Subsection 7.8.1.1. The AFWS is designed to deliver flow to the SG(s) within 60 seconds upon receipt of an AFAS.

At the low water level setpoint of the steam generator, the AFAS from the ESFAS and DPS actuates the AFWS as follows:

a. Starts the associated motor-driven pump

b. De-energizes the solenoid to open the associated turbine steam isolation bypass valve

c. Starts associated turbine-driven pump by de-energizing the solenoid to open the associated turbine steam isolation valve

d. Opens the associated AFW isolation valves if they are closed

e. Modulates the associated AFW modulating valves

f. Verifies that turbine governor speed control is at full rated speed

After the AFWS is actuated, the AFW modulating valve controls the flow to the SG(s) in order to control the steam generator normal water level. If the AFW modulating control becomes inoperable, the AFW isolation valve is controlled by a cycling signal based on the SG high and low levels. If automatic flow control fails, the operator can control the SG water level through the open/close of associated AFW isolation valves via a control switch or handwheel.

The AFW flow can be terminated by operator action within 30 minutes to close the AFW isolation valves and/or shut off the associated AFW pumps if the SG is faulted (i.e., the main feedwater or main steam line breaks).

10.4.9.2.5 Design Features for Minimization of Contamination

The AFWS is designed with specific features to meet the requirements of 10 CFR 20.1406 (Reference 37) and Regulatory Guide 4.21 (Reference 38). The basic principles of NRC RG 4.21, and the methods of control suggested in the regulations, are specifically delineated into four design objectives and two operational objectives discussed in

Subsection 12.3.1.10. The following evaluation summarizes the primary features to address the design and operational objectives for the AFWS.

The auxiliary feedwater pump turbine system consists of two non-condensing steam turbines for the auxiliary feedwater pumps and their associated piping and valves. The auxiliary feedwater pump turbine system is not used during normal power operation, startup, or shutdown. The turbines are either manually or automatically actuated by an auxiliary feedwater actuation signal from the engineered safety system or the diverse protection system, which is initiated when the steam generator water level is low. The auxiliary feedwater pump turbine system piping uses stainless steel material and is fabricated to ASME Section III, Class 3 requirements. The valve stem leak offs and drains are collected and directed to the liquid radwaste system for treatment and release. During normal operation, a small amount of steam is allowed to bypass the steam isolation valve to keep the piping warm.

The AFWS uses demineralized water as auxiliary feedwater from the demineralized water makeup system. Normally, the AFWS is not in use and is not radioactively contaminated. There is a segment of pipe, connected to the high pressure feedwater lines after the containment penetration to the steam generators, which may become contaminated by the feedwater (recycle condensate) up to the containment isolation check valves. The feedwater piping is fabricated of stainless steel material, is of welded construction, and is designed to safety Class 3 and seismic Category I requirements. This design approach minimizes leakage and unintended contamination of the facility and the environment in accordance with NRC RG 4.21.

10.4.9.3 Safety Evaluation

An adequate safety-related water supply, designed to seismic Category I, is available to allow the plant to remain at hot standby for eight hours followed by an orderly cooldown to shutdown cooling system entry condition within six hours, in conformance with BTP RSB 5-4 (Reference 28). This is possible even if the initiating event is a main feedwater line break with a spill of the AFW for 30 minutes at the maximum AFW flow.

For the design basis considerations in Subsection 10.4.9.1, sufficient AFW flow can be provided at the required temperature and pressure, even if a secondary pipe break event

occurs, if any one AFW pump fails to deliver flow and no operator action is taken for up to 30 minutes following the event.

The AFWS is the only safety-related source of makeup water to the SGs for heat removal when the feedwater system is inoperable or postulated accidents. Therefore, the AFWS is designed with redundancy, diversity, and separation to provide reasonable assurance of its ability to perform the safety function.

In conformance with BTP ASB 10-1 (Reference 27), the AFWS has diversity in motive power sources and consists of two full-capacity independent divisions that use separate and multiple power sources. Redundancy is provided by using two 100 percent capacity motor-driven AFW pumps, two 100 percent turbine-driven AFW pumps (one each for each steam generator), and two 100 percent capacity auxiliary feedwater storage tanks.

Diversity is provided by using two types of pump drivers (steam turbines and electrical motors) and AC and DC emergency electrical power sources. Separation is provided with separate power and instrumentation and control subsystems having appropriate measures that preclude interaction between subsystems. In addition, independent piping subsystems are incorporated into the design and protected at interconnection points with appropriate isolation or check valves to provide redundancy and diversity for AFW flow path to SGs.

In the event of a station blackout, the turbine-driven pump lines provided with battery-backed power are capable of providing auxiliary feedwater to the steam generators coincident with a single failure for 16 hours. Battery-backed power is also available to the turbine governor speed control. An AAC source of standby power is provided for the operation of the motor-driven AFW pump lines during an extended SBO.

The failure modes and effects analysis, assuming a postulated pipe failure concurrent a single active component failure, is presented in Table 10.4.9-3. Analysis of transients and accidents requiring the AFWS to function (addressed in Chapter 15), demonstrates that the AFWS satisfies the design basis described in Subsection 10.4.9.1.

Following a primary-side LOCA, the AFWS may be used to provide reasonable assurance that the steam generator tubes are covered to enhance the closed-system containment

boundary. The two motor-driven pumps are used for this purpose because steam for the turbine-driven pumps may or may not be available.

Water hammer can be caused by conditions such as introduction of voids, steam, or heated water in normally water-filled lines, condensation, and water entrainment in steam-filled lines, or rapid valve actuation. The AFWS is designed as follows to preclude water hammer in accordance with BTP 10-2 and NUREG-0927:

a. The temperature upstream of the AFW isolation check valve on each AFW line is continuously monitored for early detection of back leakage from the main feedwater to minimize heated water introduction, and is alarmed in the MCR.

b. The steam supply line up to AFW pump turbine steam isolation valve is warmed up during normal power operation to minimize condensation.

c. A low point drain upstream of the AFW pump turbine steam isolation valve provides a continuous blowdown through a pressure reducing orifice to minimize water entrainment.

The COL applicant is to provide operating and maintenance procedures for the following items in accordance with NUREG-0927 and a milestone schedule for implementation of the procedure (COL 10.4 (4)).

a. Introduction of void, steam, or heated water in water-filled lines and components

b. Filling and venting of water-filled lines and components

c. Condensation and water entrainment in steam-filled lines and components

d. Warmup and drainage of steam-filled lines

e. Prevention of rapid valve actuation

f. Valve alignment effects on line conditions

Steam binding of the AFW pumps is minimized by the following design and operational features:

a. The temperature upstream of the AFW isolation check valve on each AFW line is monitored continuously for early detection of back leakage from the main feedwater and is alarmed in the MCR. In the event of loss of MCR indication, the sensor also provides alarm and conditions monitored locally.

b. As the leakage continues, the steam voids, which can occur around the check valve and can reach the AFW pump casing and cause the AFW pump to become steam binding. The steam binding of the AFW pumps is avoided by continuous system venting through the AFWST. In the event that steam binding of the AFW pumps occurs, the MCR alarm associated with the temperature sensor discussed above signals the plant operator to vent the AFW pumps. Leakage through the check valve(s) is corrected by implementing appropriate procedures.

The AFWS is designed in conformance with the intent of GDC 2 regarding the effects of natural phenomena such as wind, tornado, hurricane, flood, and earthquake, as described in Sections 3.3, 3.4, and 3.7. All AFWS components are located in seismic Category I structures, which also protects the components from external environmental hazards in conformance with NRC RG 1.29 (Reference 11), Seismic Design Classification.

The AFWS is designed in conformance with the intent of GDC 4 regarding the dynamic effects including the effects of missiles, pipe whipping, and discharge of fluids.

All piping and components essential to AFW operation are designed to seismic Category I standards as described in Section 3.7, and are designed to accommodate, are located to protect against, or are protected from internal flooding and internal missiles as discussed in Sections 3.4 and 3.5. All components and piping are designed to protect against the effects of high- and moderate-energy pipe ruptures as discussed in Section 3.6.

The AFWS is designed in conformance with the intent of GDC 5 regarding sharing of systems among nuclear power units.

The AFWS can be manually or automatically actuated by an AFAS from the MCR to safely operate and maintain the plant under normal and accident conditions, including LOCAs, in conformance with GDC 19.

The AFWS is designed in conformance with the intent of GDC 34 and 44 regarding suitable redundancy in components and features to remove residual heat. The AFWS is provided with AC and DC emergency power and suitable redundancy in components and features to supply the AFW to the SG(s) for removal of heat in the event of single active component failure.

In conformance with GDC 45 and 46, the system is designed to perform periodic inspection of the system components, and periodic pressure and functional testing for the system operability and functional performance as described in Subsection 10.4.9.4.

10.4.9.4 Inspection and Testing Requirements

Inspections and tests during the AFWS component fabrication are performed and documented in accordance with ASME Section III for the safety-related components and ASME B31.1 (Reference 5) for the non-safety-related components. The component performance tests are performed in the vendor's facility as necessary. The AFWS is designed and installed for inservice inspections and tests in accordance with ASME Section XI (Reference 7).

10.4.9.4.1 Auxiliary Feedwater Performance Tests

Testing of the AFWS is conducted in accordance with Subsection 14.2.12.

10.4.9.4.2 Reliability Tests and Inspections

a. System-level tests

   Following completion of installation, and prior to initial startup, the entire AFWS is hydrostatically tested in accordance with the requirements of ASME Section III. After the plant is brought into operation, periodic tests and inspections of the

AFWS components and subsystems in accordance with Technical Specifications are performed to provide assurance of proper operation.

The scheduled tests and inspections are necessary to verify system operability, since during normal plant operation, the AFWS components are aligned for emergency operation and serve no other function. The tests defined permit a complete checking at the component level during normal plant operation. Satisfactory operability of the complete system can be verified during normal scheduled refueling shutdown. The complete schedule of tests and inspections of the AFWS is detailed in Chapter 16.

b. Component tests

In addition to the system level tests, tests to verify proper operation of the AFWS components are also conducted. These tests supplement the system level tests by verifying acceptable performance of each active component in the AFWS. Pumps and valves are tested in accordance with ASME OM (Reference 22). A full-flow test line is provided so that the pumps can be performance-tested after maintenance at various flow rates up to and including the design point.

In accordance with the recommendations of NUREG-0611, a 48-hour endurance test is to be performed on the AFW pumps to demonstrate that the pumps have the capability for continuous operation over an extended time period without failure.

10.4.9.5 Instrumentation Requirements

Sufficient instrumentation and controls are provided to adequately monitor and control the AFWS. Appropriate methods are employed to provide reasonable assurance of independent operation of the instrumentation and control channels to prevent any adverse and undesirable interaction between the AFW lines. All non-safety-related instrumentation and controls are designed so that any failure will not cause degradation of any safety-related equipment function. All valve and pump controls, and status and parameter indications are listed in Table 10.4.9-4. The emergency power train designations for instrumentation and controls are given in Table 10.4.9-2. All AFWS parameter measurements and indication instrumentation are described below.

10.4.9.5.1 Pressure Instrumentation

a. Auxiliary feedwater pump discharge pressure

The MCR and RSR are provided with a discharge pressure indication downstream of each of motor-driven AFW pump and turbine-driven AFW pump.

b. Auxiliary feedwater pump suction pressure

The MCR and RSR are provided with a suction pressure indication and low pressure alarm upstream of each of motor-driven AFW pump and turbine-driven AFW pump.

c. Auxiliary feedwater pump turbine inlet pressure

The MCR and RSR are provided with inlet pressure indication for AFW pump turbines.

d. Local pressure indications

Local pressure indications are provided at the following locations:

1) AFW pump turbine steam inlets

2) AFW pump turbine steam exhausts

3) Each AFW pump suction

4) Each AFW pump discharge

10.4.9.5.2 Temperature Instrumentation

a. Auxiliary feedwater isolation valve downstream temperature

The MCR is provided with temperature indication downstream of AFW isolation valves and a high-temperature alarm for detection of back leakage and steam voiding.

b. Auxiliary feedwater storage tank temperature

The MCR is provided with AFWST temperature indication and high-temperature and low-temperature alarms.

c. Auxiliary feedwater pump turbine bearing temperatures

The MCR has an AFW pump bearing temperature indication.

10.4.9.5.3 Flow Instrumentation

a. Auxiliary feedwater pump discharge flow

Flow indications for the motor-driven AFW pump and turbine-driven AFW pump discharge are provided locally in the MCR and RSR. These are designed and procured to meet the criteria given in NRC RG 1.97 (Reference 29).

b. Auxiliary feedwater pump recirculation flow

Flow indications for the motor-driven AFW pump and turbine-driven AFW pump recirculation are provided locally and in the MCR.

10.4.9.5.4 Level Instrumentation

a. Auxiliary feedwater storage tank level

Level indications and low-level alarms for AFWSTs are provided in the MCR and RSR. These are provided by redundant level instrumentation on each tank.

The low-level alarm is set at a point to allow 30 minutes for manual alignment of the other AFWST or the non-safety backup makeup supply before the level

decreases to a point where pump suction is lost. These are designed and procured to meet the criteria given in NRC RG 1.97.

b. Steam supply line drip leg level high-high alarms

   An alarm is annunciated in the MCR when the drip leg level is at the high-high level. This alerts the operator that the drip leg level control valve is not operating properly and is to be opened manually from the MCR.

10.4.9.5.5 Turbine-Driven Pump Turbine Speed

Instrumentation is provided in the MCR and RSR for indication of the turbine speed. The AFW pump turbine is brought to the rated speed by modulating the associated AFW pump turbine governor valve.

10.4.10 Auxiliary Steam System

The auxiliary steam system supplies auxiliary steam to all usage points through an auxiliary steam header interconnecting the main steam system and the auxiliary boiler.

10.4.10.1 Design Basis

The auxiliary steam system has the following functions:

a. During normal plant operation, the auxiliary steam system furnishes auxiliary steam to various equipment by extracting main steam, and then the condensate from these equipment is returned to the condenser.

b. During plant startup, shutdown, or cleanup/recirculation when main steam is unavailable, the auxiliary steam comes from the auxiliary boiler and is supplied to various equipment, and the condensate from this equipment is collected into the auxiliary boiler.

10.4.10.2 System Description

10.4.10.2.1 General Description

The auxiliary steam system piping and instrumentation diagram is shown in Figure 10.4.10-1.

The auxiliary steam system consists primarily of a main steam pressure reducing valve on the auxiliary steam header, a condensate receiver tank with vent condenser, condensate return pumps, an auxiliary boiler package, associated piping, valves, instrumentations, and controls.

The auxiliary steam system provides steam for the following purposes:

a. Deaerator pegging during recirculation/cleanup and low power operation mode

b. Turbine seals until main turbine extraction steam is available

c. Feedwater pump turbine seals until main steam is available

d. Feedwater pump turbine testing during plant shutdown

e. Auxiliary feedwater pump turbine testing during plant shutdown

f. Boric acid concentrator package and gas stripper package in the chemical and volume control system

g. Decontamination services in the reactor containment building and fuel handling area

h. Solid radwaste system (SRS) for heating SRS concentrates treatment system

   Condensate from the boric acid concentrator package, gas stripper package, and solid waste treatment system is collected in the condensate receiver tank and transferred to the condenser if the source of steam is from the MSS, or to the

auxiliary boiler if the source of steam comes from the auxiliary boiler by using the condensate return pumps. Any condensate that flashes inside the condensate receiver tank is condensed in the attached vent condenser and then returns to the condensate receiver tank.

At the discharge of the condensate return pump, the condensate is monitored continuously for radioactivity. If contaminated, the radiation monitor actuates an alarm in the MCR and automatically diverts the radioactive or potentially radioactive condensate to the liquid radwaste system.

Condensate from the others is collected at the condenser because it is considered non-potentially radioactive condensate.

The auxiliary boiler is located inside the auxiliary boiler building in yard area, and makeup water to the auxiliary boiler is provided from the makeup demineralizer system.

10.4.10.2.2 System Operation

The auxiliary boiler supplies saturated steam at 16.2 kg/cm^2A (230 psia) to the auxiliary steam header during plant startup, cleanup/recirculation, and shutdown when main steam is not available.

During plant normal operation, the main steam system of the unit provides steam to the auxiliary steam header. When main steam is used as the source of auxiliary steam, the steam enters the auxiliary steam header by opening a motor operated valve. The pressure of the steam is reduced to 15.1 kg/cm^2 G (215 psig) through a pressure-reducing valve. However, when the auxiliary steam boiler is used as the source of auxiliary steam, the motor operated valve is closed.

If a pressure-reducing valve fails closed, manual bypass valves are provided to allow for manual operation. If a pressure-reducing valve fails open, pressure relief valves downstream of the pressure-reducing valve are provided to protect the piping system and equipment from over-pressurization. Manual isolation valves are provided upstream and downstream of the valve to allow for maintenance of the pressure-reducing valve. A drain

valve located between the upstream isolation valve and the pressure-reducing valve is provided for drainage of the hot fluid.

The condensate return pumps are controlled by the water level in the condensate receiver tank. When the condensate reaches the high water level, one condensate return pump starts. When the condensate reaches the low water level, the pump stops. If the lead pump is tripped, the standby pump automatically starts.

10.4.10.2.3 Design Features for Minimization of Contamination

The APR1400 is designed with specific features to meet the requirements of 10 CFR 20.1406 and NRC RG 4.21. The basic principles of NRC RG 4.21, and the methods of control suggested in the regulations, are specifically delineated into four design objectives and two operational objectives discussed in Subsection 12.3.1.10. The following evaluation summarizes the primary features to address the design and operational objectives for the auxiliary steam system.

The auxiliary steam system is designed to provide process steam during plant startup, shutdown, and normal operation. The auxiliary steam system shares the same process deaerator that is supplied with extraction steam during normal operation. The auxiliary steam system has been evaluated for leakage potential from the SSCs that contain radioactive or potentially radioactive materials, the areas and pathways where leakage may occur, and the methods of leakage control are incorporated into the design of the system. The leak identification evaluation indicates that the auxiliary steam system is designed to facilitate early leak detection and the prompt assessment and response to manage collected fluids. Thus, unintended contamination to the facility and the environment is minimized and/or prevented by the SSC design, by operational procedures and programs, and by inspection and maintenance activities.

Prevention/Minimization of Unintended Contamination

a. The auxiliary steam system condensate receiver tank, vent condenser, and pumps are located in an enclosed area at the foundation level inside the auxiliary building. The boiler is located in its dedicated auxiliary boiler building outside the auxiliary building. The components are designed to be skid mounted vendor packaged

units. The floors are sloped, coated with epoxy, and provided with drains that are routed to the local drain hubs. This design approach prevents unintended contamination of the facility and the environment.

b. The auxiliary steam system is designed with sufficient capacity and redundancy to support plant operation when main steam is not available. The components are designed in accordance with ASME Section VIII and other applicable codes for life-cycle planning, thus minimizing unintended contamination and waste generation.

