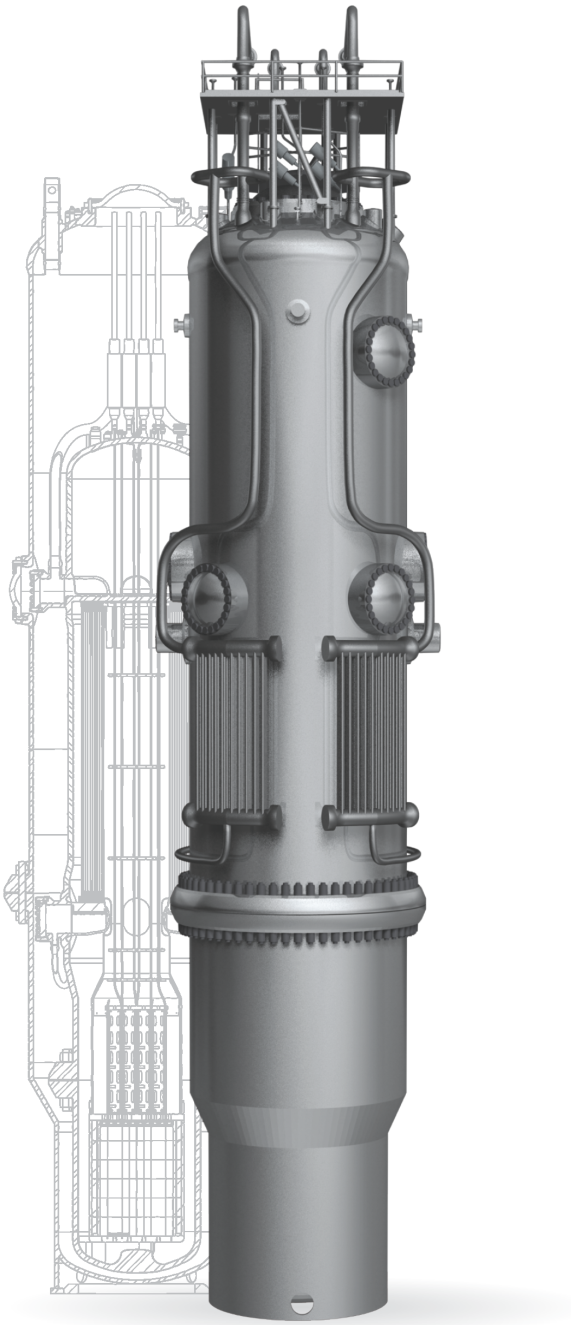

NuScale Standard Plant
Design Certification Application

Chapter Ten

Steam and Power Conversion System

PART 2 - TIER 2

Revision 0
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CHAPTER 10 STEAM AND POWER CONVERSION SYSTEM

10.1 Summary Description

The steam and power conversion system removes and directs heat energy from the reactor coolant system. The heat energy from the NuScale Power Module is transferred from the primary coolant by two helical-coil steam generators to convert the secondary coolant to steam. This steam energy is then converted to electrical power in the turbine generator. Each NuScale Power Module has its own steam and power conversion system. The steam and power conversion system has no safety-related function.

The steam and power conversion system includes the pipe, fittings, valves, and instruments from (and including) the removable pipe spools at the containment system main steam isolation valves (MSIVs), to (and including) the removable pipe spools at the containment system feedwater isolation valves. The steam and power conversion system is comprised of the following components and process systems:

- turbine generator system (TGS) (Section 10.2)
- main steam system (MSS) (Section 10.3)
- main condenser (MC) (Section 10.4.1)
- condenser air removal system (CARS) (Section 10.4.2)
- turbine gland sealing system (Section 10.4.3)
- turbine bypass system (Section 10.4.4)
- circulating water system (CWS) (Section 10.4.5)
- condensate polishing system (CPS) (Section 10.4.6)
- condensate and feedwater system (CFWS) (Section 10.4.7)
- auxiliary boiler system (ABS) (Section 10.4.10)
- feedwater treatment system (FWT) (Section 10.4.11)

Table 10.1-1 provides the major system operating parameters at rated thermal power and turbine generator design data.

Figure 10.1-1 provides a power conversion system block flow diagram of a NuScale Power Module. Figure 10.1-2 provides a heat balance diagram at rated thermal power. Figure 10.1-3 provides a heat balance diagram at stretch power (valves wide open).

10.1.1 General Description

During normal operation, steam generated in the two helical-coil steam generators is supplied by the MSS to the turbine through the turbine stop and control valves which regulate steam flow.

The turbine is a single-inlet design 10-stage condensing steam turbine with three uncontrolled extractions, one stop valve, and a steam chest with multiple inlet control

valves. The generator is a three-phase water to air cooled generator, directly coupled to the turbine with an operating speed provided in Table 10.1-1.

After expanding across the high-pressure and low-pressure turbine blading, the condenser receives the exhaust steam from the turbine.

The MC transfers the heat rejected in the cycle to the circulating water system. The MC operates at a vacuum maintained by the CARS. Extraction steam from the turbine is routed to three feedwater heaters (FWHs) where it is condensed. The FWHs are arranged to cascade the drains from the higher-pressure heaters to the lower-pressure heaters, returning the condensate through the lower-pressure FWH to the MC.

The condensate pumps take suction from the MC hotwell. From the condensate pumps, the feedwater is sent through the condensate polishers, gland steam condenser, the low-pressure and intermediate-pressure FWHs, and to the feedwater pumps. From the feedwater pumps, the feedwater passes through the high-pressure FWH and returns through the main feedwater lines to the steam generator (SG).

Water quality in the steam-water cycle is maintained by the feedwater treatment subsystem in conjunction with the condensate polishing system. The condensate storage tank supplies makeup water for the steam cycle. The process sampling system monitors feedwater chemistry during normal operations.

The unique SG design minimizes water hammer as discussed in Section 5.4.1.

10.1.2 Protective Features

10.1.2.1 Loss of External Electrical Load or Turbine Trip

In the event of a loss of external electrical load or turbine trip, steam is automatically dumped to the MC through the turbine bypass valve. Load rejection capabilities of the steam and power conversion system are further described in Section 10.3 and Section 10.4.4. See Section 15.2 for the associated safety analysis.

10.1.2.2 Overpressure Protection

Overpressure protection of the steam and power conversion system is provided by main steam safety valves located on the MSS header, in accordance with the ASME BPV Code, Section III. The valves are described in Section 10.3.2.

10.1.2.3 Loss of Main Feedwater Flow

The decay heat removal system is automatically initiated by the engineered safety features actuation system for postulated transients in which a loss of normal cooling has occurred, including loss of main feedwater. For plant accidents and transients that result in a loss of feedwater to both of the steam generators, the decay heat removal system cools the reactor coolant system. This event is further addressed in Section 10.4.7 and Section 15.2.7.

10.1.2.4 Turbine Overspeed Protection

Turbine overspeed protection is provided by two independent and diverse electronic overspeed protection features. The turbine stop and control valves, and the extraction steam block and non-return valves close upon actuation of the emergency trip system within a time period to preclude unsafe turbine overspeed. Additionally, the valve arrangements and valve closure times are such that a failure of a single valve to close will not result in unsafe turbine overspeed in the event of a trip signal. Turbine overspeed protection is further discussed in Section 10.2.2.

10.1.2.5 Turbine Missile Protection

Turbine rotor integrity minimizes the probability of generating turbine missiles and is discussed in Section 10.2.3. The combination of turbine rotor inspections and the low probability of turbine missile generation is sufficient to protect SSC from the adverse effects of turbine missiles. Turbine missiles are discussed in Section 3.5.

10.1.2.6 Radioactivity Protection

Under normal operating conditions, there are no significant radioactive contaminants present in the steam and power conversion system. However, it is possible for the system to become contaminated through primary-to-secondary side steam generator tube leakage or in the unlikely event of a steam generator tube failure. Radiation monitors in the MSS and the CARS alarm in the control room for operator action on a high radiation signal. Primary-to-secondary side leakage is specified in the Technical Specifications.

10.1.2.7 Flow-Accelerated Corrosion Protection

The MSS and feedwater system piping is designed considering the effects of flow-accelerated corrosion and erosion/corrosion. Erosion/corrosion resistant chromium-molybdenum material has been selected for piping downstream of the MSIVs. The feedwater system piping is also designed with chromium-molybdenum to avoid erosion damage.

The process sampling system provides chemistry monitoring of the MSS and FWS for corrosion products and other contaminants as discussed in Section 10.3.

Table 10.1-1: Major Steam and Power Conversion System Parameters and Turbine-Generator Design Data

Description	Design Parameter	Nominal Value
Main Steam System		
	Steam flow (full power)	532,100 lbm/hr
	Normal steam pressure	500 psia
	Normal steam temperature	575°F
	Design pressure upstream / downstream of the secondary MSIVs	2100 psia / 1000 psia
	Design temperature	650°F
	Normal feedwater temperature	300°F
Turbine Generator Design Data		
	Type	Single, 10-stage condensing uncontrolled extraction
	Operating speed	3600 rpm
	Phase/frequency	3PH/60Hz/13.8kV
	Power factor	0.85 p.f.
	Estimated power	57,502 kVA
	Generator power output (a)	50 MWe

Notes: (a) Electrical output dependent on environmental conditions.

Figure 10.1-1: Power Conversion System Block Flow Diagram

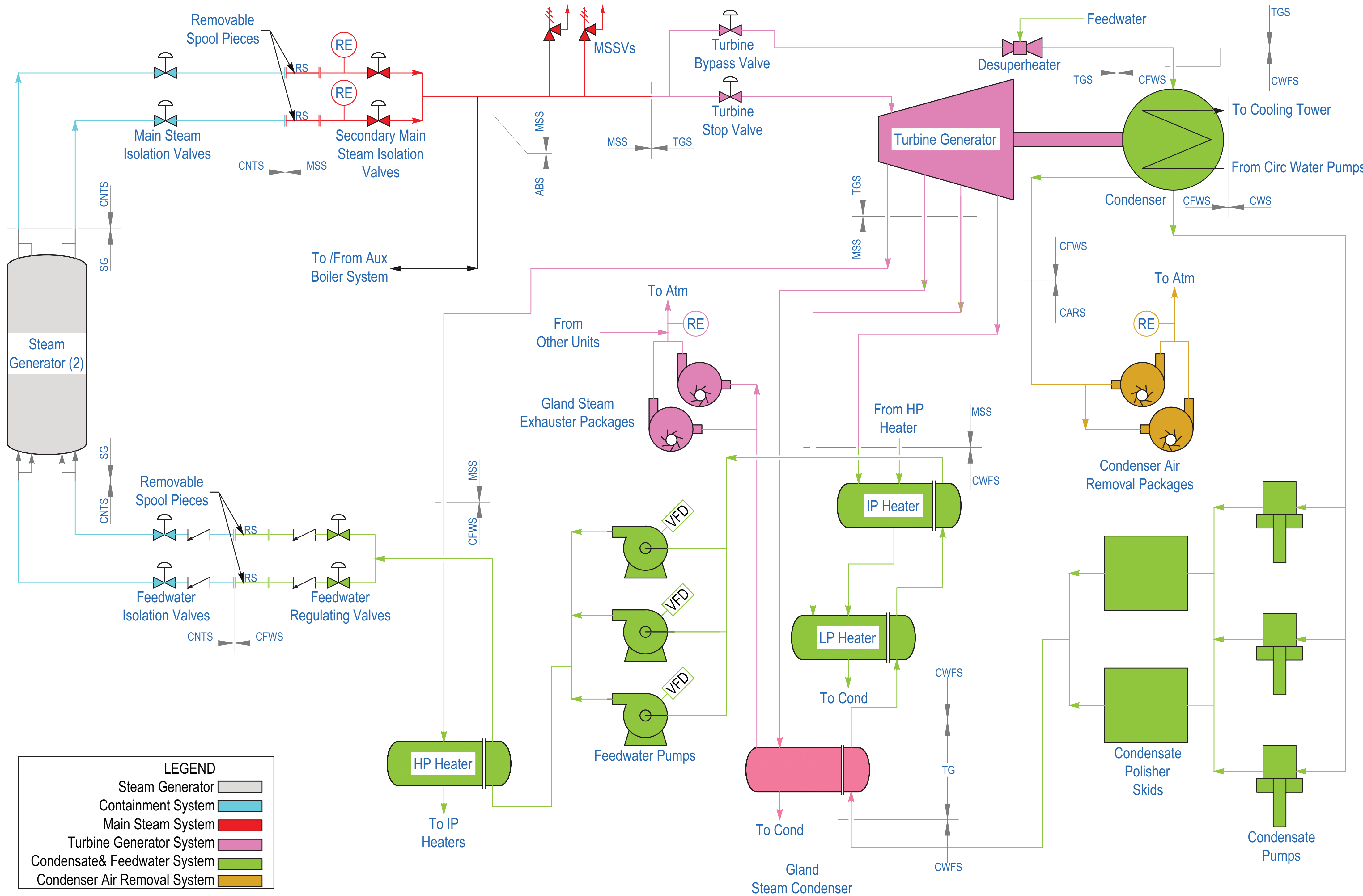
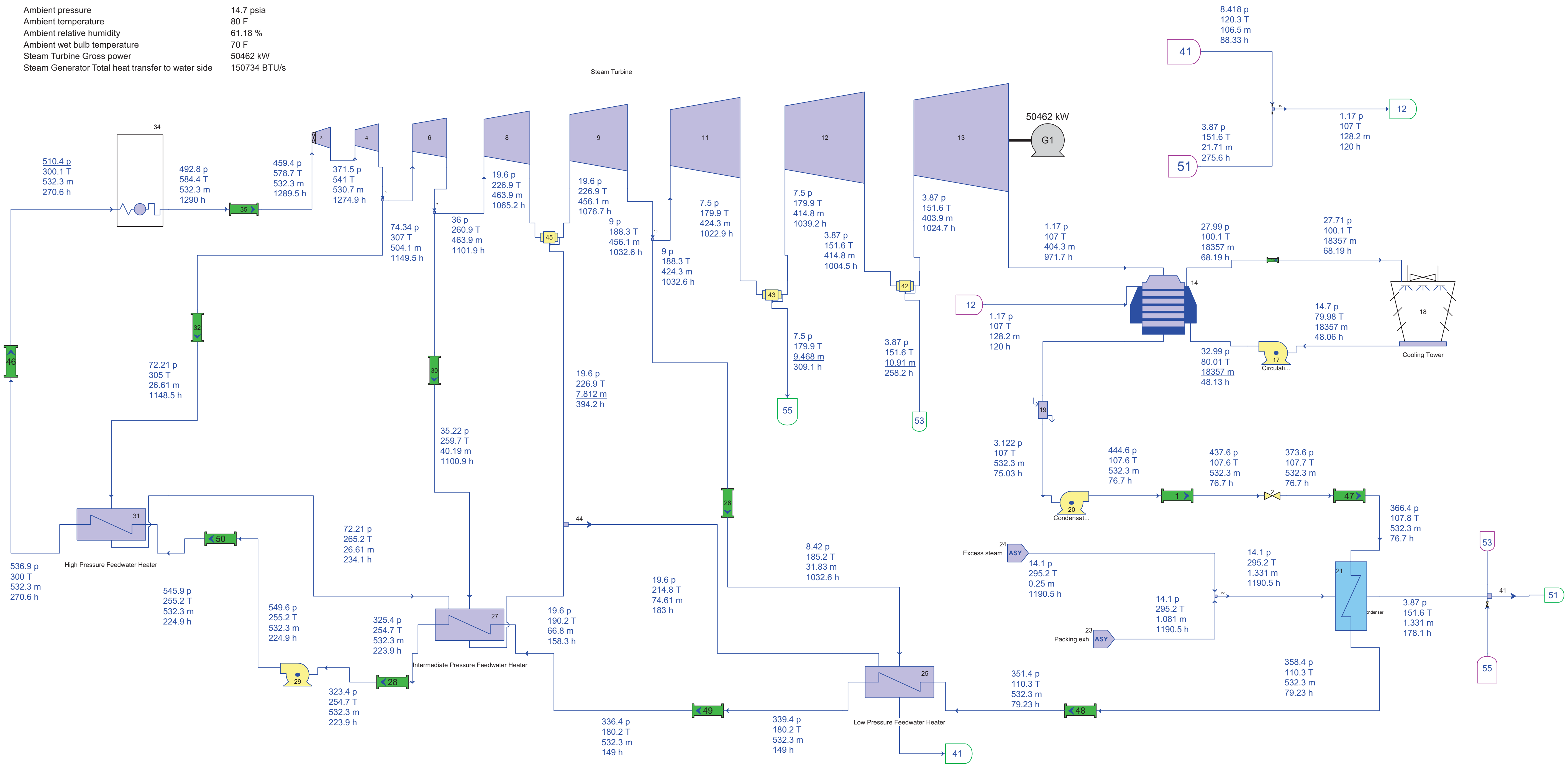
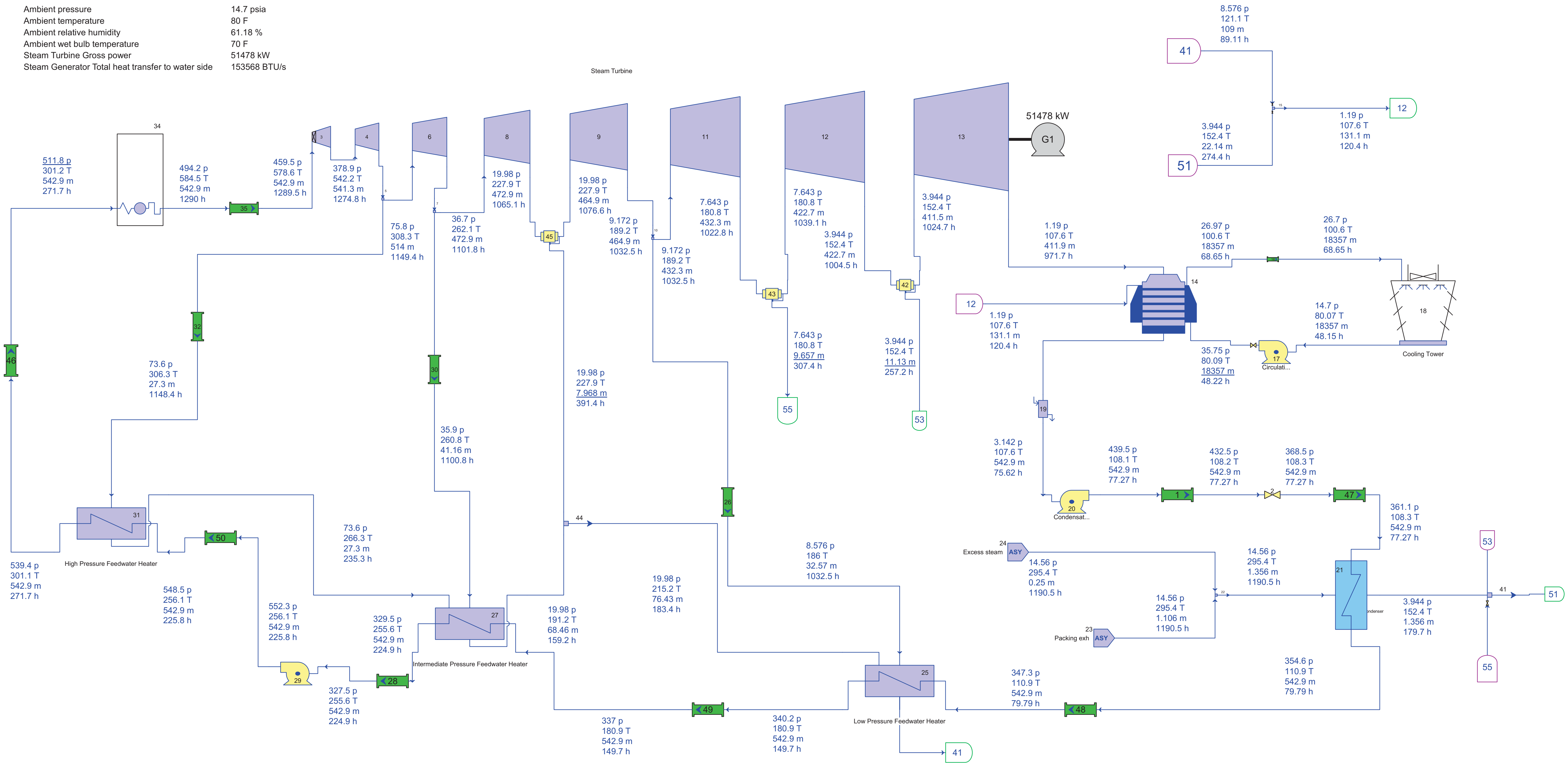