Adequate and Early Leak Detection

a. The auxiliary steam system is designed for automated operation with manual initiation for the different modes of operation. Adequate instrumentation, including level and pressure elements and a radiation monitor, is provided to monitor the system operation. Upon receipt of a high radiation signal, the condensate from the condensate return pump discharge line is diverted to the liquid waste management system for treatment and release. This design approach provides early leakage detection and minimizes the spread of contamination.

Reduction of Cross-Contamination, Decontamination, and Waste Generation

a. The SSCs are designed with life-cycle planning through the use of nuclear industry-proven materials compatible with the chemical, physical, and radiological environment, thus minimizing waste generation.

b. The auxiliary steam system is equipped with a radiation monitor to continuously assess the contamination level in the condensate as well as connections for sampling for confirmation and calibration of the radiation monitor results. If the radiological contamination level exceeds a pre-determined setpoint, an alarm is initiated in the MCR for operator actions, and a signal is sent to open the condensate transfer valves to redirect the condensate to the liquid waste management system for treatment. This design approach minimizes the spread of contamination to other components and the resultant need for decontamination.

Decommissioning Planning

a. The SSCs are designed for the full service life and are fabricated as individual assemblies for easy removal.

b. The SSCs are designed to facilitate decontamination. Demineralized water is provided to the system for makeup as well as for decontamination purposes. Design features, such as the utilized welding techniques, surface finishes, etc., are included to minimize the need for decontamination and resultant waste generation in order to facilitate decommissioning.

c. The auxiliary steam system is designed without any embedded or buried piping, thus preventing contamination to the environment. Yard piping is routed in an underground concrete tunnel that is designed with a leakage collection sump, level switch, and a sump pump. An alarm is also provided in the MCR for operator actions in the event of the detection of accumulated liquid.

Operations and Documentation

a. The auxiliary steam system is designed with adequate instrumentation for automatic operation with manual initiation for the different plant modes of operation. The auxiliary boiler is a self-contained package complete with its own instrumentation. The auxiliary boiler operation is controlled from a local panel but with remote shutdown capabilities from the MCR.

b. The auxiliary steam system condensate receiver tank, vent condenser, and pumps are located in an enclosed cubicle inside the auxiliary building, and the boiler is located in the independent auxiliary boiler building for separation purposes. Adequate space is provided around the equipment to enable access for a prompt assessment and responses when required.

c. The COL applicant is to establish operational procedures and maintenance programs as related to leak detection and contamination control in accordance with NRC RG 4.21 (COL 10.4(7)).

d. The COL applicant is to maintain the complete documentation of system design, construction, design modifications, field changes, and operations (COL 10.4(8)).

Site Radiological Environmental Monitoring

a. The auxiliary steam system is designed to manage low levels of contamination as a result of leakage in the condensate receiver tank, the vent condenser, pumps, auxiliary boiler, and the associated piping and instruments. Industry experiences demonstrate that the integrity of the auxiliary steam system is well maintained. The control methods included in the current design further minimize and/or prevent contamination of the facility and the environment. Therefore, inclusion in the site radiological environmental monitoring program is not required for this system.

10.4.10.3 Safety Evaluation

The auxiliary steam system has no safety-related function and therefore does not require a nuclear safety evaluation.

10.4.10.4 Inspection and Testing Requirements

Preoperational testing of the auxiliary steam system is performed as described in Section 14.2 to demonstrate that the systems and components operate in accordance with applicable test programs and specifications.

10.4.10.5 Instrumentation Requirements

The steam pressure of the auxiliary steam system is indicated locally and in the MCR and RSR. High and low steam pressures are alarmed in the MCR and RSR. Main steam flows to the auxiliary steam header are indicated in the MCR and RSR.

Steam flow rate to the boric acid concentrator package is indicated locally. The fluid level and pressure in the condensate receiver tank are indicated locally. High-high and low-low level alarms are provided at the local panel. The auxiliary boiler package is provided with

the necessary controls and indications for local or remote monitoring of the system's operation.

The radiation monitor is provided to monitor leaked radioactive materials in the condensed water from the boric acid concentrator package, gas stripper package, or solid waste treatment system. If the condensate is contaminated, the radiation monitor actuates an alarm in the MCR and automatically redirects the condensate to the liquid waste management system for treatment.

10.4.11 Combined License Information

COL 10.4(1) The COL applicant is to provide the location and design of the cooling tower, basin, and CW pump house.

COL 10.4(2) The COL applicant is to provide elevation drawings.

COL 10.4(3) The COL applicant is to determine the wet bulb temperature correction factor to account for potential interference and recirculation effects.

COL 10.4(4) The COL applicant is to provide operating and maintenance procedures in accordance with NUREG-0927 and a milestone schedule for implementation of the procedure.

COL 10.4(5) The COL applicant is to describe the nitrogen or equivalent system design for SG drain.

COL 10.4(6) The COL applicant is to address the discharge to waste water system including site-specific requirements.

COL 10.4(7) The COL applicant is to establish operational procedures and maintenance programs for leak detection and contamination control.

COL 10.4(8) The COL applicant is to maintain the complete documentation of system design, construction, design modifications, field changes, and operations.

COL 10.4(9) The COL applicant is to address the design features for the prevention of contamination.

10.4.12 References

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2. 10 CFR 50, Appendix A, "General Design Criteria for Nuclear Power Plants,"
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20. NUREG-0927, "Evaluation of Water Hammer Occurrences in Nuclear Power Plants," Rev. 1, U.S. Nuclear Regulatory Commission, March 1983.

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24. NUREG-0737, "Clarification of TMI Action Plan Requirements," U.S. Nuclear Regulatory Commission, November 1980.

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29. NRC RG 1.97, "Criteria for Accident Monitoring Instrumentation for Nuclear Power Plants," Rev. 4, U.S. Nuclear Regulatory Commission, June 2006.

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33. ASME PTC 23, "Atmospheric Water Cooling Equipment," November 2003.

34. NRC RG 1.37, "Quality Assurance Requirements for Cleaning of Fluid Systems and Associated Components of Water-Cooled Nuclear Power Plants," Rev. 1, U. S. Nuclear Regulatory Commission, March 2007.

35. NUREG-0800 Branch Technical Position 5-1, "Monitoring of Secondary Side Water Chemistry in PWR Steam Generators," Rev. 3, U.S. Nuclear Regulatory Commission, March 2007.

36. NRC RG 8.8, "Information relevant to Ensuring the Occupational Radiation Exposures at Nuclear Power Stations will be ALARA," Rev. 3, U.S. Nuclear Regulatory Commission, June 1978.

37. 10 CFR 20.1406, "Radiological Criteria for Unrestricted Use."

38. NRC RG 4.21, "Minimization of Contamination and Radioactive Waste Generation: Life-Cycle Planning."

39. NRC Generic Letter 89-08, "Erosion/Corrosion-Induced Pipe Wall Thinning," May 2 1989.

40. NUREG-0800 Subsection 10.4.2, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants." Rev.3, U.S. Nuclear Regulatory Commission, March 2007.

41. Heat Exchange Institute, "Performance Standards for Liquid Ring Vacuum Pumps" 3rd Edition, September, 2005.

Table 10.4.1-1

Main Condenser Design Parameters

Description	Parameter
Condenser type	Single-pressure, Single-pass, Surface cooling type
Number of shell	3
Design operating pressure	0.09 kg/cm^2 A (2.6 in HgA)
Heat transfer rate	2,659 MW (9.1 × 10^9 Btu/hr)
Circulating water flow	4,580,349 L/min (1,210,000 gpm)
Circulating water inlet temperature	32.4 °C (90.3 °F)
Circulating water outlet temperature	40.8 °C (105.4 °F)
Circulating water temperature rise	8.4 °C (15.1 °F)
Hotwell storage capacity	Supply maximum condensate flow for 5 minutes
Tube outside diameter	25 mm (1 in)
Tube thickness (BWG)	22
Design shell pressure	Full vacuum ~ 1.054 kg/cm^{2}G (Full vacuum ~ 15 psig)
Material	
Shell	Carbon steel
Tube	Titanium
Tube sheet	Titanium clad
Waterbox	Carbon steel with lining

Table 10.4.2-1

Condenser Vacuum Pump Design Parameters

Condenser Vacuum Pump	
Quantity	4
Capacity per pump	707,920 SCCM (25 SCFM) at 0.035 kg/cm^2A (1.0 in HgA)
Type	Water-sealed rotary type
Driver	Electric motor

Table 10.4.5-1 (1 of 2)

Circulating Water System Design Parameters

Cooling Tower	
Type	Mechanical induced draft
Number of towers	2
Number of cells (total)	56
Design inlet wet bulb temperature	27.2 °C (81 °F) including recirculation of 1.1 °C (2 °F)(1)
Cooling tower inlet temperature	40.7 °C (105.2 °F)
Cooling tower outlet temperature	32.4 °C (90.3 °F)
Process Parameter	
Circulating water system flow for condenser	4,580,349 L/min (1,210,000 gpm)
Flow for TGBCCW heat exchanger	56,781 L/min (15,000 gpm)
Number of circulating water pumps	6
CW pump capacity (per each)	779,795 L/min (206,000 gpm)
System maximum design pressure	4.5 kg/cm^2 G (50 psig)
System minimum design pressure	0.0 kg/cm^2 G (-14.7 psig)
Materials	
Cooling tower and basin structure	Concrete reinforced with ASTM A615 Grade 60
Conduit	Concrete reinforced with ASTM A615 Grade 60
CW pipe discharge pipe	ASTM A672 Grade B60 welded carbon steel with lining
Circulating water pump	316 L Super austenitic stainless steel

Table 10.4.5-1 (2 of 2)

Cooling water makeup system	
Capacity	83,279 L/min (22,000 gpm)
Number of makeup water pumps	3
Pump capacity (per each)	41,640 L/min (11,000 gpm)
Blowdown system	
Capacity	49,210 L/min (13,000 gpm)
Number of makeup water pumps	3
Pump capacity (per each)	24,605 L/min (6,500 gpm)

(1) The COL applicant is to determine wet bulb temperature correction factor to account for the potential interference and recirculation effects (COL 10.4(3)).

Table 10.4.6-1

Condensate Polishing System Design Parameter

[[

Cation bed ion exchanger vessel

Number of vessels	7
Type	Vertical
Design flow rate per vessel	395 L/min (3,850 gpm)
Design pressure	242 kg/cm^{2}G (650 psig)
Materials	Carbon steel with rubber lining

Mixed bed ion exchanger vessel

Number of vessels	7
Type	Vertical
Design flow rate per vessel	395 L/min (3,850 gpm)
Design pressure	242 kg/cm^{2}G (650 psig)
Materials	Carbon steel with rubber lining

Spent resin holding tank

Number of vessels	2
Type	Vertical
Materials	Carbon steel with rubber lining

Resin holding tank

Number of vessels	1
Type	Vertical
Materials	Carbon steel with rubber lining

Resin mixing and holding tank

Number of vessels	1
Type	Vertical
Materials	Carbon steel with rubber lining

Resin trap

Number of sets	14 (For service) 2 (For recirculation)
Type	Vertical, Cylindrical
Materials	304 stainless steel with 304 liner

]]

Table 10.4.7-1 (1 of 3)

Major Components Design Parameters

Condensate pump	
Quantity	3
Type	Vertical, centrifugal, can type
Motor	13.2 KV/3 phase/60 Hz
Rated flow	48,075 L/min (12,700 gpm)
Rated head	305 m (1,000 ft)
Motor rated horsepower	3,432 kW (4,600 hp)
Main feedwater pump	
Quantity	3
Type	Turbine-driven variable speed, horizontal, centrifugal
Rated speed	4,570 rpm
Rated flow	54,131 L/min (14,300 gpm)
Rated head	610 m (2,000 ft)
Feedwater booster pump	
Quantity	3
Type	Horizontal, centrifugal, single stage
Motor	13.2 KV/3 phase/60 Hz
Rated flow	54,131 L/min (14,300 gpm)
Rated head	294 m (963 ft)
Motor rated horsepower	3,730 kW (5,000 hp)

Table 10.4.7-1 (2 of 3)

Startup feedwater pump	
Quantity	1
Type	Horizontal, centrifugal
Motor	13.2 KV/3 phase/60 Hz
Rated flow	9,085 L/min (2,400 gpm)
Rated head	854 m (2,800 ft)
Motor rated horsepower	3.7 kW (5 hp)
Low pressure feedwater heaters	
Quantity	9
Type	Horizontal U-tube
Rated flow	722 kg/s (5,732,067 lb/hr)
Material (Shell)	Carbon Steel
Material (Tube)	Stainless Steel
High pressure feedwater heaters	
Quantity	6
Type	Horizontal U-tube
Rated flow	1,187 kg/s (9,417,714 lbm/hr)
Material (Shell)	Carbon Steel
Material (Tube)	Stainless Steel
Deaerator	
Quantity	1
Type	Combination Spray-Tray, Horizontal, Cylindrical
No. of Spray Valves	338
No. of Tray	2,288
Material	Carbon Steel
Deaerator storage tanks	
Quantity	2
Type	Horizontal, Cylindrical
Capacity	1,097,012 L (289,800 gal) below normal operating level

Table 10.4.7-1 (3 of 3)

Downcomer main feedwater isolation valves	
Quantity	4
Type	Gate
Size	254 mm (10 in)
Actuator	Hydraulic to open, gas spring to close
Economizer main feedwater isolation valves	
Quantity	4
Type	Gate
Size	610 mm (24 in)
Actuator	Hydraulic to open, gas spring to close
Downcomer feedwater control valves	
Quantity	2
Type	Globe
Size	254 mm (10 in)
Actuator	Pneumatic piston
Economizer feedwater control valves	
Quantity	2
Type	Globe
Size	610 mm (24 in)
Actuator	Pneumatic piston

Table 10.4.7-2

Condensate and Feedwater System Failure Modes and Effects Analysis

Component	Fail Mode	Effect on System	Failure Detection
Main Feedwater Isolation Valves (MFIVs) FW-V121, V122, V123, V124, V131, V132, V133, V134	Fail closed or fail to open on demand	No safety-related effect. No adverse effect on integrities of the reactor or RCPB. Plant can remain hot standby mode or go to hot shutdown.	Valve position indication in MCR

Table 10.4.8-1 (1 of 4)

Steam Generator Blowdown System Major Component Design Parameters

Flash Tank		
Type	Vertical cylindrical	
Number of tanks	1	
Capacity	One SG EBD and the other ABD with 200 second	
Design pressure	2.06 MPa (300 psig)	
Design temperature	216.6 °C (422 °F)	
Operating pressure	1.72 MPa (250 psig)	
Operating temperature	207.7 °C (406 °F)	
Materials of construction	Stainless Steel TP304	
Radwaste safety class	RW-IIc	
Regenerative heat exchangers		
Type	Shell and tube	
Number of exchangers	1	
Design heat duty	14.91×10^6 W (50.9×10^6 Btu/hr)	
Operating conditions	Shell side	Tube side
Fluid	SG blowdown water	Condensate
Operating temperature In Out	 207.7 °C (406 °F) 57.2 °C (135 °F)	 53.3 °C (128 °F) 143.3 °C (291 °F)
Design flow rate	78.9 ton/hr (174×10^3 lb/hr)	140.6 ton/hr (310×10^3 lb/hr)
Design pressure	2.06 MPa (300 psig)	4.27 MPa (620 psig)
Design temperature	216.6 °C (422 °F)	216.6 °C (422 °F)
Materials of construction	Carbon steel	Stainless steel
Radwaste safety class	RW-IIc	

Table 10.4.8-1 (2 of 4)

Wet layup recirculation pump	
Number of demineralizers	2/Unit
Type	Horizontal, Centrifugal
Design flow rate	1,627 lpm (430 gpm)
Total discharge head	112.7 m (370 ft)
Radwaste safety class	RW-IIc
Pre-filter	
Type	Cartridge
Number of coolers	2
Design flow rate	3,255 lpm (860 gpm)
Operating pressure	1.72 MPa (250 psig)
Operating temperature	57.2 °C (135 °F)
Design pressure	2.06 MPa (300 psig)
Design temperature	121.1 °C (250 °F)
Rating	98 removal efficiency for the particles greater than 0.5 micron
Material of construction	
Filter Body	Stainless Steel Stainless Steel
Radwaste safety class	RW-IIc

Table 10.4.8-1 (3 of 4)

Post-filter	
Type	Vertical cylindrical, cartridge
Number of filters	1
Design flow rate	3,255 lpm (860 gpm)
Operating pressure	1.72 MPa (250 psig)
Operating temperature	57.2 °C (135 °F)
Design pressure	2.06 MPa (300 psig)
Design temperature	121.1 °C (250 °F)
Rating	98 removal efficiency for particles larger than 25 microns
Material of construction	
Filter Body	Stainless Steel Stainless Steel
Radwaste safety class	RW-IIc
Demineralizers	
Number of demineralizers	2
Type	Mixed bed
Resin amount	6.5 m^3 (230 ft^3)
Design flow rate	3,255 lpm (860 gpm)
Operating pressure	1.72 MPa (250 psig)
Operating temperature	57.2 °C (135 °F)
Design pressure	2.06 MPa (300 psig)
Design temperature	121.1 °C (250 °F)
Materials of construction	Stainless Steel
Radwaste safety class	RW-IIc

Table 10.4.8-1 (4 of 4)

Containment isolation valves	
Number of valves	4
Type	Air-operated gate (2) / Motor-operated gate (2)
Nominal valve size	200 mm (8 in)
Design pressure	8.17 MPa (1185 psig)
Design temperature	298.8 °C (570 °F)
Material of construction, body	Stainless Steel
Construction Code	ASME Section III, Class 2
Seismic Category	I

Table 10.4.8-2

Steam Generator Blowdown System Failure Modes and Effects Analysis

Name/No.	Potential Failure Mode	Plant Condition	Symptoms & Local Effect Including Dependent Failure	Method of Detection	Inherent Compensating Provisions	Remarks & Other Effects
1. Steam Generator Blowdown Containment Isolation valve SGS-AOV-005/006	a. Fails to close on demand	Loss of Non-emergency AC Power Loss of normal Feedwater Feedwater System Pipe Break Steam Generator Tube Rupture Safe shutdown	No safety-related impact on plant Isolation is achieved by redundant steam generator blowdown isolation valve (SGS-AOV-007/008)	Valve information: Valve position indication in MCR	Redundant steam generator blowdown isolation valve	Normally opened, fail closed air-operated valve
	b. Fails to close on demand	Loss of Coolant Accident	No safety-related impact on plant Containment boundary remains intact with redundancy provided by this valve, SGs lines	Valve information: Valve position indication in MCR	Redundant steam generator blowdown isolation valve	Normally opened, fail closed air-operated valve
2. Steam Generator Blowdown CV Isolation valve SGS-AOV-007/008	a. Fails to close on demand	Loss of Non-emergency AC Power Loss of normal Feedwater Feedwater System Pipe Break Steam Generator Tube Rupture Safe shutdown	No safety-related impact on plant Isolation is achieved by redundant steam generator blowdown isolation valve (SGS-AOV-005/006)	Valve information: Valve position indication in MCR	Redundant steam generator blowdown isolation valve	Normally opened, fail as-is motor operated valve
	b. Fails to close on demand	Loss of Coolant Accident	No safety-related impact on plant Containment boundary remains intact with redundancy provided by this valve, SGs lines	Valve information: Valve position indication in MCR	Redundant steam generator blowdown isolation valve	Normally opened, fail as-is motor operated valve

Table 10.4.8-3

Codes and Standards for Equipment in the SGBS

Equipment	Design and Fabrication	Material	Welder Qualifications and Procedures	Inspection and testing
Pressure Vessels	ASME Section VIII, Div. 1 or 2	ASME Sec. II	ASME Sec. IX	ASME Section VIII, Div. 1 or 2
Pumps	API-610; API-674; API-675; ASME Sec. VIII, Div. 1 or Div. 2	ASME Sec. II	ASME Sec. IX	ASME Sec.III, Class 3
Piping and Valves	ANSI/ASME B31.3	ASME-Sec. II	ASME, Sec. IX	ANSI/ASME B31.3
Demineralizer	ASME Sec. VIII, Div. 1	ASME Sec. II	ASME, Sec. IX	ASME Sec. VIII, Div. 1
Filters	ASME Sec. VIII, Div. 1	ASME Sec. II	ASME, Sec. IX	ASME Sec. VIII, Div. 1
Heat Exchangers	TEMA STD, 8th Edition; ASME Sec. VIII Div. 1 or Div. 2	ASTM B359-98 or ASME Sec. II	ASME, Sec. IX	ASME Section VIII, Div. 1 or 2

Table 10.4.9-1 (1 of 3)

Auxiliary Feedwater System Component Parameters

Auxiliary Feedwater Pumps	
Quantity	2 motor driven, 2 turbine driven
Type	Multi-stage, horizontal, centrifugal
Design code	ASME Section III, Class 2
Seismic Category	I
Design pressure	201.4 kg/cm^2A (2,864 psia)
Design temperature	60 °C (140 °F)
Design flow rate	2,461 L/min (650 gpm)(1)
Design head at 48.9 °C (120 °F)	1,066.8 m (3,500 ft)
NPSH available (design point) at 48.9 °C (120 °F)	9.4 m (31 ft)
Maximum shutoff head at rated speed	1,356.4 m (4,450 ft)
Auxiliary Feedwater Cavitating Venturi	
Quantity	2
Design code	ASME Section III, Class 2
Seismic Category	I
Design pressure	201.4 kg/cm^2A (2,864 psia)
Design temperature	298.9 °C (570 °F)
Choked flow at inlet pressure of 122.8 kg/cm^2A (1,747 psia)	3,407 L/min (900 gpm)
Operating temperature range	4.4 °C (40 °F) – 48.9 °C (120 °F)
Minimum pressure recovery at choked flow, %	82

(1) Flow rate is 2,461 L/min (650 gpm) to steam generator, excluding the recirculation flow for minimum flow pump protection.