Figure 10.1-2: Flow Diagram and Heat Balance Diagram at Rated Power for Steam and Power Conversion System Cycle



For reference only - actual values are site dependent.

Figure 10.1-3: Flow Diagram and Heat Balance Diagram at Stretch Power (valves wide open) for Steam and Power Conversion System Cycle



For reference only - actual values are site dependent

10.2 Turbine Generator

The primary function of the turbine generator system is to convert steam into electricity. Each turbine generator system services one NuScale Power Module (NPM). There are up to two turbine generator buildings, each with up to six separate turbine generator systems.

10.2.1 Design Bases

This section identifies the turbine generator system (TGS) required or credited functions, the regulatory requirements that govern the performance of those functions, and the controlling parameters and associated values that ensure that the functions are fulfilled. Together, this information represents the design bases (as defined in 10 CFR 50.2) for the TGS.

The TGS serves no safety-related functions, is not credited for mitigation of a design basis accident, and has no safe shutdown functions. General Design Criteria (GDC) 2, 4, and 5 were considered in the design of the TGS. No safety-related structures, systems, and components (SSC) are affected by natural phenomena such as earthquakes. The design of the TGS provides protection of safety-related SSC from the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents, including the effects of turbine missiles (Section 10.2.2). The components in the TGS are not shared among NPMs; therefore failure of the TGS of one NPM does not significantly impair the ability of other NPMs to perform their safety functions. Consistent with 10 CFR 20.1101(b), the TGS design supports keeping radiation exposures as low as reasonably achievable (ALARA). The TGS is designed consistent with the requirements of 10 CFR 20.1406 as it relates to minimization of contamination of the facility. See Section 10.2.4 for the safety evaluation.

The TGS control system is designed to automatically trip the turbine on the abnormal conditions listed in Section 10.2.2.4.

As discussed in Section 10.2.2.3.3, turbine overspeed protection ensures that a full-load turbine trip does not cause the turbine to overspeed beyond the acceptable limits. The single failure of a component or subsystem does not cause an unsafe turbine overspeed. The TGS design parameters are listed in Table 10.2-1.

10.2.2 System Description

10.2.2.1 General Description

The TGS for each NPM has three supporting subsystems: the turbine, the generator, and the turbine lube oil system. Figure 10.2-1 shows the TGS simplified piping and instrumentation diagram. The TGS and associated piping, valves, and controls are located completely within the turbine generator building. There are no safety-related systems or components located within the turbine generator building.

The TGS is Seismic Category III and TGS piping is designed to ASME B31.1. Components, piping, and structures are designed in accordance with applicable codes and standards as discussed in Section 3.9. Table 3.2-1 provides the seismic and quality group classifications for the TGS structures, systems, and components. High-energy and

moderate-energy pipe breaks are addressed in Section 3.6.1. Turbine rotor integrity is discussed in Section 10.2.3.

The following areas address aspects of the TGS design:

- Risk significant equipment and the reliability assessment program (Section 17.4)
- Regulatory treatment of nonsafety systems equipment (Section 19.3)
- Quality assurance (Chapter 17)
- Fire protection (Section 9.5.1)

To maintain the radiation exposure to operating and maintenance personnel ALARA, the TGS is designed to facilitate maintenance, inspection, and testing in accordance with the guidance in Regulatory Guide 8.8.

There are no relevant generic letters or unresolved safety issues for this system. Operating experience insights are incorporated into this system as noted. The system has no relevant TMI requirements.

10.2.2.1.1 Turbine Subsystem Description

One turbine is utilized for each NPM. The superheated steam is provided by the main steam system from the steam generator to the turbine. The steam passes through the stages of turbine blades converting the thermal energy to mechanical energy. The turbine subsystem performs the following functions:

- converts thermal energy into rotational energy
- controls steam flow to match control system demand
- provides extraction steam for the feedwater heaters
- transports steam to the condenser
- supports major pipe connection reactions for main steam (Section 10.3), extraction steam, and exhaust steam piping systems

The components of the turbine subsystem include the

- turbine
- stop valve
- control valves
- turbine bypass valve and desuperheater
- steam piping between turbine valves and casing
- outlet connections for extraction steam
- drain and vent connections
- turbine shaft journal and thrust bearings and housings
- turning gear
- gland seal steam control skid

- turbine rotor grounding device
- turbine to generator shaft coupling

The boundary between the main steam system and TGS is the upstream side of the turbine generator vendor package interface, the upstream side of the gland steam condenser connection point, and downstream of the extraction line connection points. See Figure 10.2-1 and Section 10.3 for additional information.

The turbine generator design utilizes a condensing steam turbine with uncontrolled extractions. The turbine is a single inlet design with one stop valve and a steam chest with multiple inlet control valves.

The turbine shaft journal bearings are lubricated by the lube oil subsystem. The turbine is also restrained via a thrust bearing to absorb the axial thrust of the turbine. Turbine materials are listed in Table 10.2-2.

The turbine generator design includes a spray system which provides cooling to the turbine exhaust hood upon sensing a high temperature condition.

The gland seal steam control skid (Section 10.4.3) is also a part of the turbine subsystem. The gland seal steam control skid performs the following functions:

- prevents air leakage into the turbine under vacuum and prevent steam leakage out of the turbine under pressure for anticipated load conditions
- provides for the use of redundant steam supplies and controlling devices

Areas of the turbine requiring attention during operation are accessible during expected plant operating conditions.

10.2.2.1.2 Generator Subsystem Description

The generator takes the rotational mechanical energy from the turbine and converts it into electricity by spinning the generator rotor through a magnetic field. The magnetic field is produced by self-excitation of the stator coils. The frequency is synchronized with the offsite transmission system and power is transferred to the grid. The generator is directly coupled to the turbine, and is air cooled. Cooling water for the generator air cooling is provided by the site cooling water system. Components of the generator subsystem include the

- generator stator
- generator air coolers
- generator rotor
- brushless or static exciter
- shaft grounding devices
- high voltage bushings
- bushing current transformer assembly

- grounding system

10.2.2.1.3 Lube Oil Subsystem Description

The turbine and generator each rotate with the support of journal bearings to maintain proper radial alignment of shaft components, as well as a thrust bearing to maintain axial alignment. The lube oil system provides lubrication and cooling to these bearings during normal operation. The lube oil system performs the following functions:

- supplies normal and emergency lubrication needs of turbine, generator, and exciter
- maintains oil purity within operating limits
- maintains oil temperature within operating limits for normal operation and on turning gear

Components of the lube oil subsystem include the

- lube oil tank
- alternating current (AC) motor driven primary oil pump
- AC motor driven back-up auxiliary oil pump
- direct current (DC) motor driven emergency oil pump
- shaft lift oil system
- lube oil coolers
- vapor extractor
- oil mist eliminator
- bearing oil header pressure regulator
- full flow filtration assemblies
- lube oil conditioner and purification system

The lube oil subsystem is skid mounted and provides oil via the main or auxiliary lube oil pump. An emergency lube oil pump is also provided to protect the bearings from damage following a loss of the main pumps. Once the oil is returned to the reservoir, the oil is cooled, filtered, and conditioned to remove air and moisture. The lube oil subsystem heat exchangers are cooled by the site cooling water system.

10.2.2.2 Component Description

Table 10.2-1 contains the TGS component design parameter details.

10.2.2.2.1 Turbine Stop Valve

The steam flow to the turbine is controlled by a single stop valve, located adjacent to the turbine. The valve is used to control the flow entering the turbine during startup and shutdown.

The stop valve is hydraulically operated and isolates steam flow to the turbine upon receiving a trip signal. The stop valve also includes a throttling pilot to support startup and shutdown operations. If a loss of oil pressure occurs, an independent hydraulic trip relay closes the turbine stop and control valves. Hydraulic fluid is supplied to the stop valve by a control oil skid.

10.2.2.2.2 Turbine Control Valves

Multiple inlet control valves are used to throttle steam flow to the turbine during normal operation. These valves close upon actuation of the emergency trip signal within a time period to preclude unsafe turbine overspeed. The valve arrangements and valve closure times are designed such that a failure of a single valve to close will not result in unsafe turbine overspeed in the event of a trip signal. The turbine control valves are positionable by hydraulic operators. If a loss of oil pressure occurs, an independent hydraulic trip relay closes the valves. Hydraulic fluid is supplied to the control valves by a control oil skid.

Turbine Bypass Valve and Desuperheater

Turbine bypass is capable of transferring up to 100 percent of the main steam flow to the condenser to remove heat from the reactor and prevent overpressure following a reduction or loss of electrical load. A desuperheater is used downstream of the turbine bypass valve to reduce the steam temperature of bypassed steam. The design and operation of the turbine bypass valve and desuperheater is described in Section 10.4.4.

10.2.2.2.3 Speed Sensors

Three turbine shaft mounted speed sensors are contained in both the turbine overspeed emergency trip system and the governor overspeed detection circuit. Each turbine overspeed speed detection probe has its own magnetic pickup and power supply. The modules can be individually tested and replaced online without causing a trip.

The governor overspeed detection circuit reads the turbine rotational speed with redundant magnetic speed pickups. Each magnetic speed pickup has its own overspeed detection circuit. Overspeed protection is further discussed in Section 10.2.2.3.

10.2.2.3 Control Functions

The TGS is monitored and controlled by the main turbine control and diagnostics system, which is a subsystem of the TGS. The main turbine control and diagnostics system interfaces with the module control system (MCS). The turbine trip output

from the main turbine control and diagnostics system to the MCS is redundant and hard wired. Alarm signals are transmitted from the main turbine control and diagnostics system to the MCS for monitoring and display. The MCS provides instrumentation and control of the TGS inside the main control room. The startup, shutdown, and normal operation functions of the TGS are controlled. The main control room also provides indication and control of turbine generator supporting systems such as the lube oil subsystem, stop valves and drain valves. The TGS instrument list is provided in Table 10.2-3. In addition to control room indication, local indication is provided within the turbine generator building. Additional information on the module MCS is provided in Chapter 7. A list of major TGS controls is provided in Table 10.2-4.

COL Item 10.2-1: A COL applicant that references the NuScale Power Plant design certification will identify the specific turbine vendor and provide a description of the turbine and control system design.

10.2.2.3.1 Speed Control

The module control system provides automatic turbine speed control. On startup, after the turbine reaches full speed, the governor maintains the speed and allows for generator synchronizing to begin.

After synchronizing, minimal operator action is necessary for the TGS when the control system is placed in automatic mode. Steam throttling via the TGS control valves is the primary method for power maneuvering.

10.2.2.3.2 Load Control

Anticipated load profiles can be accommodated by the equipment. The TGS is designed to remain online following a sudden load reduction down to the minimum operating load.

- base load operation and load follow operation.
- electric power production consistent with the capability of the NPM and main steam system.
- a 24-hour load operating cycle with the following profile: starting at 100 percent power, power ramps down to 50 percent power in two hours, power remains at 50 percent for two to ten hours, and then ramps up to 100 percent in two hours. Power remains at 100 percent for the remainder of the 24-hour cycle.
- an automatic mode in response to grid frequency changes.
- satisfy peak-to-peak power change demands of 10 percent of NPM rating at 2 percent of NPM rating per minute.
- satisfy 20 percent of rated power step demand increase or decrease within ten minutes.
- the capability to perform an increase or decrease of 10 percent in 60 seconds without trip while operating between 50 and 100 percent power.

- the capability to remain online following a sudden load reduction down to the minimum operating load.

10.2.2.3.3 Overspeed Protection

Turbine control and overspeed protection controls turbine action under normal or abnormal operating conditions and ensures that a full load turbine trip does not cause the turbine to overspeed beyond acceptable limits. Turbine overspeed is a potential initiating event that could cause turbine blades to fail and become a source of missiles. The turbine generator overspeed control system has two independent and diverse subsystems.

The turbine governor is the primary speed controller and is the first line of defense against turbine overspeed. The governor positions the internal control valves to control speed and load. It has its own set of speed sensors, its own redundant computer, and redundant power supplies. The governor is set to trip the turbine if it reaches 9 percent overspeed. A governor trip signal closes both the turbine stop valve and the control valves. Both sets of valves are hydraulically actuated so the trip mechanism consists of trip solenoids that dump the high pressure hydraulic fluid causing the valves to spring closed to their fail safe position.

The emergency trip system is the second line of defense. It monitors turbine speed independent of the governor with its own set of redundant sensors, computers, power supplies and trip solenoids. The emergency trip system is independent of and diverse from the governor, by using different manufacturers. It closes both the turbine stop valve and the control valves upon sensing 10 percent overspeed.

These two independent systems with their own internal redundancy each have the capability to shut down the turbine. Two out of three voting logic eliminates spurious trips due to a single failure while maintaining high reliability. Redundancy is enforced throughout the whole system from sensors, processors, voting logic circuits, through trip solenoids. The design speed of the turbine is 120 percent of synchronous, thus assuring that there is adequate margin between the trip settings and the design speed.

The two diverse overspeed protection systems with internal redundancy each have the capability to shut down the turbine. Triple redundancy of the speed sensors eliminates spurious trips due to a single failure while maintaining high reliability. A single failure of a component does not defeat the turbine overspeed protection. If a loss of oil pressure were to occur, an independent hydraulic trip relay closes the valves. Diversity and independence in turbine overspeed protection is achieved by having two overspeed control subsystems that do not have common components. Common cause failures of the overspeed trip protection systems are prevented through the use of redundant and diverse hardware and software.

The turbine generator overspeed control system is testable when the turbine is in operation. One circuit can be manually disconnected from service and calibrated while the other circuits remain operational. The modules can be individually tested and replaced on-line without causing a trip. This inservice testing ensures a high reliability of the system. In addition, the stop and control valves are periodically

exercised in accordance with the turbine supplier's recommendation to prevent them from building up deposits on the shafts and bushings that might hinder closure. Valve stroking ensures that the valves will close when called upon.