Table 10.4.9-1 (2 of 3)

Auxiliary Feedwater Storage Tanks	
Quantity	2
Design code	ASME Section III, Class 3
Seismic Category	I
Minimum usable volume per tank	1,514,165 L (400,000 gal)
Design pressure, internal/external	0.07 kg/cm^{2}G (1.0 psig) / 0.035 kg/cm^{2}G (0.5 psig)
Design temperature	60 °C (140 °F)
Auxiliary Feedwater Modulating Valves	
Quantity	4
Type	Glove valve
Size	150 mm (6 in)
Design pressure	201.4 kg/cm^{2}A (2,864 psia)
Design temperature	60 °C (140 °F)
Material	Stainless steel
Design Code	ASME Section III, Class 3
Seismic Category	I
Auxiliary Feedwater Isolation Valves	
Quantity	4
Type	Gate valve
Size	150 mm (6 in)
Design pressure	201.4 kg/cm^{2}A (2,864 psia)
Design temperature	60 °C (140 °F)
Material	Stainless steel
Design Code	ASME Section III, Class 2
Seismic Category	I

Table 10.4.9-1 (3 of 3)

Auxiliary Feedwater Pump Turbine Steam Isolation Valves	
Quantity	2
Type	Glove valve
Size	200 mm (8 in)
Design pressure	97.4 kg/cm^{2}A (1,385 psia)
Design temperature	301.7 °C (575 °F)
Material	Carbon steel
Design Code	ASME Section III, Class 3
Seismic Category	I

Table 10.4.9-2 (1 of 3)

Auxiliary Feedwater System Emergency Power Sources

Auxiliary Feedwater System Pump Motors	
Motor	Train
Motor-driven auxiliary feedwater pump (PP02A) motor	A
Motor-driven auxiliary feedwater pump (PP02B) motor	B
Auxiliary Feedwater System Electrically Operated Valves	
Valve	Train
AFW isolation valve V0043	A
AFW isolation valve V0044	B
AFW isolation valve V0045	C
AFW isolation valve V0046	D
AFW modulating valve V0035	D
AFW modulating valve V0036	C
AFW modulating valve V0037	B
AFW modulating valve V0038	A
Instrumentation and Controls	
Controls	Train
Motor-driven AFW pump (PP02A) start/stop	A
Motor-driven AFW pump (PP02B) start/stop	B
Turbine driven AFW pump (PP01A) start/stop	C
Turbine driven AFW pump (PP01B) start/stop	D
Steam supply line drip leg level control valve V007	C
Steam supply line drip leg level control valve V008	D
AFW isolation valve V0043 open/close	A
AFW isolation valve V0044 open/close	B
AFW isolation valve V0045 open/close	C
AFW isolation valve V0046 open/close	D
AFW modulating valve V0035 position controls	D
AFW modulating valve V0036 position controls	C

Table 10.4.9-2 (2 of 3)

Instrumentation and Controls (cont.)	
Controls	Train
AFW modulating valve V0037 position controls	B
AFW modulating valve V0038 position controls	A
Steam isolation valve V0009 open/close	C
Steam isolation valve V0010 open/close	D
AFW pump turbine (TA01A) speed control	C
AFW pump turbine (TA01B) speed control	D
Steam supply line drip leg level control valve V0007 open/close	C
Steam supply line drip leg level control valve V0008 open/close	D
Indication and Alarms	Train
Motor-driven AFW pump PP02A discharge pressure	A
Motor-driven AFW pump PP02B discharge pressure	B
Turbine driven AFW pump PP01A discharge pressure	C
Turbine driven AFW pump PP01B discharge pressure	D
AFW isolation valves (V0043, V0045) downstream temperature and high-temperature alarm	A
AFW isolation valves (V0043, V0045) downstream temperature and high-temperature alarm	C
AFW isolation valves (V0044, V0046) downstream temperature and high-temperature alarm	B
AFW isolation valves (V0044, V0046) downstream temperature and high-temperature alarm	D
Motor-driven AFW pump PP02A suction pressure and low-pressure alarm	A
Motor-driven AFW pump PP02B suction pressure and low-pressure alarm	B
Turbine driven AFW pump PP01A suction pressure and low-pressure alarm	C
Turbine driven AFW pump PP01B suction pressure and low-pressure alarm	D
Turbine driven AFW pump turbine (TA01A) inlet pressure	C
Turbine driven AFW pump turbine (TA01B) inlet pressure	D
Motor-driven AFW pump PP02A flow	A
Motor-driven AFW pump PP02B flow	B

Table 10.4.9-2 (3 of 3)

Instrumentation and Controls (cont.)	
Indication and Alarms	Train
Turbine driven AFW pump PP01A flow	C
Turbine driven AFW pump PP01B flow	D
AFWST TK01A level and low alarm	A
AFWST TK01A level	B
AFWST TK01A level	C
AFWST TK01B level and low alarm	B
AFWST TK01A level	D
AFWST TK01B level	A
AFWST TK01B level	C
AFWST TK01B level	D
Turbine driven AFW pump turbine TA01A speed	C
Turbine driven AFW pump turbine TA01B speed	D
Motor-driven AFW pump PP02A running status	A
Motor-driven AFW pump PP02B running status	B
Turbine driven AFW pump PP01A running status	C
Turbine driven AFW pump PP01B running status	D
AFW isolation valve V0043 open/close position	A
AFW isolation valve V0044 open/close position	B
AFW isolation valve V0045 open/close position	C
AFW isolation valve V0046 open/close position	D
AFW modulating valve V0035 close/modulating position	D
AFW modulating valve V0036 close/modulating position	C
AFW modulating valve V0037 close/modulating position	B
AFW modulating valve V0038 close/modulating position	A
Steam isolation valve V0009 open/close position	C
Steam isolation valve V0010 open/close position	D
Steam supply line drip leg level control valve V0007 open/close position	C
Steam supply line drip leg level control valve V0008 open/close position	D

Table 10.4.9-3 (1 of 2)

Auxiliary Feedwater System Failure Modes and Effects Analysis

No.	Component	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Remarks and Other Effects
1.	Motor-driven auxiliary feedwater pump AFW – PP01A/B	Fails to start or run	Electrical malfunction, bearing failure	Loss of auxiliary feedwater flow from affected AFW line to intact steam generator	Flow and discharge pressure indicators in MCR or RSR	Redundant 100 percent capacity, turbine-driven pump line	—
2.	Turbine driven auxiliary feedwater pump AFW – PP02A/B	Fails to start or run	Governor fails to control steam flow, trip, and throttle valve trips closed, steam isolation valves fail to open.	Loss of auxiliary feedwater flow from affected AFW line to intact steam generator	Flow, discharge pressure, and speed indicators in MCR or RSR Steam isolation valve, trip and throttle valve, or governor valve position indicators in MCR or RSR	Redundant 100 percent capacity, motor-driven pump line	—
3.	Pump discharge check valve AFW – V1003A/B, V1004A/B	Fails to open	Mechanical binding, corrosion	Loss of auxiliary feedwater flow from affected AFW line to intact steam generator	Flow indicator in MCR or RSR	Redundant 100 percent capacity, motor-driven or turbine-driven pump line	This valve is normally close in standby mode.
4.	Auxiliary feedwater modulating valves AFW – V0035 ~ 38	Fails to open	Mechanical binding, corrosion	Loss of auxiliary feedwater flow from affected AFW line to intact steam generator	Flow indicator and valve position indicator in the MCR or RSR	Redundant 100 percent capacity, motor-driven or turbine-driven pump line	Valves fail – open on loss of power. This valve is normally open in standby mode.
		Fails to modulate or close	Electrical failure, mechanical binding	Flow of auxiliary feedwater to intact or affected steam generator cannot be controlled utilizing the valve	Flow indicator and valve position indicators in MCR or RSR	Flow control to intact steam generator is accomplished by open/close control of AFW isolation valve. The AFW flow to affected steam generator may be terminated by operator action within 30 minutes to close the AFW isolation valves and/or shutoff the associated AFW pumps.	—

Table 10.4.9-3 (2 of 2)

No.	Component	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Remarks and Other Effects
5.	Auxiliary feedwater isolation valves AFW – V0043 ~ 46	Fails to open	Mechanical binding	Loss of auxiliary feedwater flow from affected AFW line to intact steam generator	Flow indication and valve position indication in MCR or RSR	Redundant 100 percent capacity, motor-driven or turbine-driven pump line	Valves fail-lock on loss of power This valve is normally open in standby mode.
		Fails to close	Electrical failure, mechanical binding	Flow of auxiliary feedwater to intact or affected steam generator cannot be controlled utilizing this valve	Flow indication and valve position indicator in MCR or RSR	Flow to intact steam generator can be controlled by the flow modulating valves. The AFW flow to affected steam generator may be terminated by operator action within 30 minutes to close the AFW isolation valves and/or shutoff the associated AFW pumps.	—
6.	Auxiliary feedwater isolation check valves AFW – V1007A/B, V1008A/B	Fails to open	Mechanical binding, corrosion	Loss of auxiliary feedwater flow from the affected AFW line to intact steam generator	Flow indicator in MCR and RSR	Redundant 100 percent capacity, motor-driven or turbine-driven pump line	This valve is normally close in standby mode.
7.	Steam isolation valves AT – V0009~10	Fails to open	Solenoid failure, plugged air port, mechanical binding	See Item No. 2	See Item No. 2	See Item No. 2	—

Table 10.4.9-4

Auxiliary Feedwater System Instrumentation and Control

Item	Main Control Room	Remote Shutdown Room
Motor-driven AFW pump start/stop	×	×
turbine driven AFW pump start/stop	×	×
Individual auxiliary feedwater isolation valves open/close	×	×
Individual valve position for AFW modulating valves	×	×
Steam isolation bypass valves open/close	×	×
Steam isolation valves open/close	×	×
AFW pump turbine stop valves control	×	—
AFW pump turbine speed control	×	—
Steam supply line drip leg level control valves open/close	×	—
Motor-driven AFW pump discharge pressure	×	×
Turbine driven AFW pump discharge pressure	×	×
Motor-driven AFW pump suction pressure and low-pressure alarm	×	×
Turbine driven AFW pump suction pressure and low-pressure alarm	×	×
Turbine driven AFW pump turbine inlet pressure	×	×
AFW isolation valves downstream temperature and high-temperature alarm	×	×
AFWST temperature and high- temperature and low-temperature alarm	×	×
Motor-driven AFW pump flow	×	×
Turbine driven AFW pump flow	×	×
Individual steam supply line drip leg level high-high-level alarms	×	×
Turbine driven AFW pump turbine speed	×	—
Motor-driven pump running status	×	×
Turbine driven AFW pump running status	×	—
Individual AFW modulating valves position indication	×	×
Steam isolation bypass valves open/closed position indication	×	×
Steam isolation valves open/closed position indication	×	×

Table 10.4.9-5

Principal Auxiliary Feedwater System Pressure Retaining Materials

ESF Component	Material	Class, Grade, or Type
Auxiliary Feedwater Pumps		
Pump Outer Casing	SA-487	GR. CA6NM
Closure Stud Bolts	SA-193	Gr. B7
Closure Stud Nuts	SA-194	Gr. 2H
Auxiliary Feedwater Pump Turbines		
Turbine Casing	SA-216	Gr. WCB
Closure Stud Bolts	SA-193	Gr. B7
Closure Stud Nuts	SA-194	Gr. 2H
Piping	SA-312	Gr. TP304
	SA-106	Gr. B
Valves	SA-216	Gr. WCB
	SA-105	
	SA-351	Gr. CF8M
	SA-182	Gr. F316
Fitting / Flange	SA-105	
	SA-234	Gr. WPB
	SA-403	Gr. WP304
	SA-182	Gr. F304
Weld Filler Material	SFA-5.1	E7016, E7018
	SFA-5.4	E308-15, E308-16, E308L-15, E308L-16, E309L-16
	SFA-5.9	ER308, ER309, ER308L, ER309L
	SFA-5.18	ER70S-2, ER70S-6

Table 10.4.9-6

Steam Generator Makeup Flow Requirement

Flow Requirement	2,461 L/min (650 gpm) to 1 SG

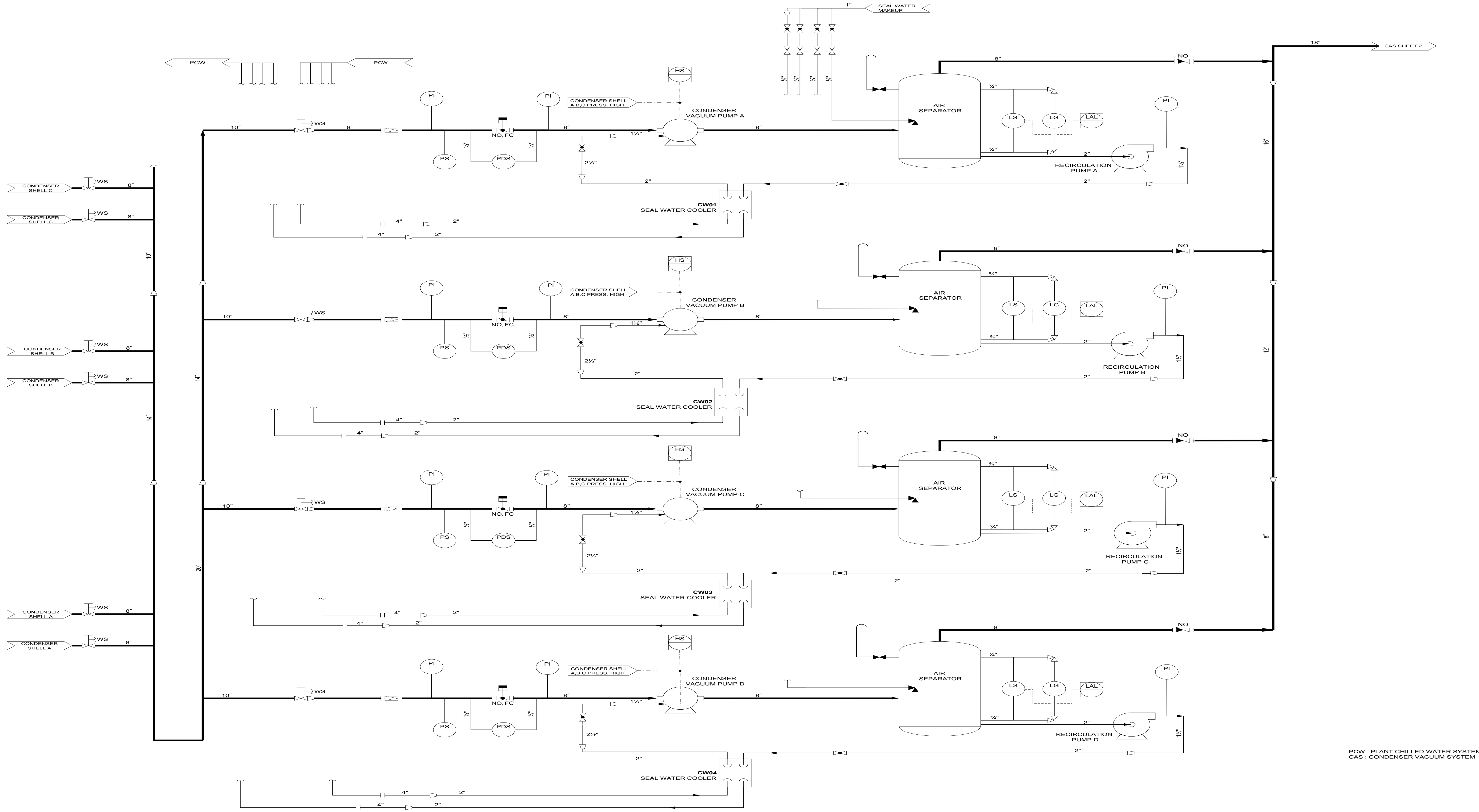

Figure 10.4.2-1 Condenser Vacuum System Flow Diagram (1 of 2)