COL Item 10.2-2: A COL applicant that references the NuScale Power Plant design certification will describe how the functional requirements for turbine overspeed are met for the vendor specific turbine design and will provide a schematic of the turbine control system and protection systems.

10.2.2.3.4 Loading and Startup Controls

The TGS is mainly an automatically operated system with turbine stop valve and control valves being the primary method for power maneuvers.

The turbine generator unit uses an automatic startup system. Using turbine overspeed sensors, the turbine control system manipulates the stop valve as well as the control valves in the steam chest to follow the startup curve for the turbine. This is to ensure the speed probes in the overspeed control and governor are working properly. As speed increases, operations personnel verify that vibration measurements and rotor position indicators are acceptable. After the turbine reaches 100% speed, the governor maintains the speed and allows for generator synchronizing to begin.

Before closing the generator breaker, the generator frequency, phase, and voltage must be matched to the grid. The generator can either be manually or automatically synchronized.

10.2.2.4 Turbine Protection System

Automated operations trip the turbine or generator on trip set points, including:

- reactor scram
- turbine overspeed
- low lube oil pressure
- high vibration
- low vacuum on condenser
- arcing on generator
- improper generator ground
- under or over voltage on generator from grid
- under or over frequency on generator from grid

The loss of connection from generator to grid does not trip the turbine. The NuScale Power Plant is designed with the capability to operate independently from the offsite power system in island mode (Section 8.3).

A turbine or generator trip causes the turbine stop valve to quickly isolate, causing an increase in steam pressure. This pressure is managed using the turbine bypass valve (see Section 10.4.4), part of the TGS.

The turbine bypass valve is capable of transferring up to 100% of the main steam flow to the condenser following a turbine trip or loss of electrical load.

10.2.2.5 Inspection and Testing

The TGS components undergo preservice inspection and testing as described in Chapter 14.

Additional information is provided in Section 10.2.3.3 on turbine rotor testing.

Major system components are accessible for inspection and are available for testing during normal plant operations. The inservice inspection and test program for the governor and overspeed protection provides reasonable assurance that flaws or component failures are detected in the inspected components. This includes the overspeed sensing and tripping subsystems, the stop valve, and the control valves. The inservice inspection program for the governor and overspeed protection includes the following provisions:

- The TGS permits periodic testing of the diverse electronic overspeed protection. Critical trip components are tested in service, such as individual testing of each overspeed module, and the exercising of the hydraulic dump valves and stop valve.
- At intervals of approximately four years, during refueling or maintenance shutdowns, the stop valve and at least one main steam control valve are dismantled for examination. If the visual and surface examinations of valve internals reveal unacceptable flaws or excessive corrosion, other valves of that type are inspected. Valve bushings are inspected and cleaned and bore diameters are checked for proper clearance.
- The stop valve and control valves are exercised at a frequency recommended by the turbine vendor or valve manufacturer.

10.2.3 Turbine Rotor Integrity

Turbine rotor integrity is provided by the integrated combination of material selection, fracture toughness requirements, rotor design, and preservice inspections and tests. The combination results in a very low probability of rotor failure.

COL Item 10.2-3: A COL applicant that references the NuScale Power Plant design certification will perform an evaluation of the probability of turbine missile generation. The report provides a calculation of the probability of turbine missile generation using established methods and industry guidance applicable to the fabrication technology employed. The analysis is a comprehensive report containing a description of turbine fabrication methods, material quality and properties, and required maintenance and inspections that addresses:

a) the calculated probability of turbine missile generation from material and overspeed related failures based on as-built rotor and blade designs and

as-built material properties (as determined in certified testing and nondestructive examination).

b) maximum anticipated speed resulting from a loss of load, assuming normal control system function without trip.

c) overspeed basis and overspeed protection trip setpoints.

d) discussion of the design and structural integrity of turbine rotors.

e) an analysis of potential degradation mechanisms (e.g., stress corrosion cracking, pitting, low-cycle fatigue, corrosion fatigue, erosion and erosion-corrosion), and any specific maintenance or operating requirements necessary for mitigation.

f) material properties (e.g., yield strength, stress-rupture properties, fracture toughness, minimum operating temperature of the high-pressure turbine rotor) and the method of determining those properties.

g) required preservice test and inspection procedures and acceptance criteria to support calculated turbine missile probability.

h) actual maximum tangential and radial stresses and their locations in the turbine rotor.

i) rotor and blade design analyses, including loading combinations, assumptions and warmup time, that demonstrate sufficient safety margin to withstand loadings from postulated overspeed events up to 120 percent of rated speed.

j) description of the required inservice inspection and testing program for valves essential to overspeed protection and any inservice tests, inspections, and maintenance activities for the turbine and valve assemblies that are required to support the calculated missile probability, including inspection and test frequencies with technical bases, type of inspection, techniques, areas to be inspected, acceptance criteria, disposition of reportable indications, and corrective actions.

The analysis/report demonstrates that the probability of turbine failure resulting in the ejection of turbine rotor (or internal structure) fragments through the turbine casing is less than 1×10^{-5} per year. The as-built turbine material properties, turbine rotor and blade designs, preservice inspection and testing results and inservice testing and inspection requirements will be verified to meet the requirements defined in the turbine missile probability analysis.

10.2.3.1 Materials Selection

The turbine is designed considering the effects of vibration and flow erosion and corrosion. Critical components that see high stress as well as critical areas for corrosion

are the turbine blades and turbine rotor. Materials for major components are listed in Table 10.2-2.

Turbine blades and rotors are made from vacuum treated or remelted alloy steel components using processes that minimize flaw occurrence and maximize fracture toughness. Elements that have a deleterious effect on toughness, such as sulfur and phosphorus, are controlled to the lowest practical concentrations appropriate to the required fracture toughness. The turbine materials have the lowest fracture appearance transition temperatures and highest Charpy V-notch energies obtainable, on a consistent basis from material at the sizes and strength levels used.

The 50% fracture appearance transition temperature as obtained from Charpy tests performed in accordance with specification ASTM A-370 is no higher than -18°C (0°F). The Charpy V-notch (Cv) energy at the minimum operating temperature of the rotor in the tangential direction is at least 8.3 kg-m (60 ft-lbs.). A minimum of three Charpy V-notch specimens are tested in accordance with specification ASTM A-370 to determine this energy level. The determination of fracture appearance transition temperature is used in lieu of nil-ductility transition temperature methods.

10.2.3.2 Fracture Toughness

Sufficient material toughness is achieved through the use of selected materials as described in Section 10.2.3.1. Stress calculations include consideration of centrifugal loads, interference fit, and thermal gradients where applicable. Sufficient warmup times are specified in the turbine operating instructions to ensure that toughness is adequate to prevent brittle fracture during startup. The ratio of the fracture toughness (k_{1c}) of the rotor material to the maximum tangential stress at speeds from normal to design overspeed is at least 10√mm (2√in), at minimum operating temperature.

Fracture toughness properties are obtained by one or more of the following methods:

- Testing of the actual material of the turbine rotor to establish the k_{1c} value at normal operating temperature.
- Testing of the actual material of the turbine rotor with an instrumented Charpy machine and a fatigue precracked specimen to establish the k_{1c} (dynamic) value at normal operating temperature.
- Estimating of k_{1c} values at various temperatures from conventional Charpy and tensile data on the rotor material using methods presented in J. A. Begley and W. A. Logsdon, Scientific Paper 71-1E7-AMSLRF-P1 (Reference 10.2-1).
- Estimating "lower bound" values of k_{Ic} at various temperatures using the equivalent energy concept developed by F. J. Witt and T. R. Mager, ORNL-TM- 3894 (Reference 10.2-2).

The Charpy V-notch test criteria are specified in Section 10.2.3.1.

10.2.3.3 Preservice Inspection

The rotor preservice inspection procedures and acceptance criteria are as follows:

- Forged or welded rotors are rough machined prior to heat treatment.
- Each finished forged or welded rotor is subjected to 100% volumetric (ultrasonic), surface, and visual examinations using procedures and acceptance criteria equivalent to those specified for Class 1 components in the ASME Boiler and Pressure Vessel Code, Sections III and V. Before welding or brazing, surfaces prepared for welding or brazing are examined. After welding or brazing, surfaces exposed to steam are surface examined, giving particular attention to stress risers and welds. Welds are ultrasonically examined in the radial and radial-tangential sound beam directions.
- Finish machined bores, keyways, and drilled holes are subjected to magnetic particle or liquid penetrant examination. Flaw indications in keyway or hole regions are not allowed.
- Each turbine rotor assembly is spin tested at 5% above the maximum speed anticipated during a turbine trip following loss of full load.

10.2.3.4 Turbine Rotor Design

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

- The design overspeed of the turbine is 5% above the highest anticipated speed resulting from a loss of load.
- The combined stresses of low-pressure turbine rotor at design overspeed due to centrifugal forces, interference fit, and thermal gradients do not exceed 0.75 of the minimum specified yield strength of the material, or 0.75 of the measured yield strength in the weak direction of the materials if appropriate tensile tests have been performed on the actual rotor material.
- The turbine shaft bearings are able to withstand a combination of the normal operating loads, anticipated transients, and accidents resulting in a turbine trip.
- The natural critical frequencies of the turbine shaft assemblies existing between zero speed and 20% overspeed are controlled in the design and operation stages so as to not cause distress to the unit during operation.
- The turbine rotor design facilitates inservice inspection of the high stress regions, including bores and keyways, without the need for removing the disks from the shaft.

10.2.3.5 Inservice Inspection

A turbine rotor inservice inspection program detects rotor or disk flaws that can lead to brittle failure at or below design speed in the steam turbine rotor assembly.

Inservice inspection and maintenance activities are performed during plant shutdown and include complete inspection of the significant turbine components, such as couplings, coupling bolts, turbine shafts, low-pressure turbine blades, low-pressure rotors, and high-pressure rotors. The turbine rotor inservice inspection program uses visual, surface, and volumetric examinations to inspect components in the turbine rotor assembly. Inspections are done during refueling outages as prescribed by the inservice inspection schedules and the turbine manufacturer's turbine missile analysis, and provide assurance that rotor flaws that might lead to brittle failure of a rotor at speeds up to design speed are detected.

The inservice inspection and maintenance program for the turbine assembly complies with the manufacturer's recommendations.

10.2.4 Safety Evaluation

The TGS serves no safety-related functions, is not credited for mitigation of a design basis accident, and has no safe shutdown functions. General Design Criterion 2 was considered in the design of the TGS. The TGS system meets RG 1.29, in that the TGS is not located in areas that contain safety-related components and is not required to operate during or after an accident.

General Design Criterion 4 was considered in the design of the TGS. The design of the TGS provides protection of safety-related SSC from the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents, including the effects of turbine missiles. The combination of turbine rotor inspections and the low probability of turbine missile generation is sufficient to protect SSC from the adverse effects of turbine missiles. Section 3.5.1.3 discusses turbine missile generation. As discussed in Section 10.2.3, measures taken to ensure turbine rotor integrity and reduce the probability of turbine rotor failure satisfy the relevant requirements of GDC 4.

General Design Criterion 5 was considered in the design of the TGS. The components of the TGS are not shared among NPMs, so their failure does not significantly impair the ability of other NPMs to perform their safety functions.

The requirements of 10 CFR 20.1101(b) was considered in the design of the TGS. Radiological considerations do not affect access to system components during normal conditions. Therefore, radiation shielding is not provided for the TGS and associated components. However, in the event of a primary to secondary system leak or steam generator tube failure, the steam could become contaminated. The Technical Specifications (Chapter 16) provide a maximum limit on secondary coolant activities. If a steam generator tube failure is detected, the secondary coolant is sampled and a radiation survey is completed for ALARA purposes before performing maintenance or modification work on the system. Access to the areas containing the system is restricted if required based on the survey results. The TGS provides for continuous monitoring for radioactivity in the effluent discharge.

Instrumentation is provided at the condenser air removal system discharge as described in Section 11.5. The TGS design satisfies 10 CFR 20.1406 requirements relating to minimization of contamination of the facility. Further discussion of the facility design features to protect against radioactive contamination is provided in Section 12.3.

Chapters 11 and 12 discuss the potential radiation of a primary to secondary coolant leak. Section 15.0.3 discusses the radiological consequences of a steam generator tube failure.

ITAAC are addressed in Section 14.3.

10.2.5 References

10.2-1 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, 1971.

10.2-2 F. J. Witt and T. R. Mager, "A Procedure for Determining Boundary Values in Fracture Toughness at any Temperature," ORNL-TM-3894, Oak Ridge National Laboratory, 1972.

Table 10.2-1: Turbine Generator Design Parameters

Turbine	Rotor	Single Turbine, 10 stage
	RPM	3600 rpm
Generator	Apparent Power	Greater than 57,000 kVA
	Active Power	Greater than 48,000 kWe
	Power Factor	0.85 p.f
	Phase/Frequency/Voltage	3PH/60Hz/13.8kV
	Cooling Type	Air (TEWAC - Totally Enclosed Water to Air Cooling)
Lube Oil	Oil Type	ISO VG 32
	Normal Power	3/60/460 VAC
	Emergency Power	250 VDC
Valves	Turbine control valves	Multiple standard globe valves, with internal spring and yoke
	Stop valve	One hydraulically operated positionable trip valve with throttling pilot for startup operation

Table 10.2-2: Major Turbine Component Materials

Turbine	Rotor	ASTM 470 CL 4 or equal
	Blades	ASTM A276 - A403 or equal
	Stop Valve Body	ASTM A217 WC9 or equal
	Turbine Shroud	ASTM A422 or equal

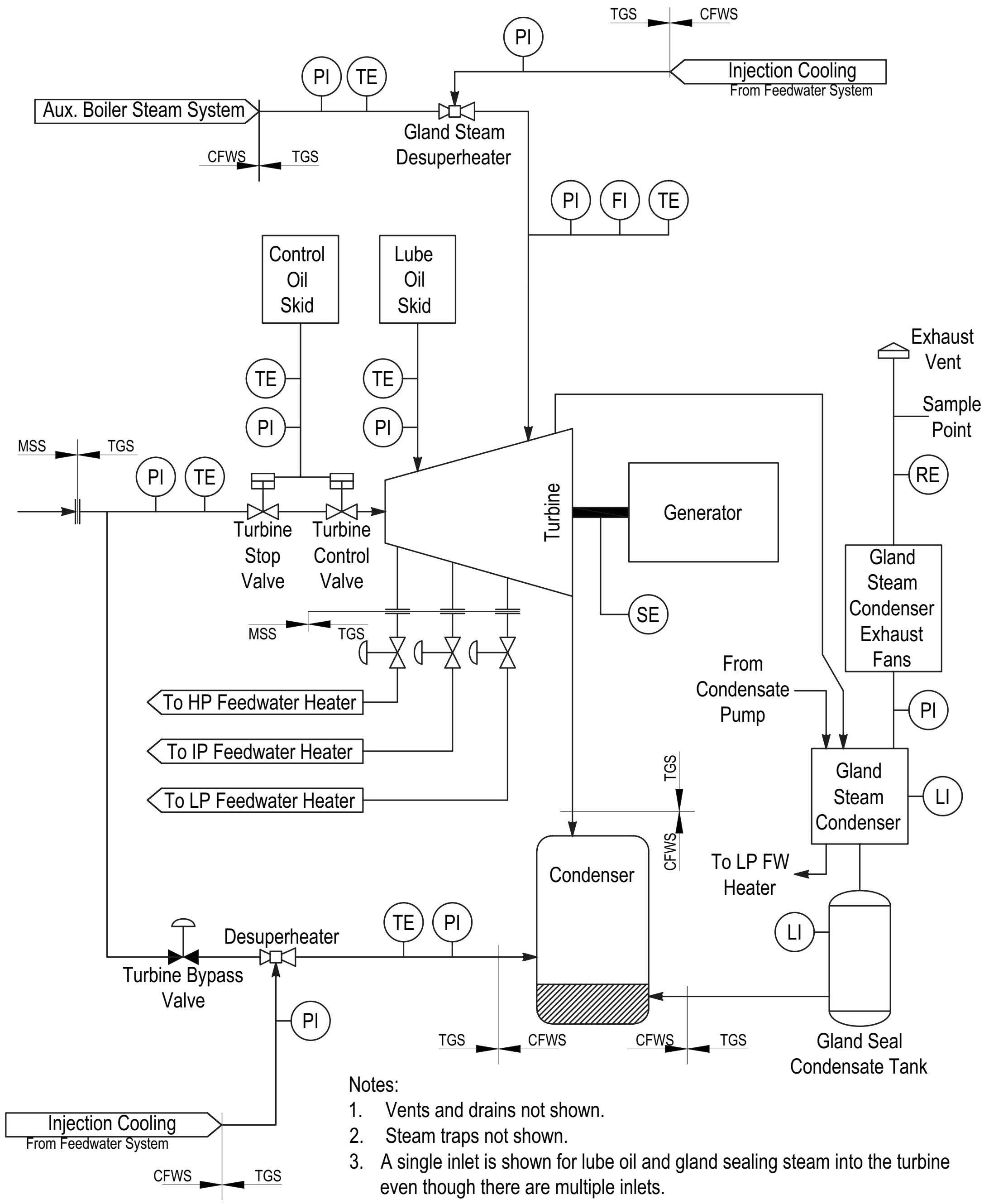
Table 10.2-3: Turbine Generator System Instrument list