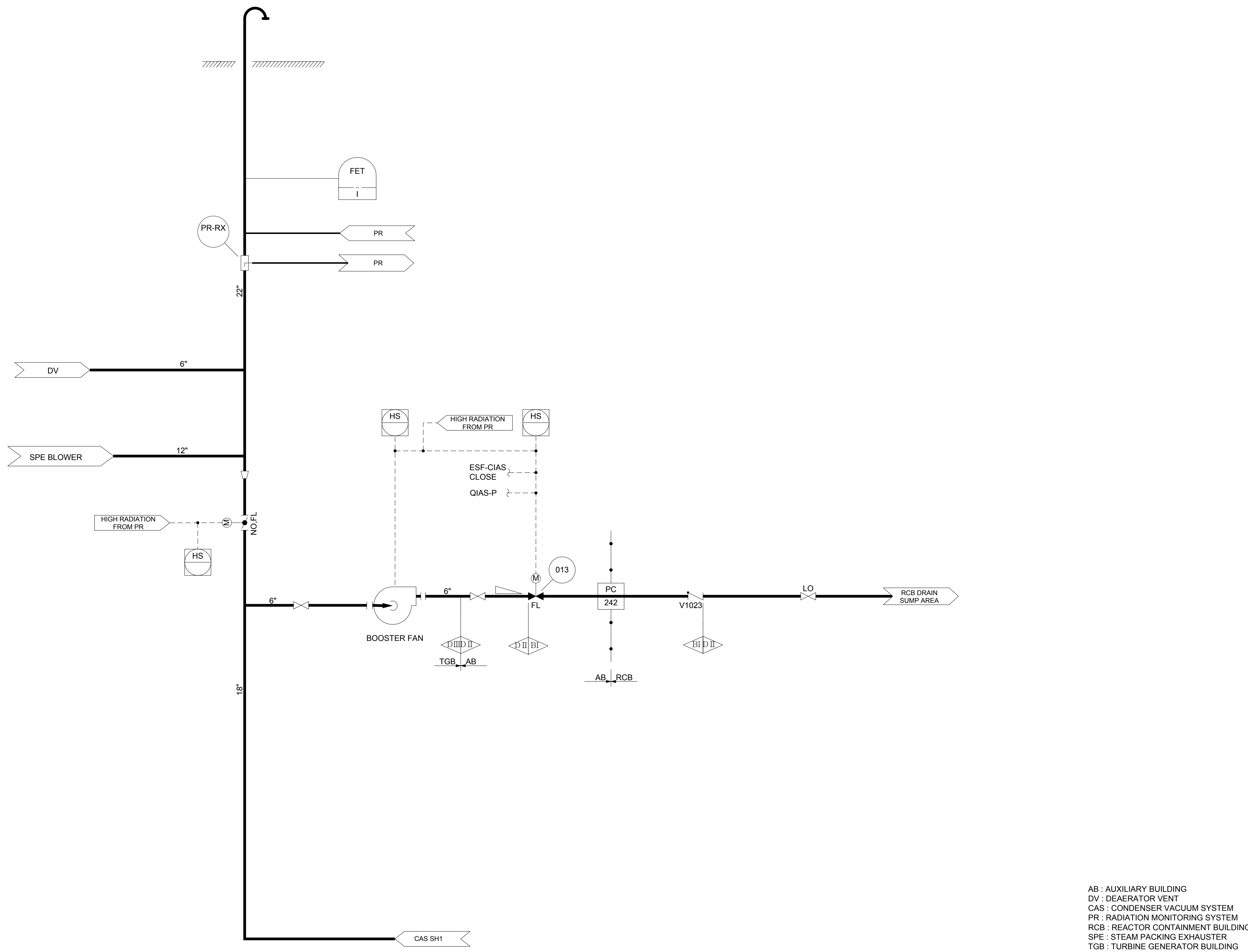

Figure 10.4.2-1 Condenser Vacuum System Flow Diagram (2 of 2)

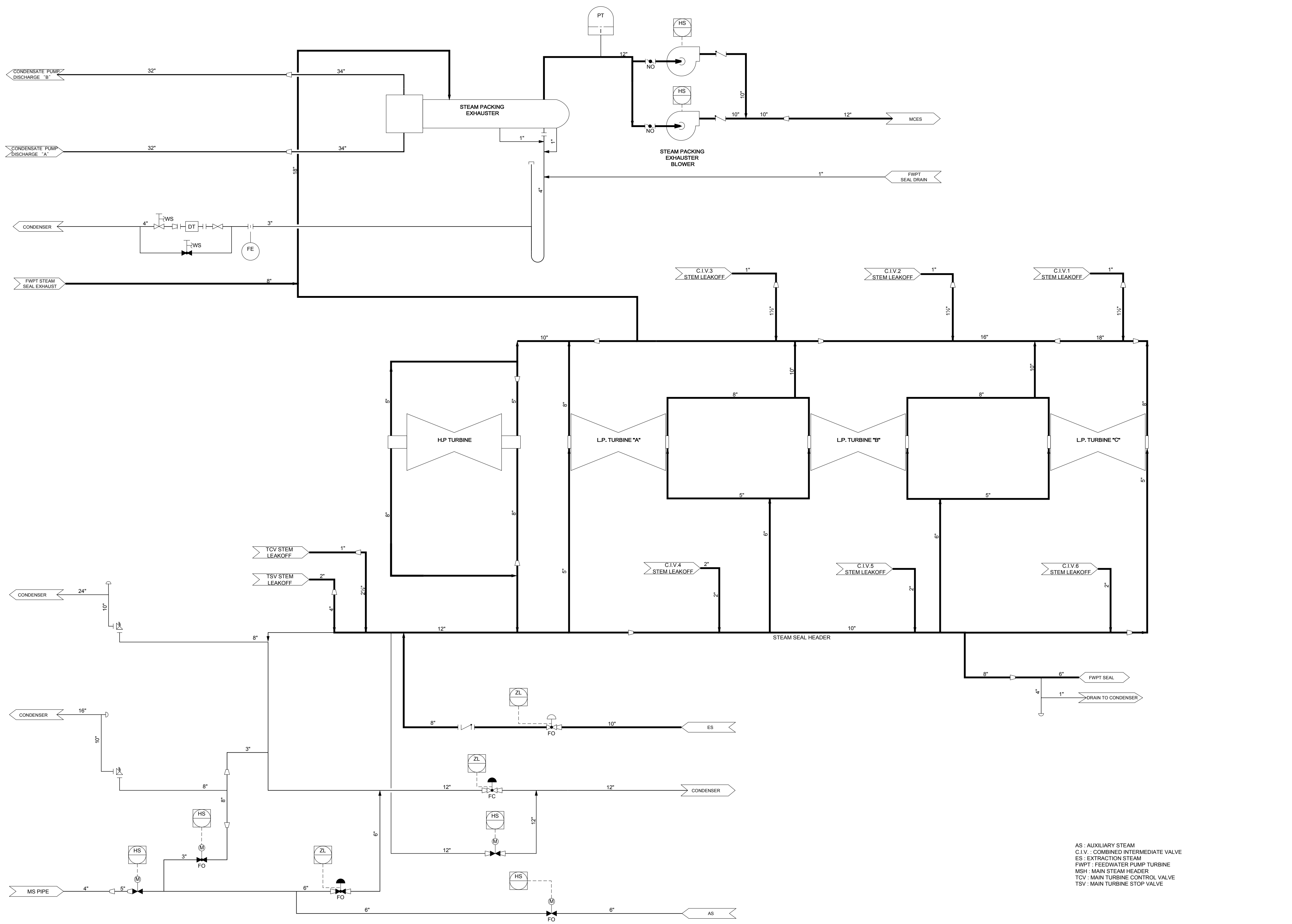

Figure 10.4.3-1 Turbine Gland Sealing System Flow Diagram

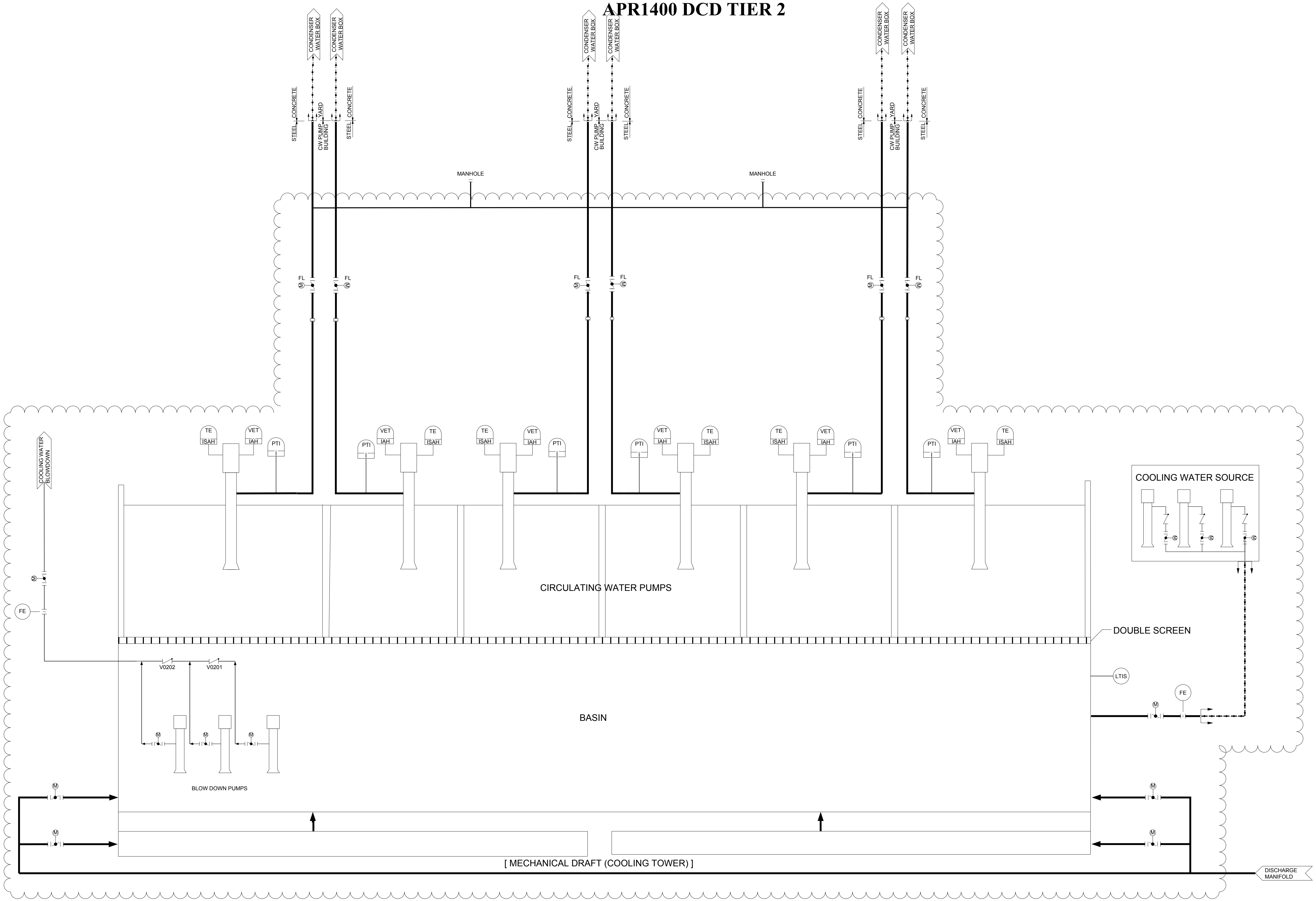

Figure 10.4.5-1 Circulating Water System Flow Diagram (1 of 2)

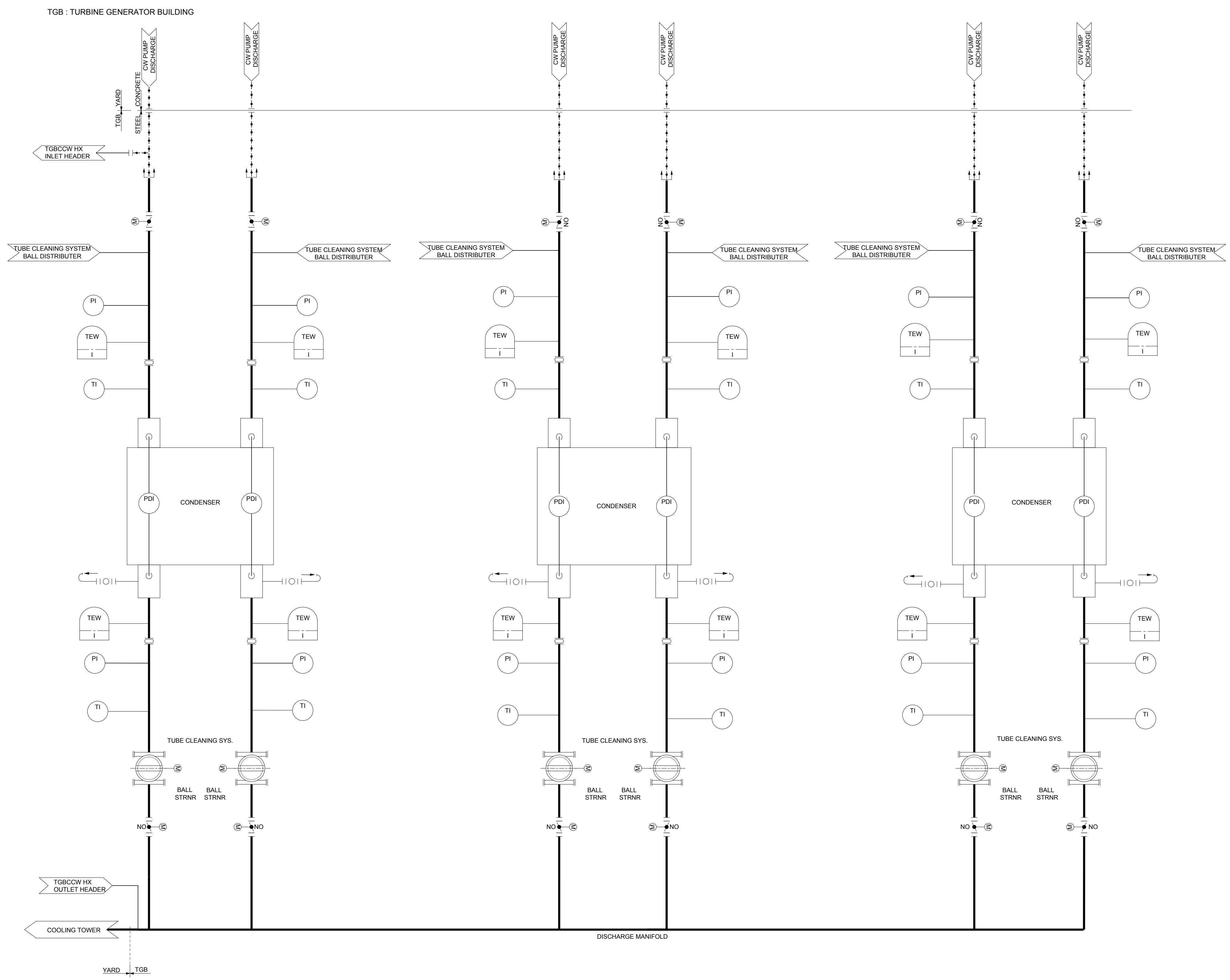

Figure 10.4.5-1 Circulating Water System Flow Diagram (2 of 2)

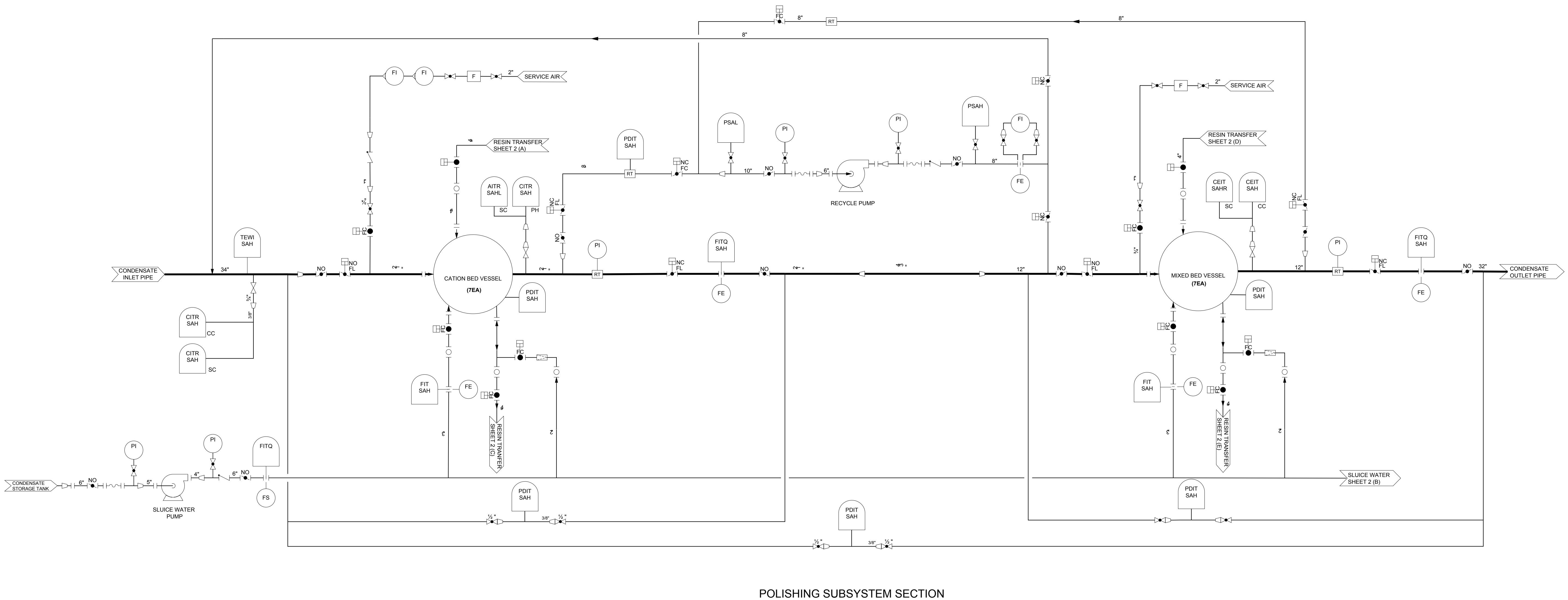

Figure 10.4.6-1 Condensate Polishing System Flow Diagram (1 of 2)