Equipment Name	Monitored Parameter	Local Display	Signal to Module Control System
TG DSH Steam Supply MOV FCV Position Transmitter	Valve Position Percent	Yes	Yes
TG DSH FW Supply Pressure Transmitter	Pressure PSIG	Yes	Yes
TG DSH FW Supply MOV FCV Position Transmitter	Valve Position Percent	Yes	Yes
TG DSH Exit Steam Temperature Transmitter	Temperature °F	Yes	Yes
Voltage Meter (upstream & downstream of breaker)	V	Yes	Yes
Generator Frequency	cps	Yes	Yes
VARS Meter	vars	Yes	Yes
MWe Indication	MWe	Yes	Yes
RPM	rpm	Yes	Yes
Vibration Monitoring		Yes	Yes
Electrical System Lockouts		Yes	Yes
Sync-Scope (synchronize with the grid)		Yes	Yes
Steam Pressure at Each Turbine Stage	psia	Yes	Yes
Stop Valve Position	%	Yes	Yes
Control Valve Position	%	Yes	Yes
Generator Ground		N/A	Yes
Generator Arcing		N/A	Yes
Anti-pumping/Reverse Motor		N/A	Yes

Table 10.2-4: Turbine Generator Control List

Description	Automatic/Manual	Local	Control Room
RPM	Automatic and Manual	N	Y
Frequency Control	Automatic and Manual	N	Y
Electrical System Lockouts	Manual	N	Y
Sync-Scope (synchronize with the grid)	Automatic and Manual	N	Y
Emergency Turbine Generator Trip	Automatic and Manual	N	Y
Lube Oil Skid Operation	Automatic and Manual	N	Y

Figure 10.2-1: Turbine Generator System Piping and Instrumentation Diagram



Notes:
1. Vents and drains not shown.
2. Steam traps not shown.
3. A single inlet is shown for lube oil and gland sealing steam into the turbine even though there are multiple inlets.
4. single turbine control valve shown, may have multiple control valves in the steam chest depending on turbine vendor design.
5. For simplicity, a single instrument of each type is shown in each location.

10.3 Main Steam System

The primary function of the main steam system (MSS) is to transport steam from the steam generators to the turbine generator system. Each NuScale Power Module (NPM) is supplied with a separate MSS.

The containment-penetrating steam supply is divided into three portions: internal to containment discussed in Section 5.4, the containment and safety-related main steam isolation valves (MSIVs) discussed in Section 6.2, and the nonsafety-related portion discussed in this section.

The MSS extends from the flange immediately downstream of the MSIVs to the inlet of the turbine generator vendor package. The extraction points from the turbine to the feedwater heaters are also considered part of the MSS although there is no direct connection to the other MSS piping.

10.3.1 Design Bases

This section identifies the MSS required or credited functions, the regulatory requirements that govern the performance of those functions, and the controlling parameters and associated values that ensure that the functions are fulfilled. Together, this information represents the design bases defined in 10 CFR 50.2 for the MSS, as required by 10 CFR 52.47(a) and 10 CFR 52.47(a)(3)(ii).

The MSS is nonsafety-related. One nonsafety-related secondary MSIV is located downstream of each containment system MSIV as backup for the performance of the containment system MSIV design bases functions as outlined in Section 6.2.4.

General Design Criteria (GDC) 2, 4, and 5 were considered in the design of the MSS. No safety-related structures, systems, and components (SSCs) are affected by the effects of natural phenomena such as earthquakes. The design of the MSS provides protection of safety-related SSCs from the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents. There are no safety-related components in the MSS that are shared among NPMs; therefore, the loss of components in one MSS does not significantly impair the ability of other NPMs to perform their safety functions.

The NPM decay and residual heat removal safety function is performed by the decay heat removal system (DHRS) flowpath requiring containment isolation. Consistent with PDC 34, the secondary MSIVs provide a nonsafety-related backup to the containment MSIVs, and provide additional assurance that the blowdown of a second steam generator (SG) is limited if a steamline were to break upstream of the MSIV. Conformance with PDC 34 is further discussed in Section 5.4 and Section 10.3.3.

Consistent with 10 CFR 50.63, the nonsafety-related portion of the MSS is not relied upon to operate in response to a station blackout (SBO). Rather, the DHRS operates in conjunction with the ultimate heat sink to fulfill the core cooling function in the event of an SBO. Conformance with 10 CFR 50.63 and the guidelines of Regulatory Guide 1.155 are discussed in Section 8.4.2 and Section 10.3.3.

Consistent with 10 CFR 20.1101(b), the MSS design supports keeping radiation exposures as low as reasonably achievable (ALARA). Consistent with 10 CFR 52.47(a)(6), the MSS is designed to meet the requirements of 10 CFR 20.1406 as it relates to minimizing contamination of the facility. The MSS is not normally a radiation hazard in a pressurized water reactor. Further discussion of the facility design features to protect against contamination is provided in Section 12.3. See Section 10.3.3 for the MSS safety evaluation.

10.3.2 System Description

The MSS (one per NPM) performs a number of nonsafety-related functions including:

- delivers steam from the steam generators
  - To the turbine generators for the entire range of flow rates, temperatures, and pressures from warming of the main steam piping to rated power conditions; the turbine generator is described in Section 10.2.
  - To the gland seal regulator; the gland sealing steam is described in Section 10.4.3.
  - Directly to the condenser through the turbine bypass valve. As described further in Section 10.4.4, the MSS, together with turbine bypass, is capable of accepting 100 percent load rejection without a reactor trip.
- collects the drainage condensed in the main steam piping and delivers it to the main condenser
- provides a means of dissipating residual and sensible heat generated by the NPM during hot standby and cooldown operations by bypassing to the main condenser
- transports extraction steam from the turbine to the feedwater heaters

10.3.2.1 General Description

Each NPM has two steam generators and a dedicated MSS. The MSS includes pipe, fittings, drains, valves, main steam safety valves (MSSV), and instruments from the flanges immediately downstream of the containment system MSIVs up to the turbine stop valve. A common section of MSS piping is provided to mix and equalize the output of the two SG lines before the steam is directed to the turbine generator. The MSS also includes the extraction steam from the turbine generator to the three feedwater heaters located in the Turbine Generator Building (TGB) and the steam supply to the gland seal steam.

Figure 10.3-1 provides a simplified piping and instrumentation diagram for the main steam system. Table 10.3-1 provides design and operational data for the MSS.

Upstream of the secondary MSIVs, connections are provided for the removable pipe spool and the secondary main steam isolation bypass valves (MSIBV). Branch piping inside the RXB downstream of the secondary MSIVs is limited to the nitrogen system (Section 9.3.1) connections for dry layup, and an additional safety valve in the secondary MSIV bypass line to protect the bypass piping during start-up operations.

The two steam lines combine to mix and equalize the output of the two SG coils. A pipe rack supports the MSS piping and components from the RXB wall to the [[TGB wall]].

Outside of the RXB, sampling points are provided on each main steam line. The MSS piping is protected from overpressure by MSSVs [[outside the TGB wall]] upstream of the sampling and auxiliary steam connections.

Branch piping inside the TGB for each MSS provides for turbine bypass to the main condenser, secondary sampling system, low point drains, feedwater heater steam, and backup auxiliary steam. The MSS provides gland steam through the auxiliary boiler system header. Connections allowing sampling are provided in appropriate locations in the secondary side piping. The secondary sampling system is described in Section 9.3.2.

As discussed in Section 10.3.1, the portion of each MSS up to and including the secondary MSIVs provides nonsafety-related backup to the MSIVs for safety-related isolation functions, and for the safety-related decay and residual heat removal safety function in PDC 34.

Design considerations of the MSS are reflected in the failure modes and effects analyses summarized in Section 5.4 (specific to providing backup to DHRS operation) and Table 10.3-2 (specific to providing backup to containment and steam line isolation functions of the MSS).

The MSS is designed to permit appropriate functional testing of system components as described further in Section 10.3.2.2 and Section 10.3.4.

The MSS piping upstream of the secondary MSIVs is designed to not exceed its service limits during a design basis event. Administrative procedures preclude filling the SG and MSS piping water-solid during normal operation, as well as during DHRS operation.

The MSS has leak detection capabilities. An MSS steam line break is detected as low steam line pressure by pressure sensors in the steam plenums (Section 5.3). This causes an isolation signal to the MSIVs, and closure signals to the turbine bypass valve, turbine stop valve, and drain line isolation valves to limit blowdown of the system.

Section 5.4.1 provides a description of SG design features to minimize fluid flow water hammer. The design and layout of the MSS include provisions to minimize the potential for water hammer and other flow instabilities (Section 3.6.3).

10.3.2.2 Component Description

The major components of the MSS include the piping, secondary MSIVs, secondary main steam isolation bypass valves, MSSVs, drains, and associated supports and appurtenances. The design and operational characteristics of these components are described below. Design parameters and associated values are provided in Table 10.3-1.