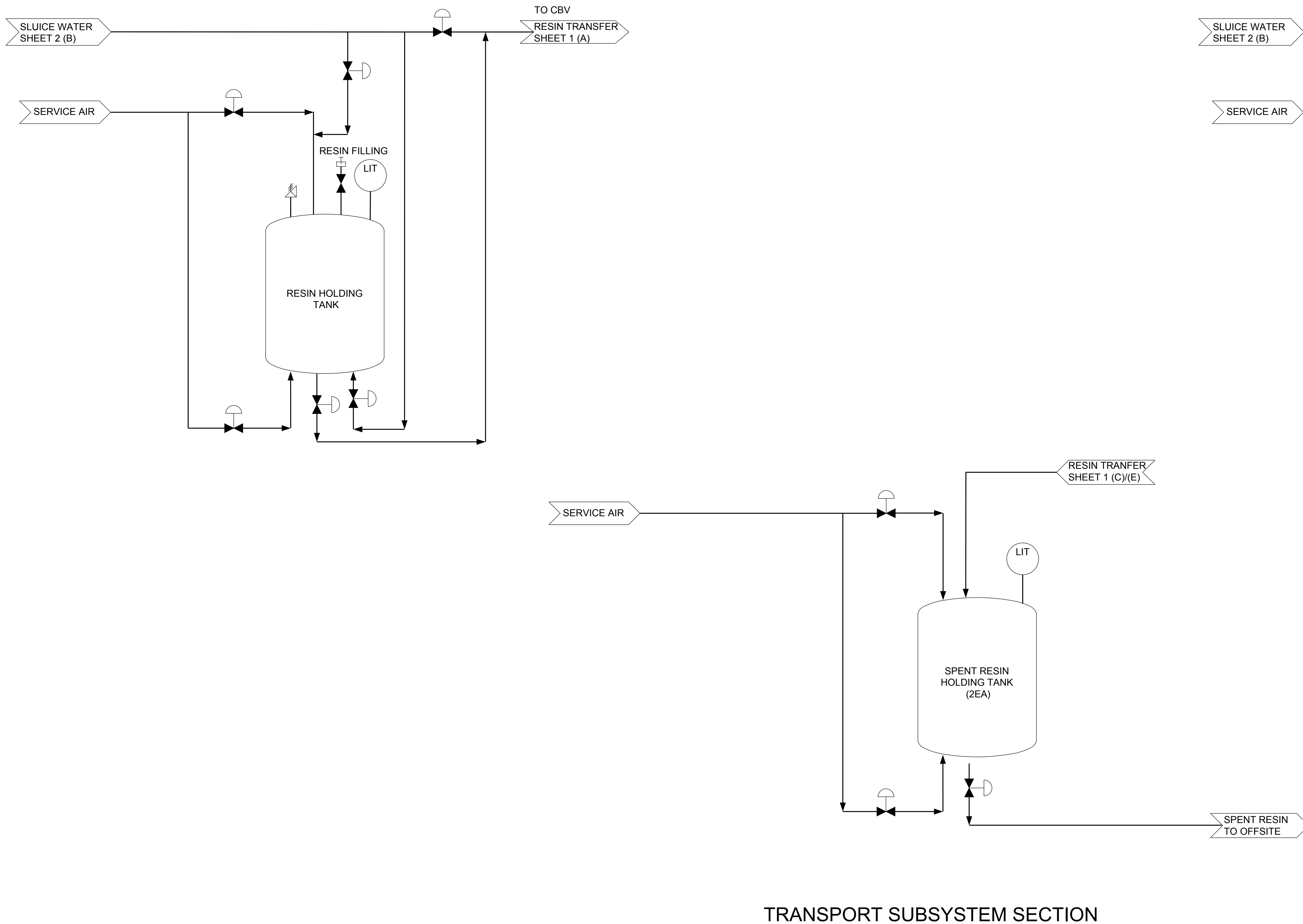

Figure 10.4.6-1 Condensate Polishing System Flow Diagram (2 of 2)

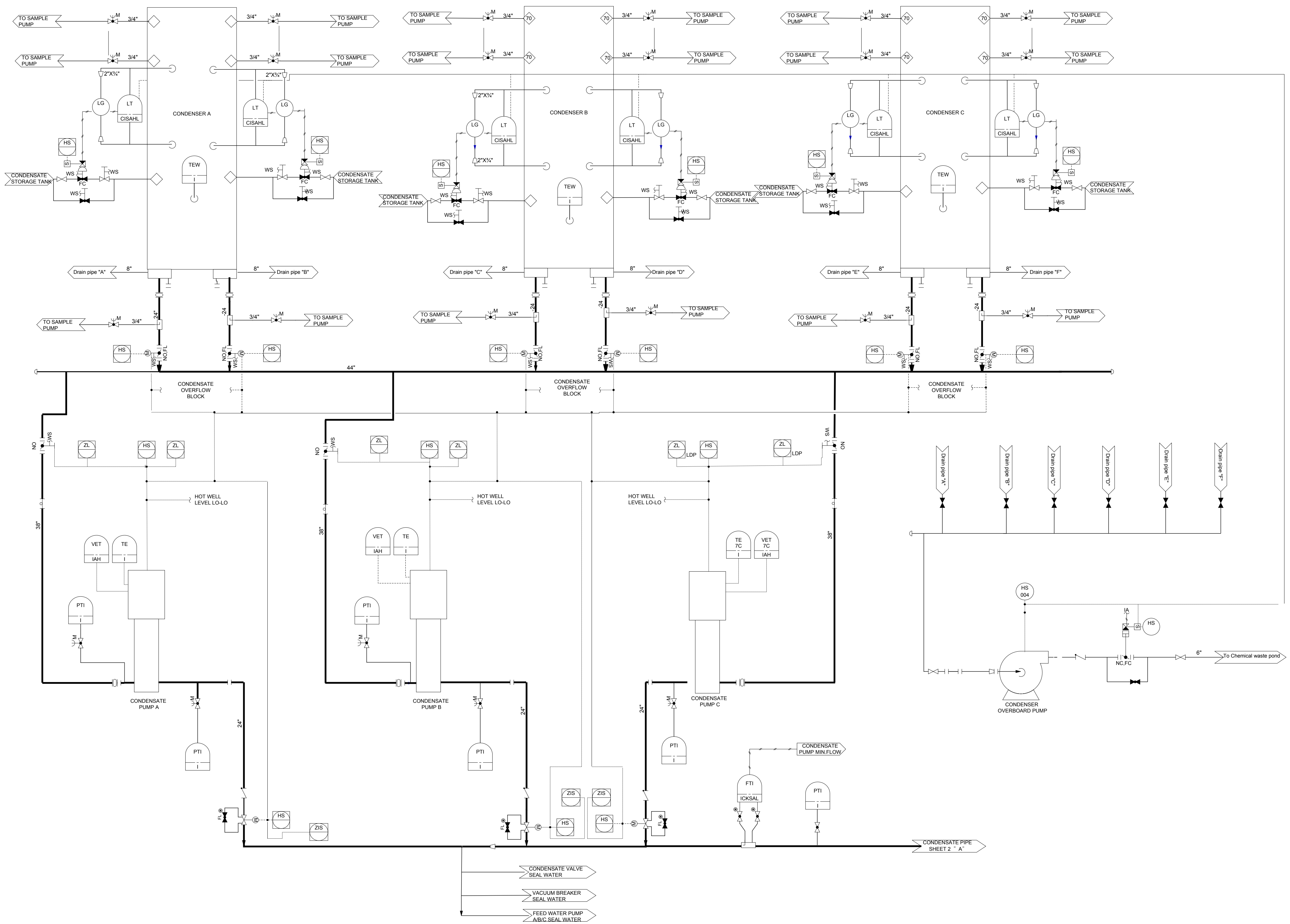

Figure 10.4.7-1 Condensate and Feedwater System Flow Diagram (1 of 11)

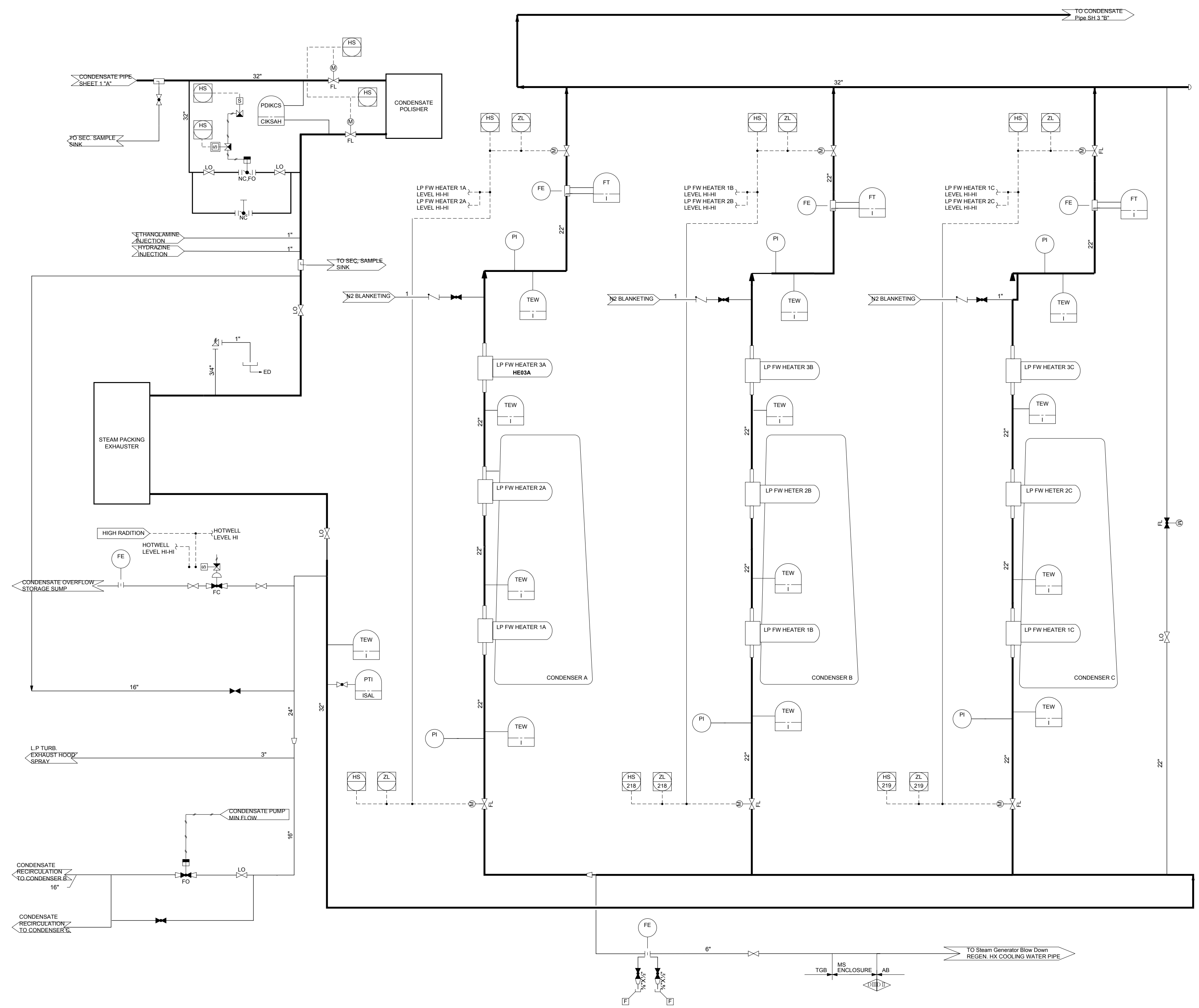

Figure 10.4.7-1 Condensate and Feedwater System Flow Diagram (2 of 11)

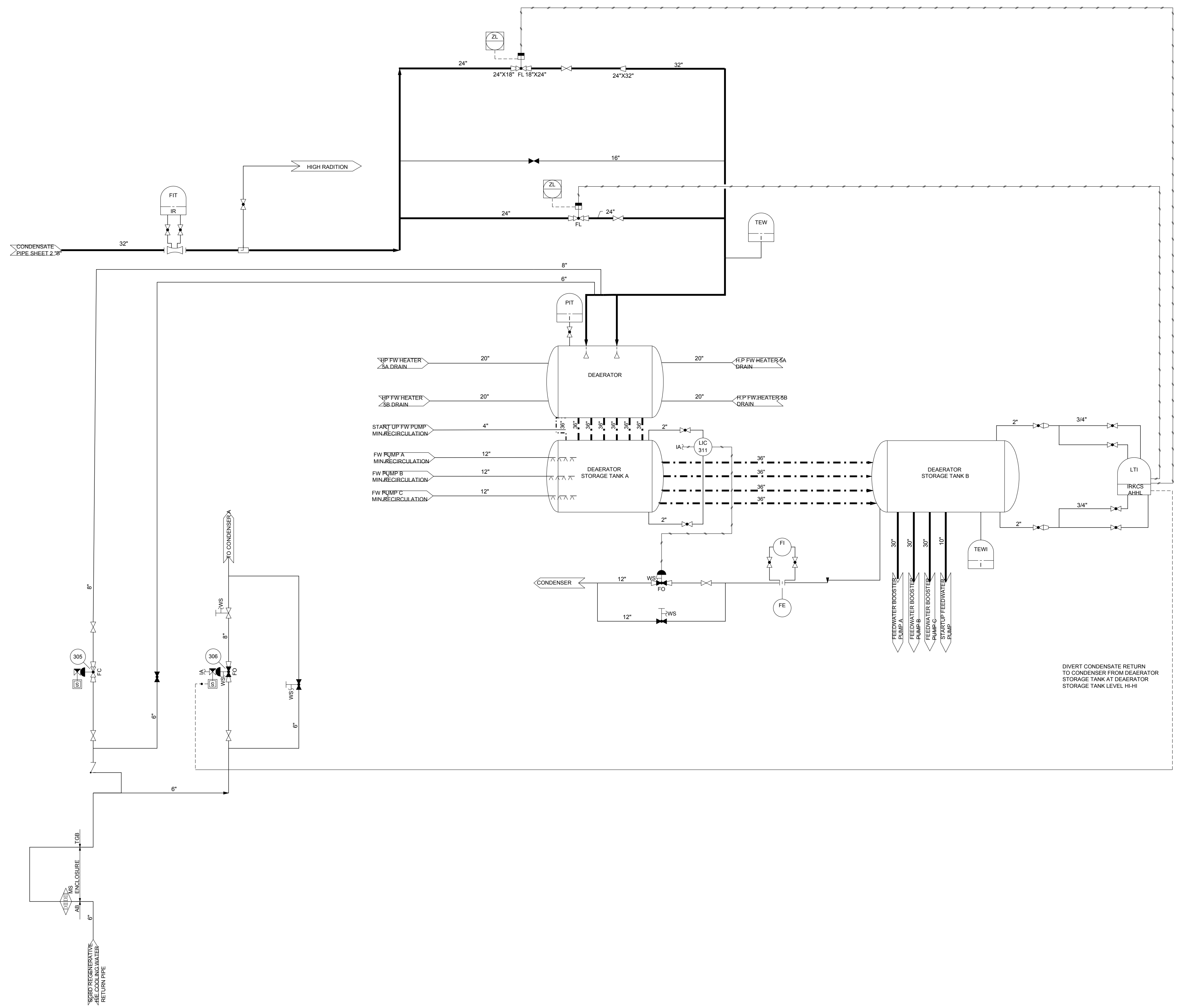

Figure 10.4.7-1 Condensate and Feedwater System Flow Diagram (3 of 11)

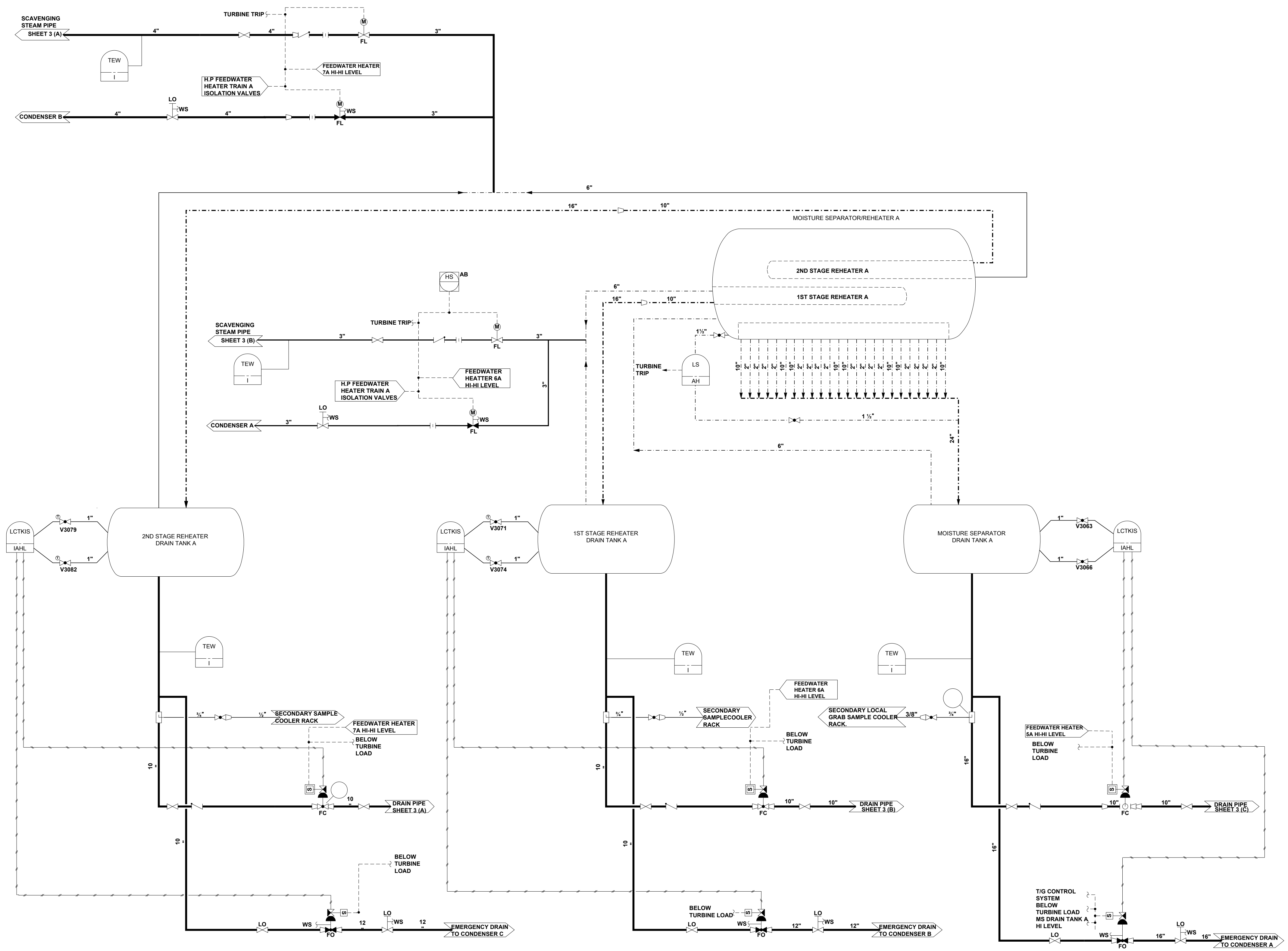

Figure 10.4.7-1 Condensate and Feedwater System Flow Diagram (4 of 11)

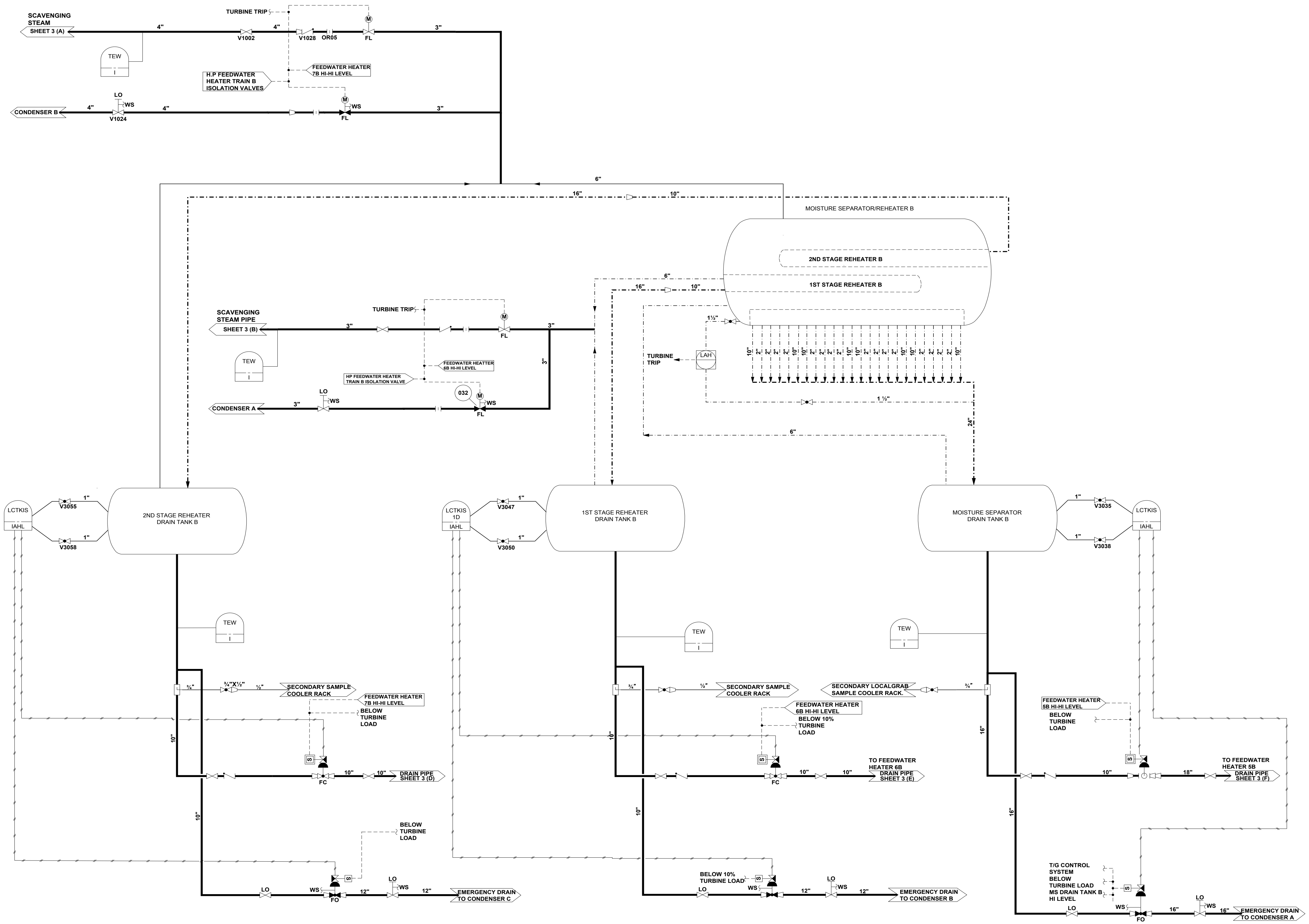

Figure 10.4.7-1 Condensate and Feedwater System Flow Diagram (5 of 11)

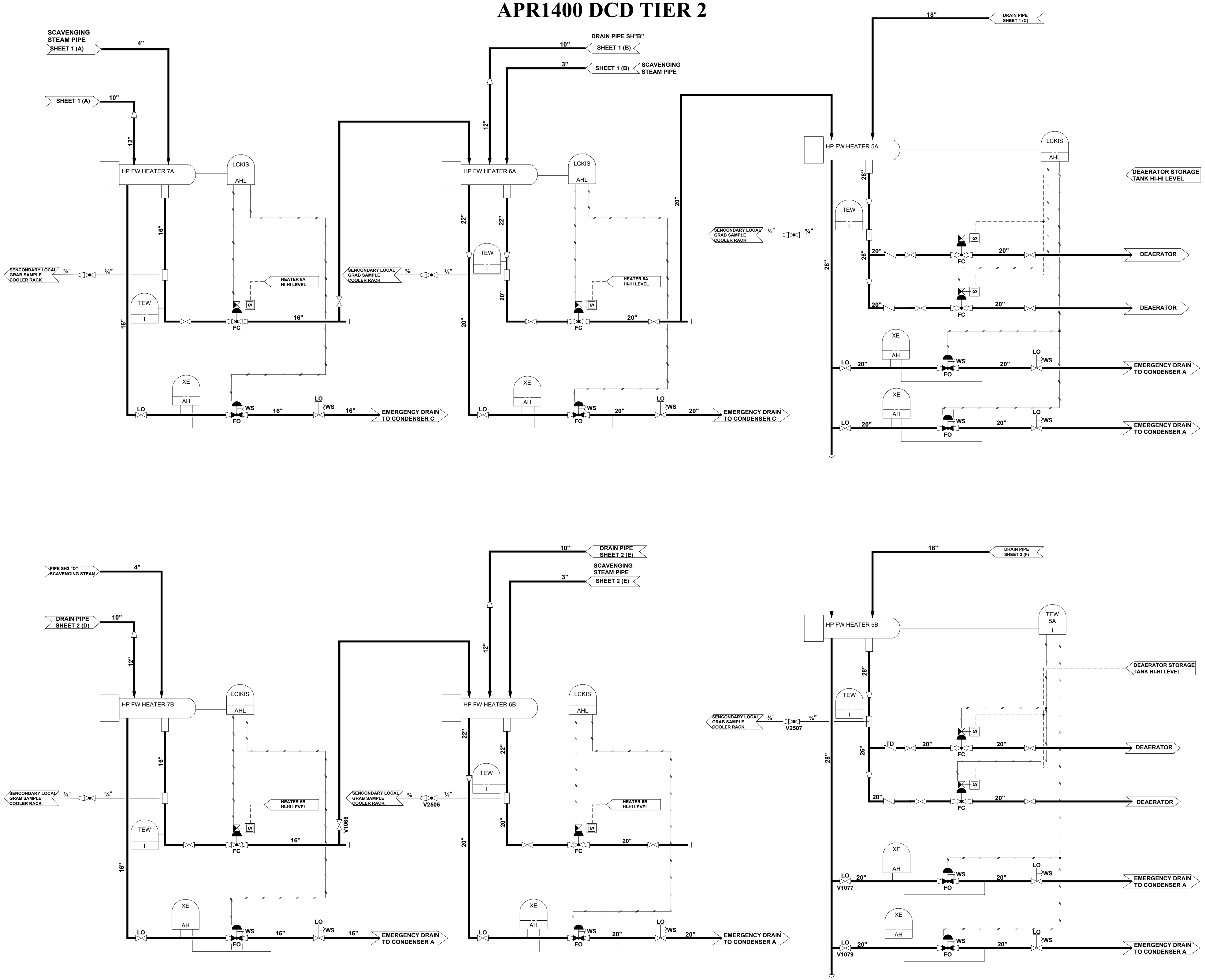

Figure 10.4.7-1 Condensate and Feedwater System Flow Diagram (6 of 11)

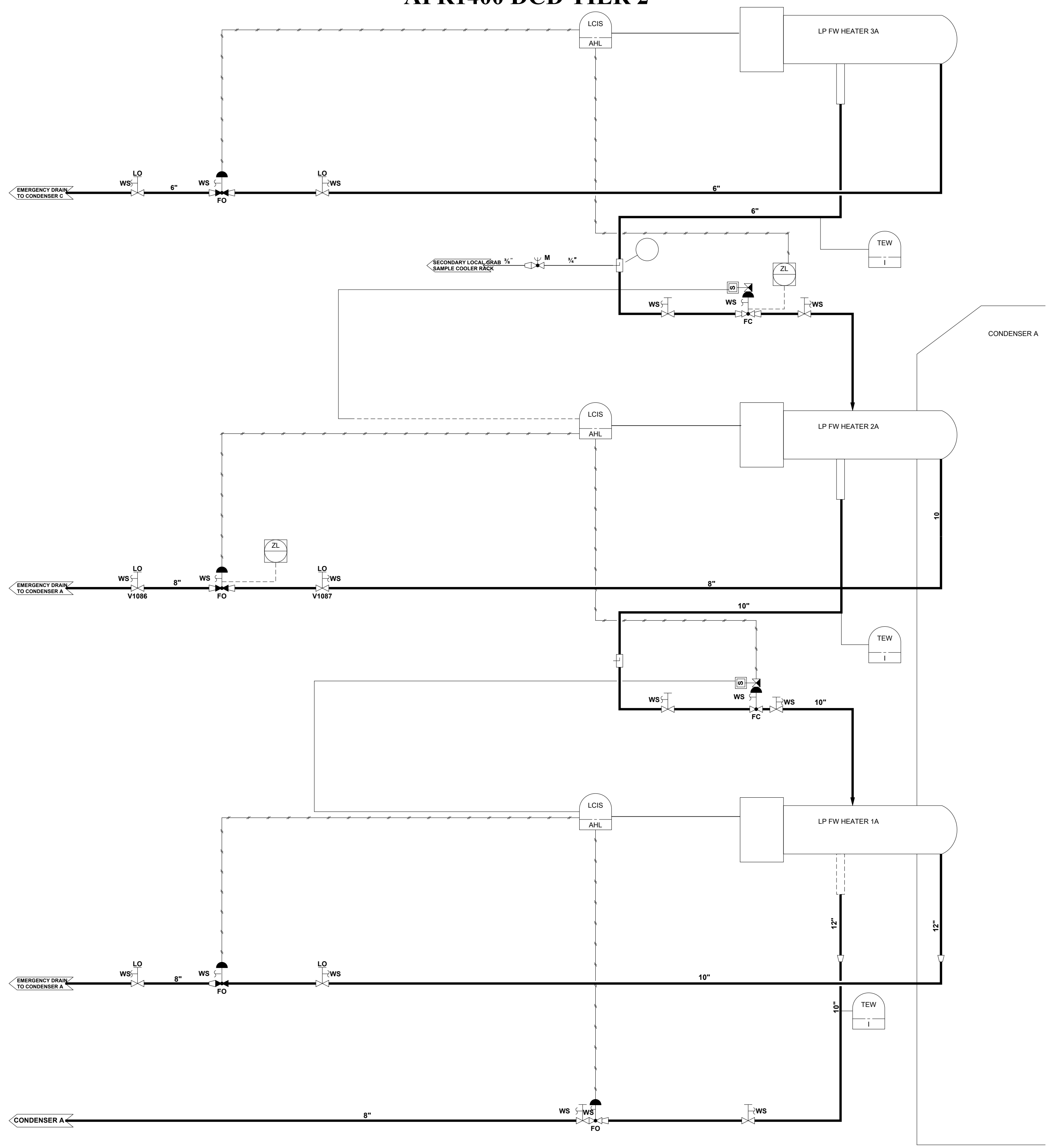

Figure 10.4.7-1 Condensate and Feedwater System Flow Diagram (7 of 11)

Figure 10.4.7-1 Condensate and Feedwater System Flow Diagram (8 of 11)

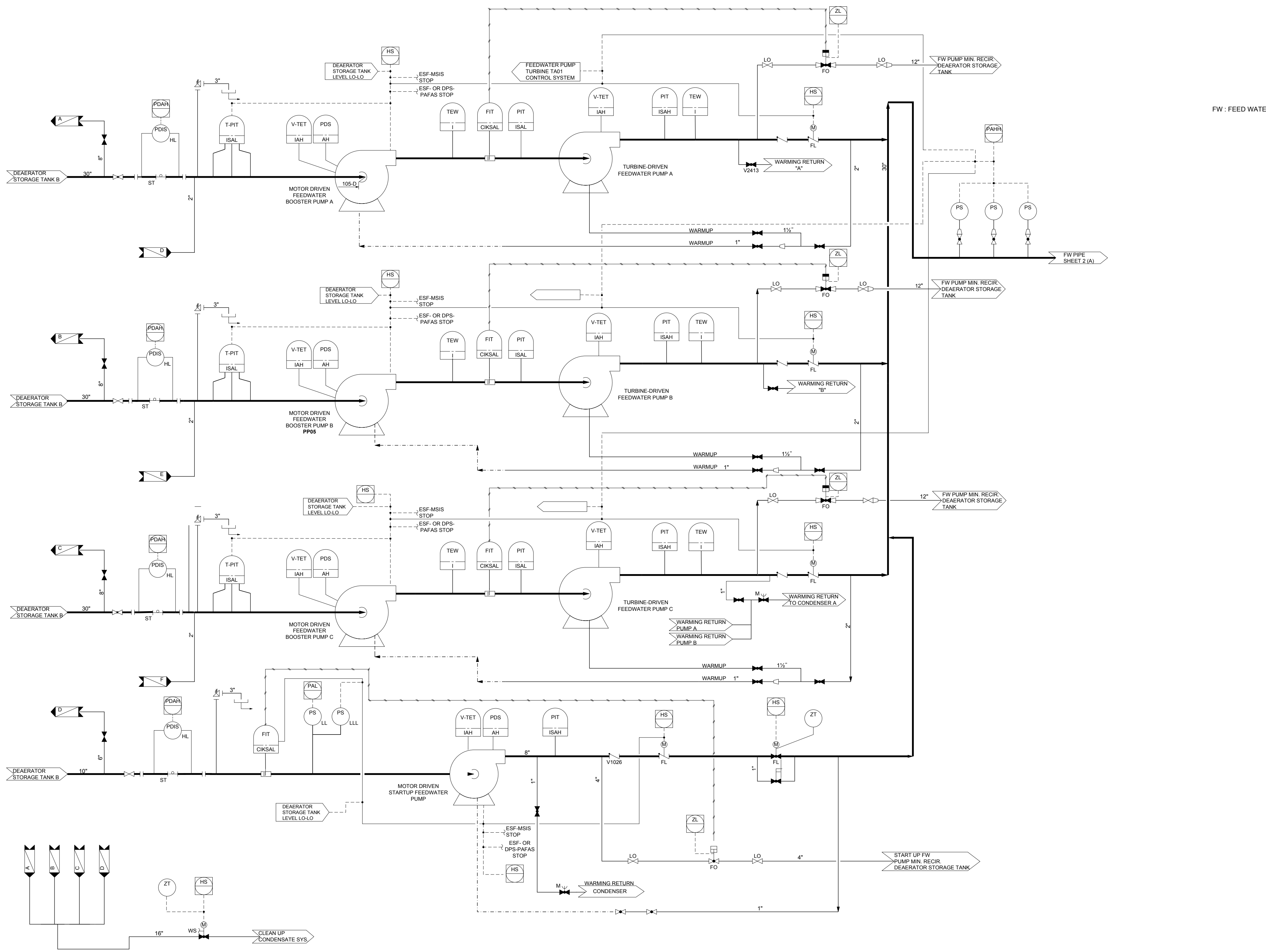

Figure 10.4.7-1 Condensate and Feedwater System Flow Diagram (9 of 11)

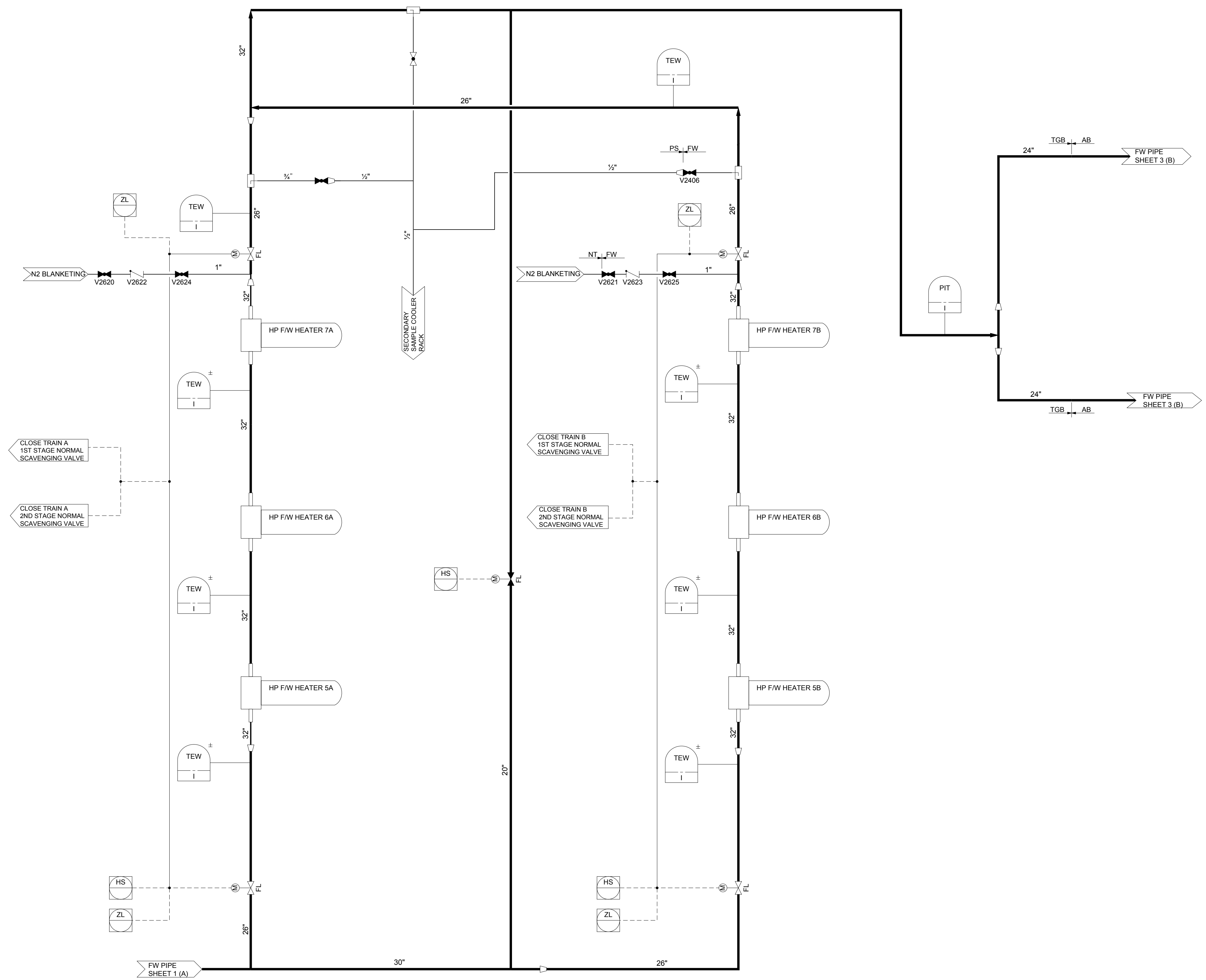

Figure 10.4.7-1 Condensate and Feedwater System Flow Diagram (10 of 11)

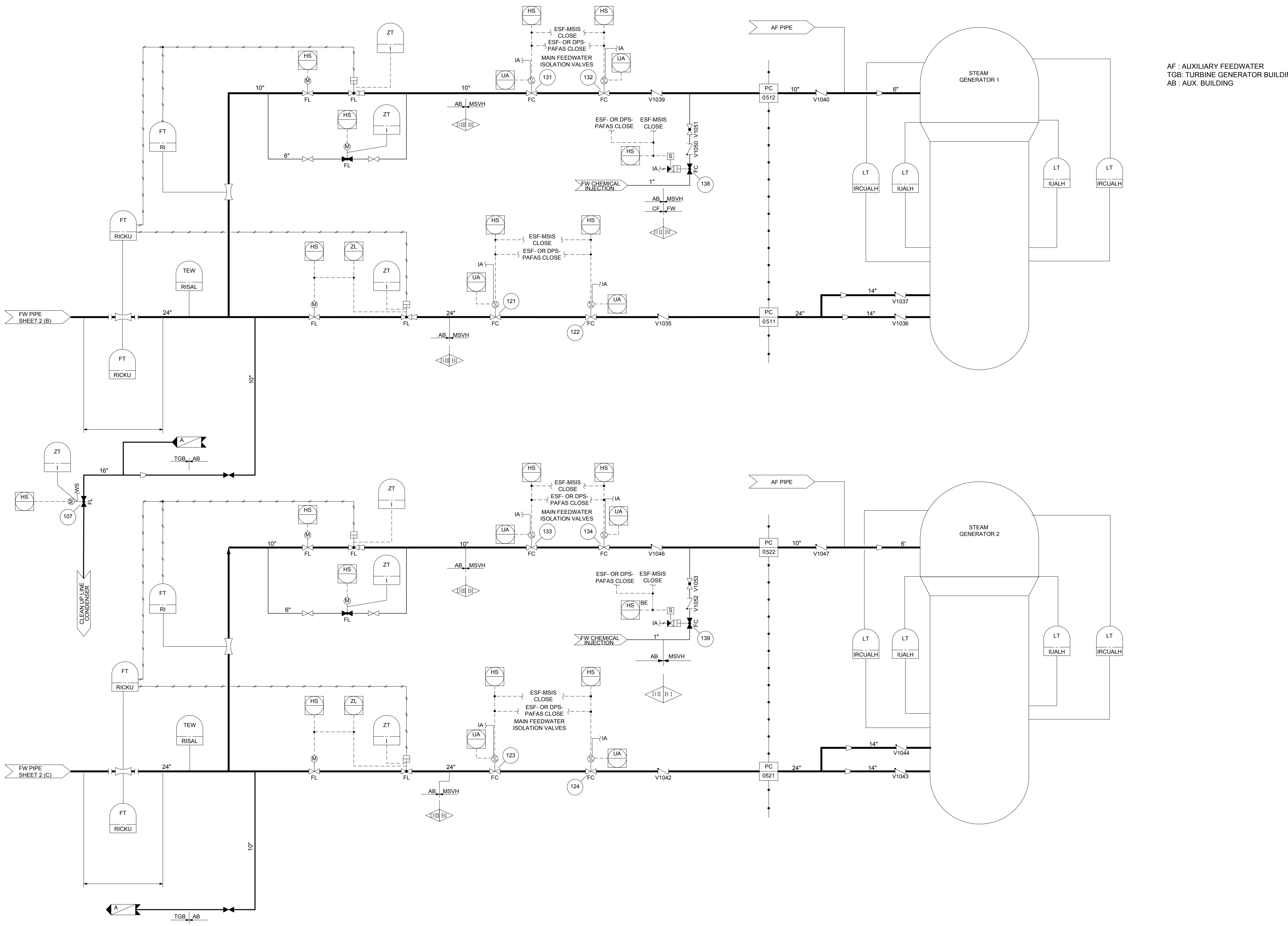

Figure 10.4.7-1 Condensate and Feedwater System Flow Diagram (11 of 11)

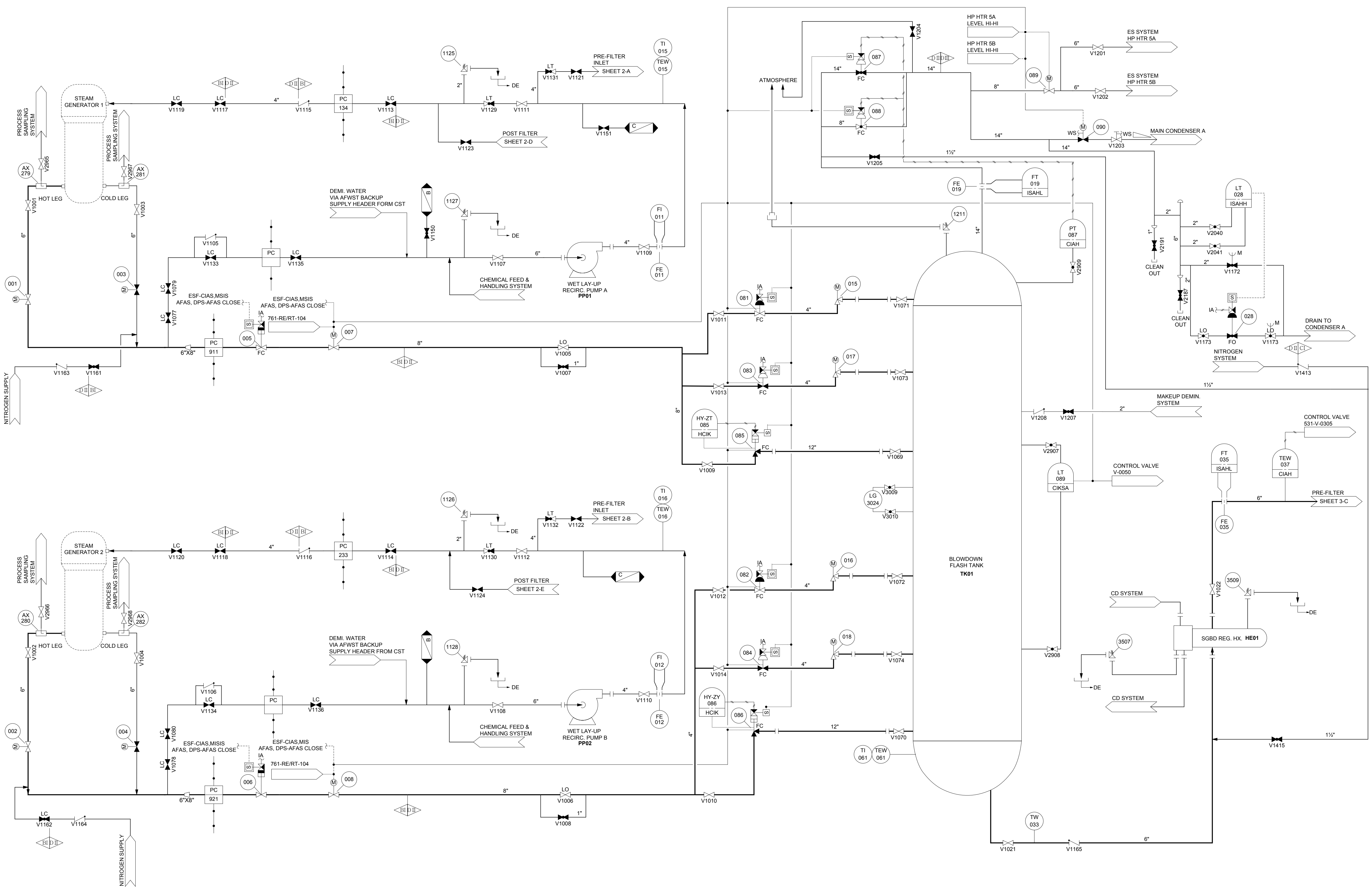

Figure 10.4.8-1 Steam Generator Blowdown System Flow Diagram (1 of 2)

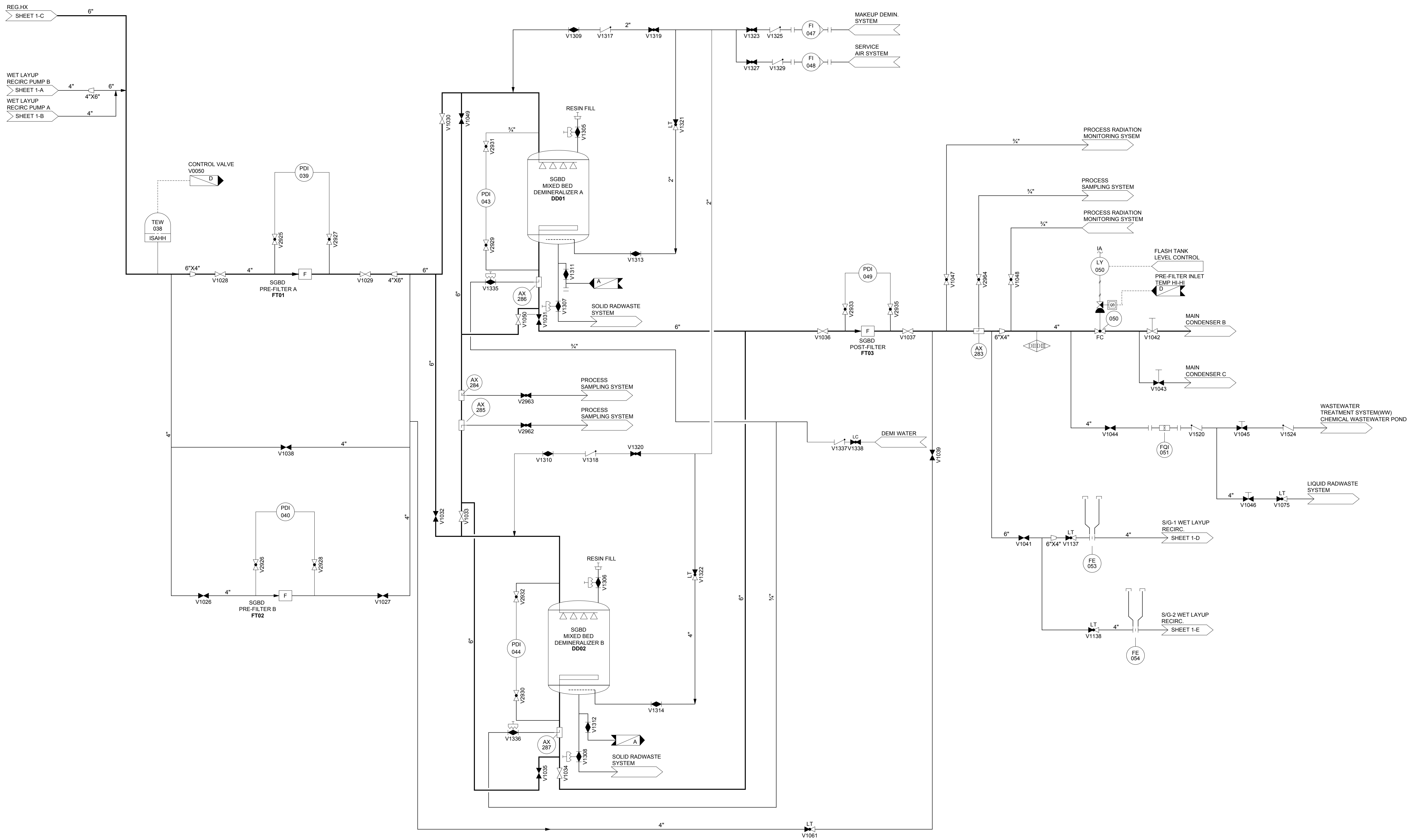

Figure 10.4.8-1 Steam Generator Blowdown System Flow Diagram (2 of 2)

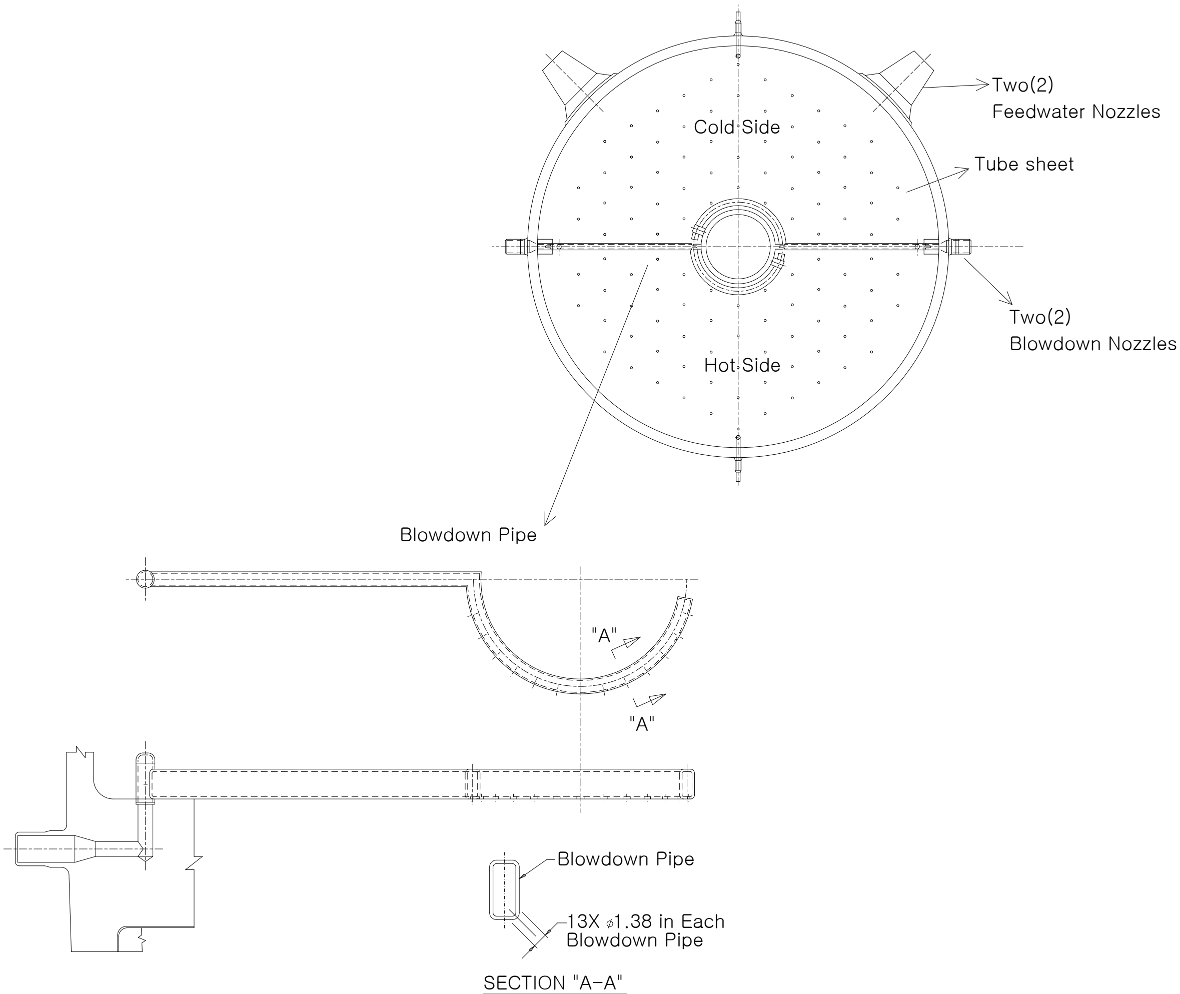

Figure 10.4.8-2 Concept of Central Blowdown

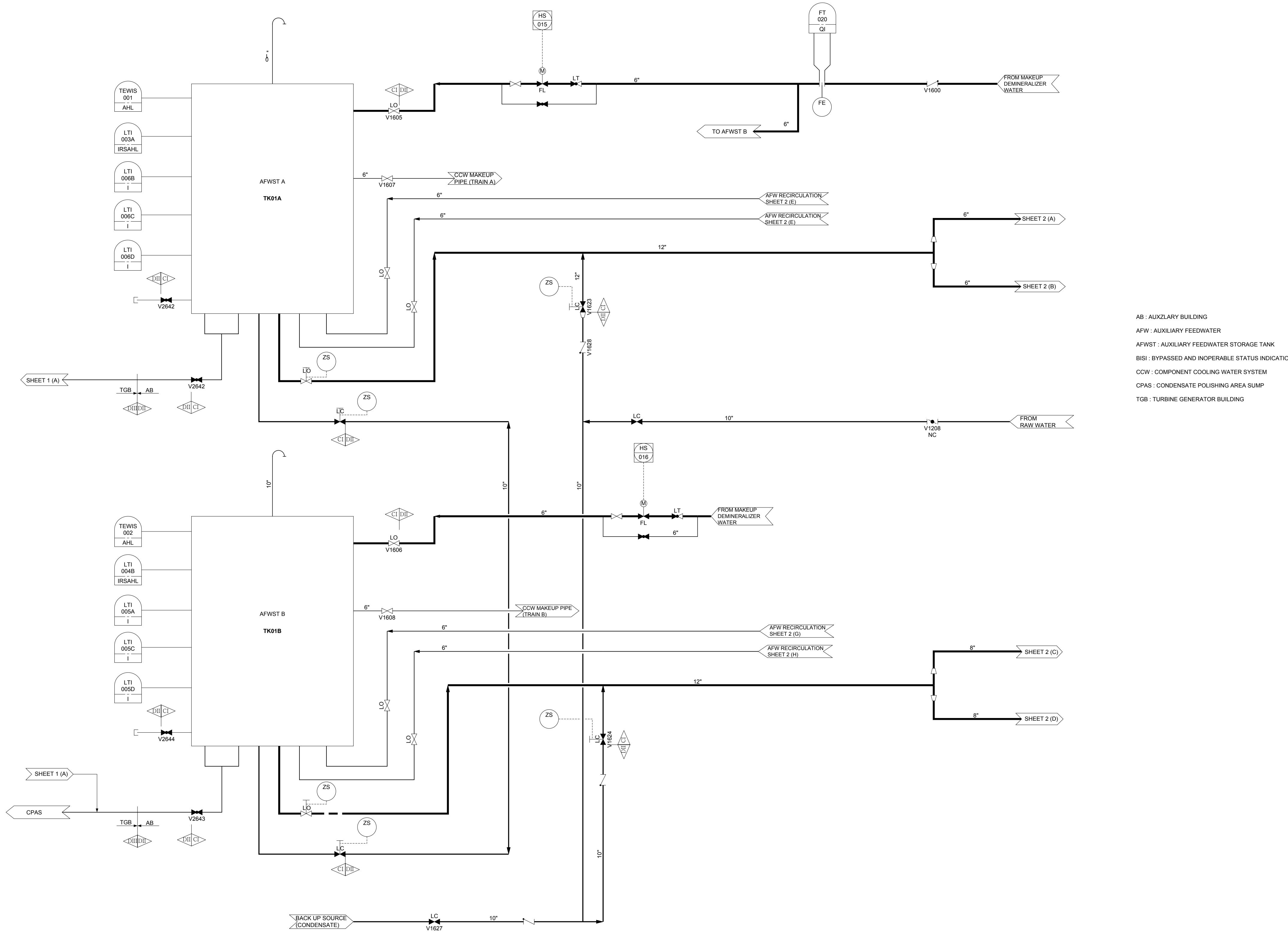

Figure 10.4.9-1 Auxiliary Feedwater System Flow Diagram (1 of 3)

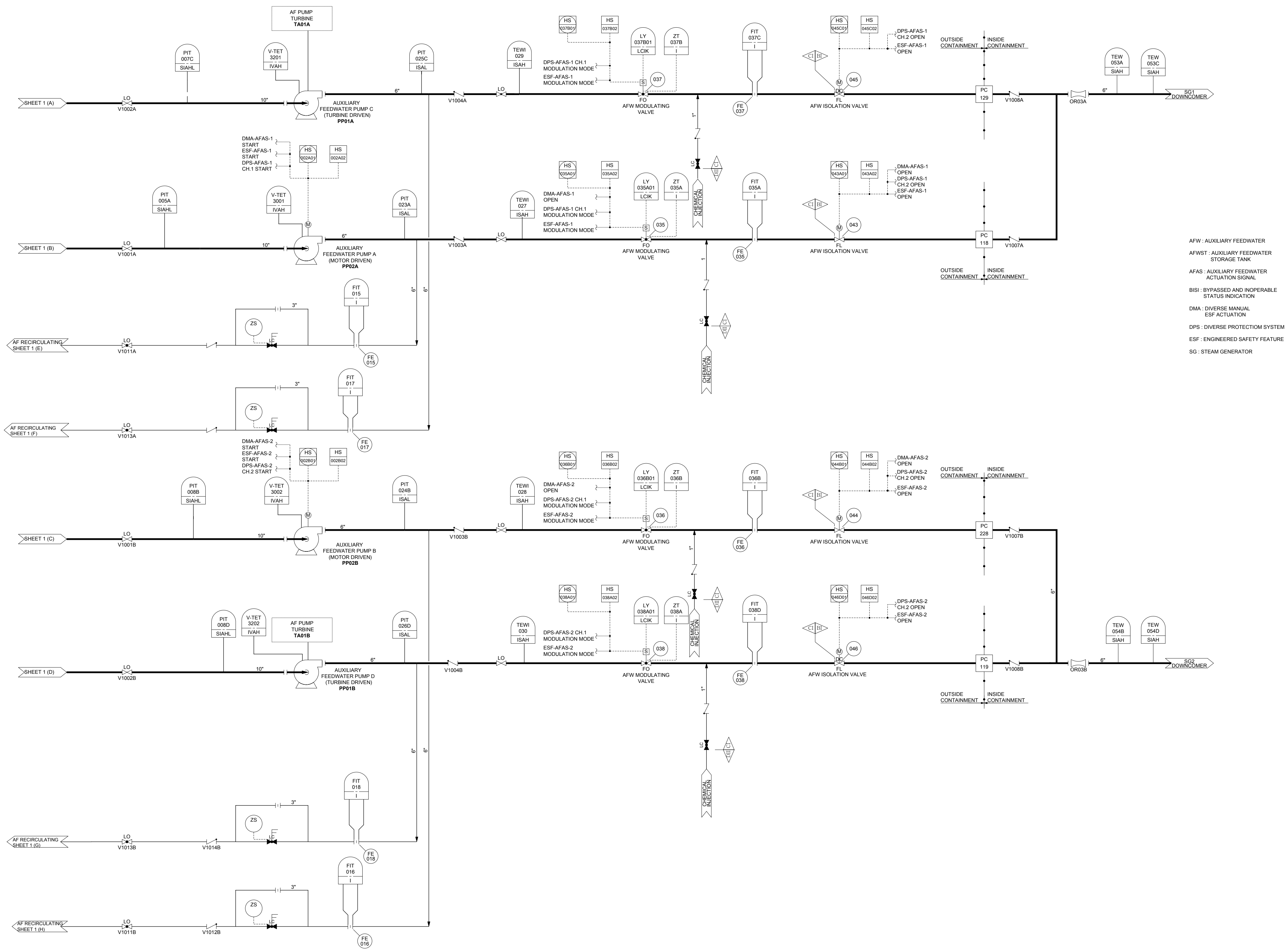

Figure 10.4.9-1 Auxiliary Feedwater System Flow Diagram (2 of 3)

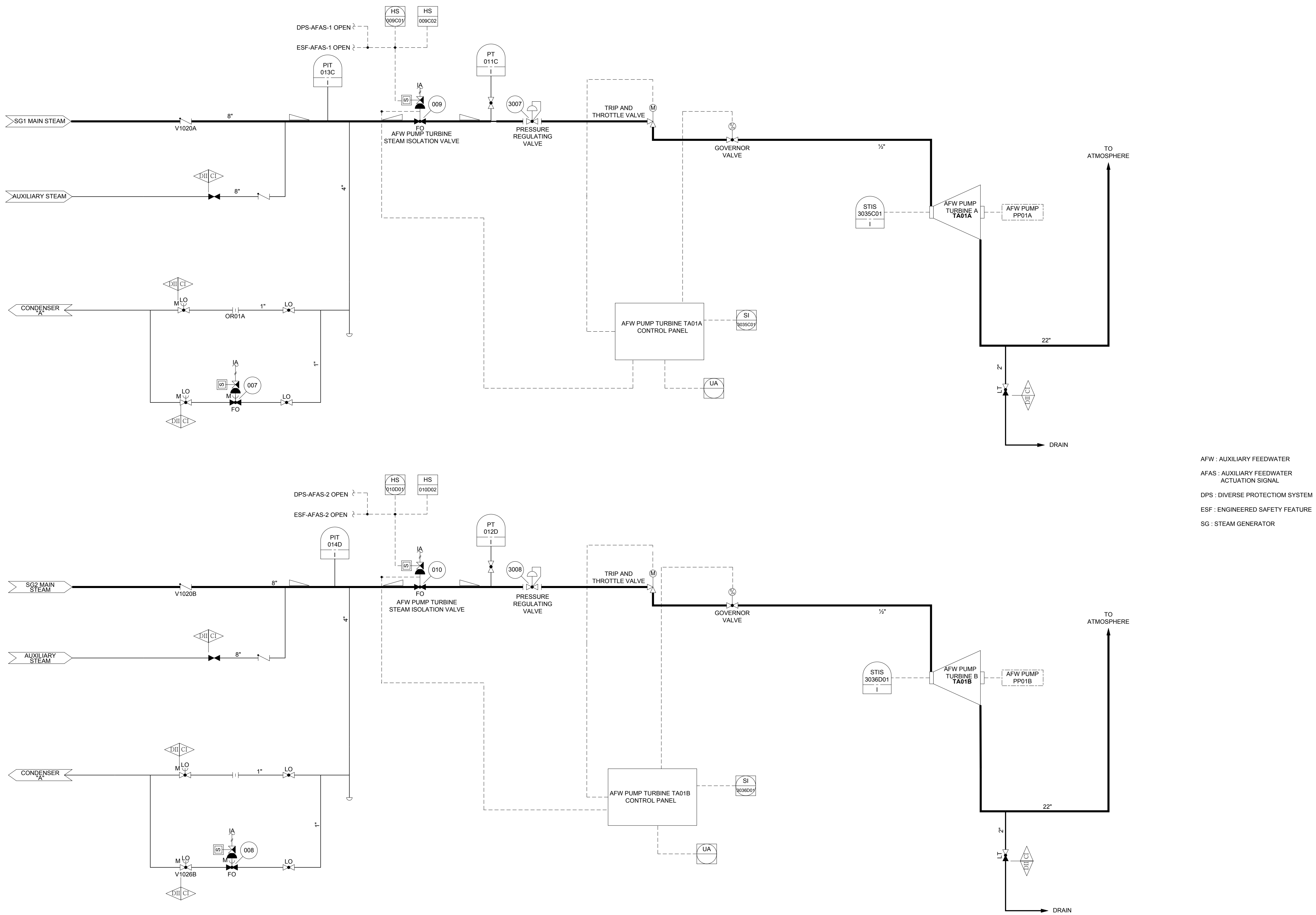

Figure 10.4.9-1 Auxiliary Feedwater System Flow Diagram (3 of 3)

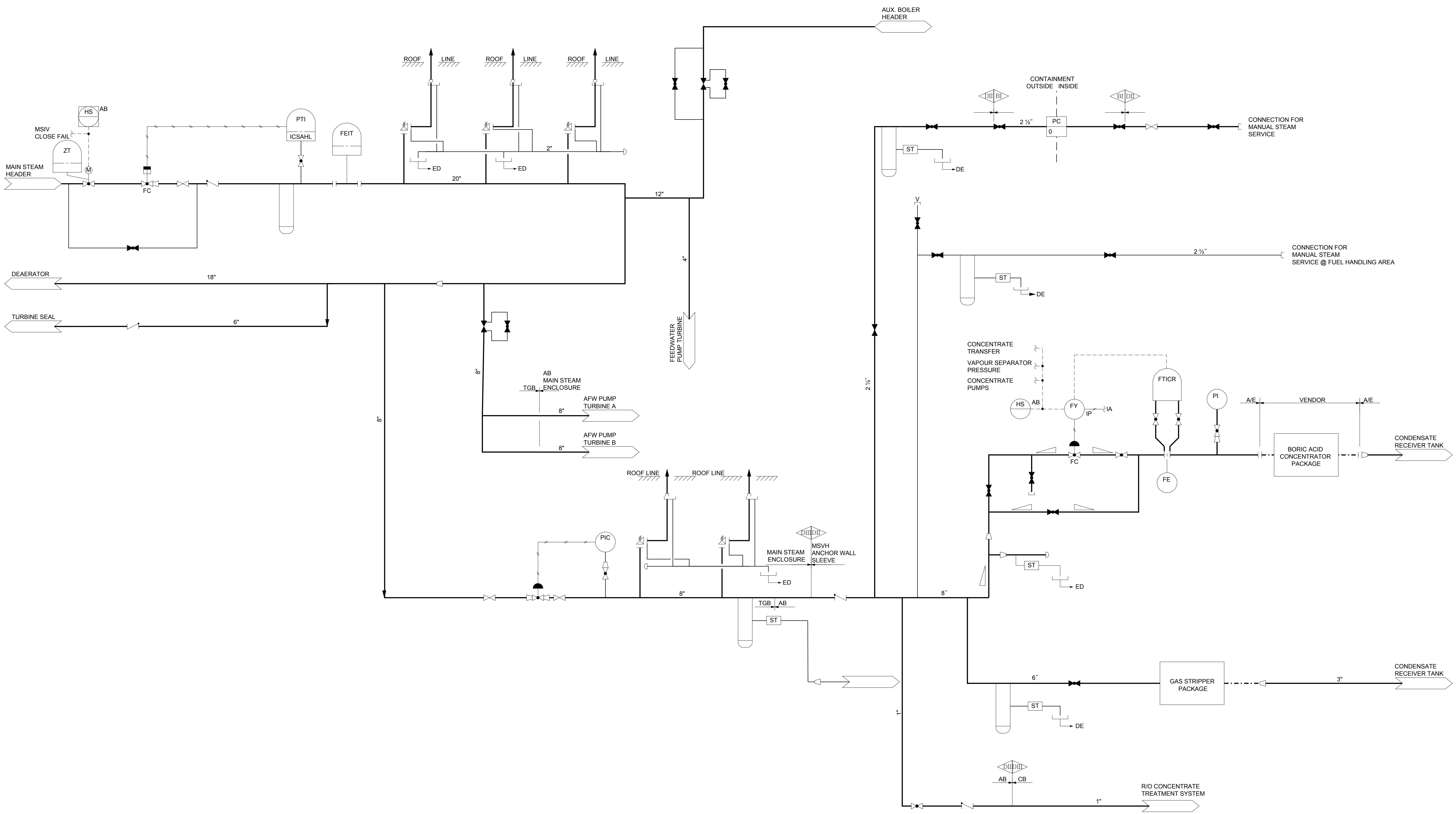

Figure 10.4.10-1 Auxiliary Steam System Flow Diagram (1 of 3)

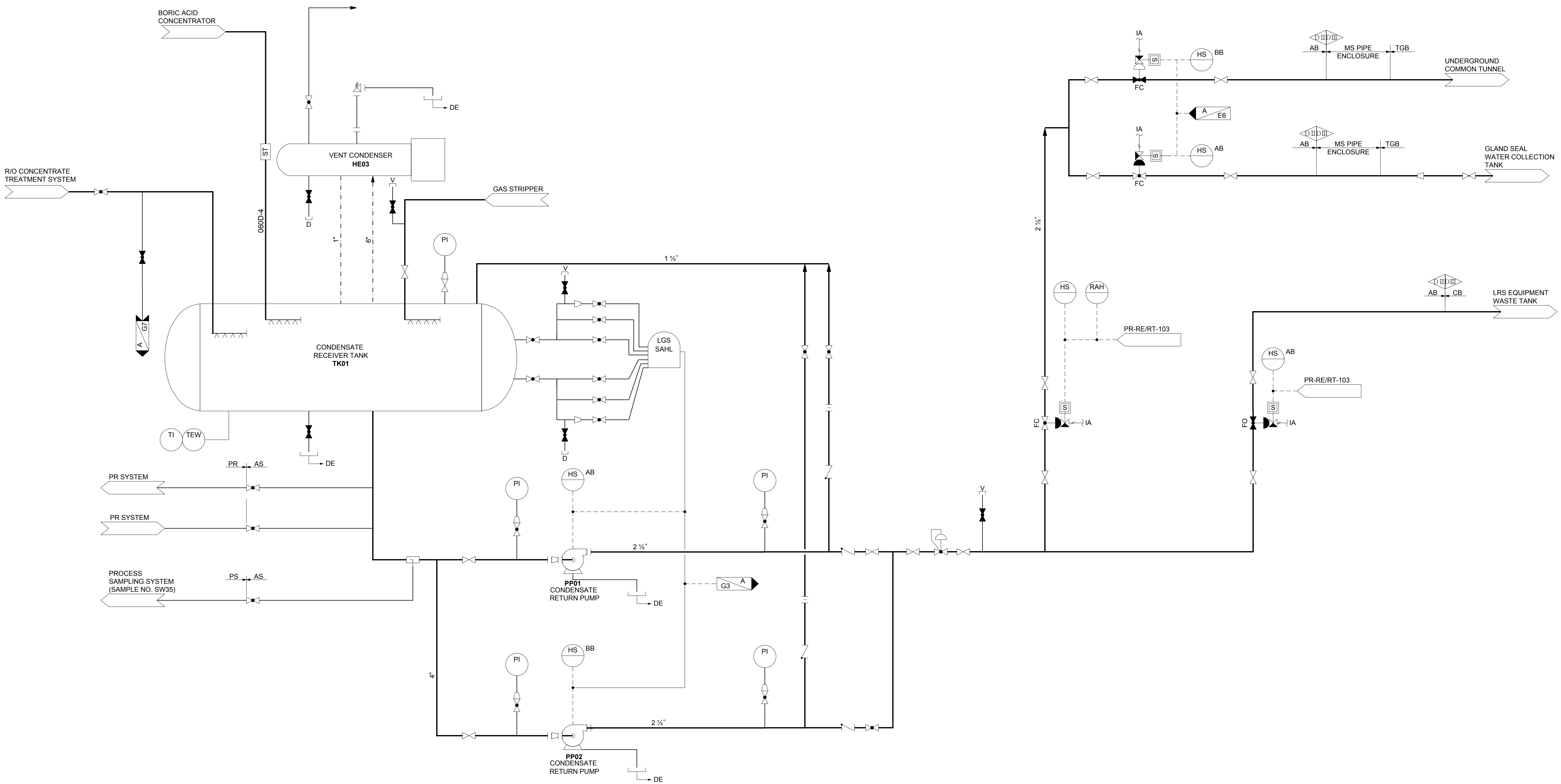

Figure 10.4.10-1 Auxiliary Steam System Flow Diagram (2 of 3)

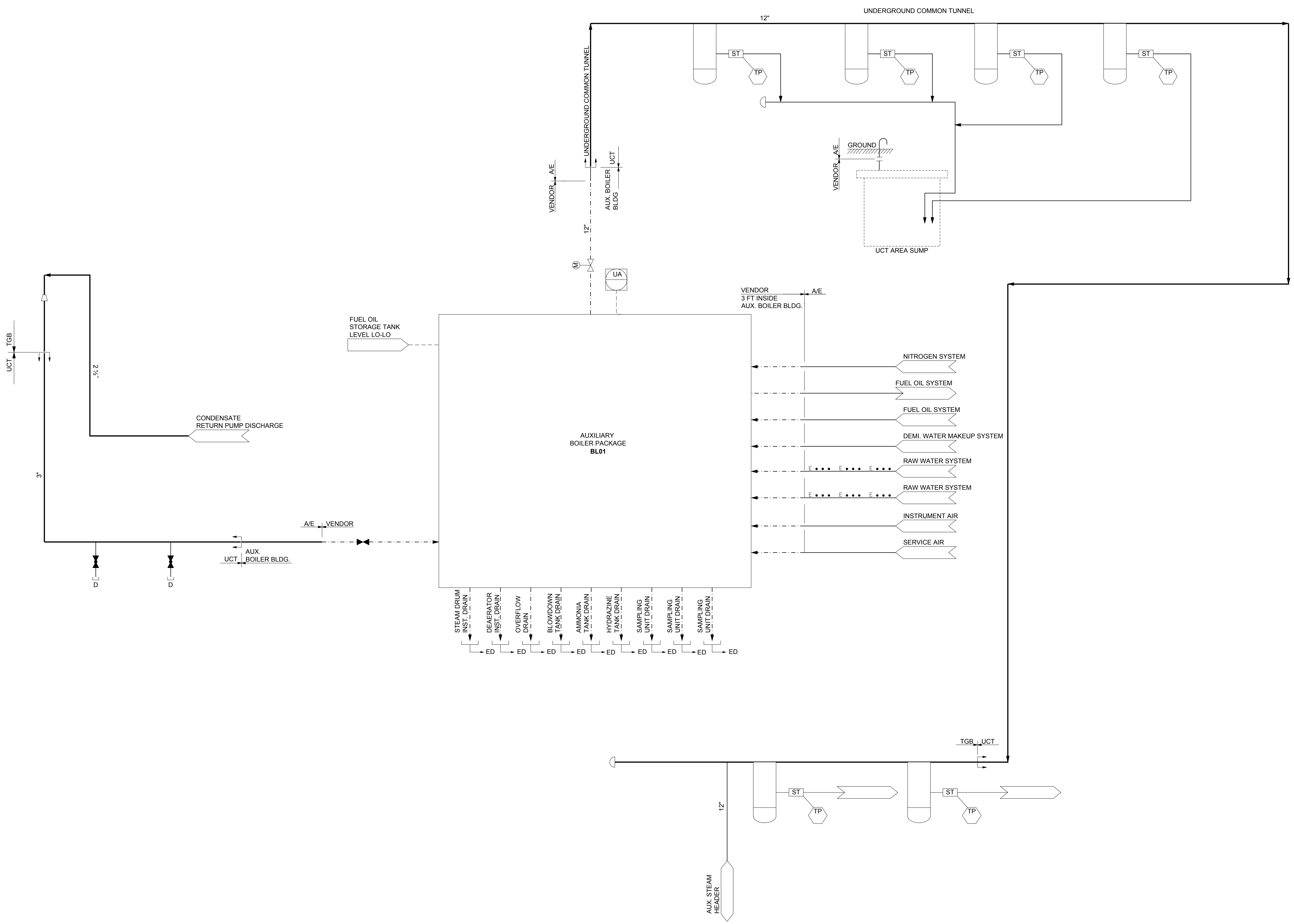

Figure 10.4.10-1 Auxiliary Steam System Flow Diagram (3 of 3)