The portion of the MSS from the outlets of the MSIVs to the first piping restraint downstream of the MSIVs is nonsafety-related, Seismic Category I, and quality group D. The remainder of the MSS is classified as nonsafety-related, non-seismic, and quality group D. Consistent with Regulatory Guide 1.26, these portions are designed in

accordance with the provisions of ASME Power Piping Code Section B31.1. Additional detail of the safety, quality, and seismic classification of the MSS components is provided in Section 3.2.

Main Steam Piping

Figure 10.1-1 depicts the MSS boundaries, including interconnections with other systems.

The two steam lines combine to mix and equalize the output of the two SG coils. Flanges immediately downstream of the MSIVs are provided to enable disconnection of the piping from the NPM in preparation for moving the module for refueling or maintenance. Immediately downstream of the flanges, the MSS lines pass through the secondary MSIV and secondary MSIBVs. Ball-joint type flanges are used downstream of the secondary MSIVs to reduce containment vessel nozzle stress.

The steam lines from six NPMs are then routed inside the RXB toward the center of the building and then exit the building above ground. They are supported on a pipe rack between the RXB and the TGB.

In the TGB, the MSS lines are each routed to their separate turbine generator set.

Secondary Main Steam Isolation Valves

Design parameters and associated values for the secondary MSIVs are provided in Table 10.3-1.

Each secondary MSIV is provided with two independent actuator control systems to ensure successful performance of the secondary MSIV function, assuming a single failure. In response to a main steam isolation signal, the secondary MSIVs automatically close.

Each secondary MSIV is designed with the capability to periodically test the operability of the valve and associated apparatus, and to determine if valve leakage is within acceptable limits. Each secondary MSIV is seat leakage tested in the forward and reverse flow directions by the valve supplier. Periodic leak testing of each secondary MSIV is performed as described in Section 3.9.

Secondary Main Steam Isolation Bypass Valves

Each of the two secondary MSIVs has a bypass valve that may be used for pressure equalization and warming during NPM startup. The secondary MSIBVs are normally closed and are Seismic Category I, quality group D, ASME B31.1 components. An isolation valve is provided to allow secondary MSIV maintenance, and a safety valve is provided on the bypass line for overpressurization protection.

Main Steam Safety Valve

The MSS piping is protected from overpressure by the use of 2 MSSVs located in the main steam header at the [[TGB wall]]. The MSSVs exhaust steam to the atmosphere outside the TGB.

Condensate Drains

The main steam piping layout provides for the collection and drainage of condensate to avoid water entrainment. The MSS lines are sloped in the direction of steam flow. Drains are located and sized to allow the removal of water prior to and during initial rolling of the turbine and during MSS shutdown. Condensate from the MSS drains is routed to the main condenser.

10.3.2.3 System Operation

NuScale Power Module and Main Steam System Startup

The MSS startup coincides with startup of the associated NPM. Prior to reactor heat-up, the secondary MSIBVs are opened and the entire MSS is warmed at once. Condenser vacuum is established and MSS heat-up is controlled by turbine bypass (Section 10.4.4) to the main condenser. During plant startup, condensate is generated in the main steam piping and is removed through low point drains to prevent water hammer and turbine damage.

Main Steam System Operation During Power Operations

During normal operation, the MSS supplies steam from the MSIV outlets to the turbine. Steam flow is decreased by the turbine control valves to operate at partial load, as required. Both of the steam generators in the NPM reactor pressure vessel are in operation discharging steam to the turbine. Extraction steam from the turbine is supplied to the feedwater heaters.

During normal power operation, main steam flow is a function of turbine load; steam pressure is not controlled, but varies with turbine load. In the case of core power exceeding turbine load, excess steam is dumped to the main condenser through the turbine bypass system (Section 10.4.4).

NuScale Power Module and Main Steam System Shutdown

Main steam system shutdown coincides with shutdown of the associated NPM. The MSS and feedwater system (FWS) are used to provide cooldown from normal operating temperature to the cut-in temperature of the containment flooding and drain system as described in Section 9.3.6. Unit load is reduced to no-load, and the turbine and reactor are shut down. During shutdown and reactor cooldown, steam generated in the steam generators is dumped to the main condenser through the turbine bypass system (Section 10.4.4). During the cooldown process, the SG water inventories are maintained by the FWS.

Anticipated Operational Occurrences and Accidents

Analyses of anticipated operational occurrences and postulated accidents are provided in Chapter 15. The events analyzed in Chapter 15 may be categorized as those that involve automatic closure of the MSIVs (i.e., isolation of the power conversion system) and certain abnormal conditions that do not involve automatic closure of the MSIVs. In the latter instance, operation of the MSS is similar to that described for NPM and MSS shutdown with the use of turbine bypass to remove core decay and primary system sensible heat. Off-normal operations for which the MSS and power conversion system may be used include:

- turbine trip
- loss of grid
- loss of condenser vacuum

The remaining events analyzed in Chapter 15 involve automatic closure of the MSIVs upon receipt of a plant signal by the engineered safety features actuation system (ESFAS). Input signals that result in an MSIV closure signal and associated actuation setpoints and time delays are addressed in Section 15.2.4. In these instances, either or both of the DHRS (Section 5.4.3) and the emergency core cooling system (Section 6.3) are relied upon to remove the reactor decay heat and primary system sensible heat.

The analyses in Chapter 15 further describe operation of the MSS in response to postulated events, including a main steam line break and steam generator tube failure (SGTF).

10.3.3 Safety Evaluation

The MSS is nonsafety-related. One nonsafety-related secondary MSIV is located downstream of each containment system MSIV as backup for the performance of the containment system MSIV design bases functions as outlined in Section 6.2.4. General Design Criterion 2 was considered in the design and arrangement of main steam components. The portions of the MSS downstream of the MSIVs to the secondary MSIVs are contained in the RXB, which is a Seismic Category I structure designed to withstand the effects of natural phenomena, such as earthquakes, tornadoes, hurricanes, floods, tsunamis, and seiches. The adequacy of the structural design of the RXB to withstand these phenomena is further described in Chapter 3. Thus, the portions of the MSS downstream of the MSIVs to the secondary MSIVs are designed to remain functional during and after a safe shutdown earthquake and meet the guidelines of Regulatory Guide 1.29. The RXB is designed as an engineered barrier to withstand a postulated design basis missile. Consistent with Regulatory Guide 1.117, this satisfies the criteria of GDC 2 by the proper design and use of missile barriers (i.e., the RXB) to protect essential SSCs against potential missiles generated by tornado or hurricane winds.

The portion of the MSS that is outside of the RXB is nonsafety-related. The design of the portion of MSS contained outside of the RXB satisfies GDC 2 in that the nonsafety-related portions are not located in areas that contain safety-related components and are not required to operate during or after an accident. No safety-related SSCs are affected by the effects of natural phenomena such as earthquakes. The seismic and quality classifications

of main steam components are described in Section 3.2. Flooding is evaluated in Section 3.4.1.

General Design Criterion 4 was considered in the design and arrangement of main steam components. Portions of the MSS are located in the RXB; thus, internally generated missiles, pipe whip, and jet impingement forces associated with pipe breaks do not prevent the MSS from performing its safety function. The portions of the MSS downstream of the MSIVs to the secondary MSIVs are protected from pipe whip and jet impingement forces resulting from breaks in nearby systems (including the MSS of adjacent power modules) by the piping design layout. The portions of the MSS downstream of the MSIVs to the secondary MSIVs are physically separated from safety-related systems in the RXB by the use of walls and other restraints and have no adverse impacts on safety functions. Refer to Section 3.12 for a description of the design of piping systems and piping supports used in Seismic Category I, Seismic Category II, and non-seismic systems. The analysis of a postulated high-energy line break is provided in Section 3.6.1 and Section 3.6.2.

The portions of the MSS downstream of the MSIVs to the secondary MSIVs are also protected from the effects of missiles generated by plant equipment failures outside the RXB by the building itself. Specifically, portions of the MSS are inside the RXB, which is a Seismic Category I structure, designed as an engineered barrier to withstand a postulated design basis missile. See Section 3.5 for the discussion of missile protection.

General Design Criterion 5 was considered in the design of the MSS. There are no safety-related components in the MSS shared among NPMs, and therefore the MSS does not significantly impair the ability of other NPMs to perform their safety functions.

Principal Design Criterion 34 was considered in the design of the MSS. The decay and residual heat removal safety function per PDC 34 is performed by the DHRS flowpath, and containment isolation function of the containment system performed by the MSIVs and the feedwater isolation valves. Consistent with PDC 34, the nonsafety-related secondary MSIVs downstream of the MSIVs are credited as backup isolation components in the event that an MSIV fails to close. Although not safety-related, the secondary MSIVs are designed to close under postulated worst-case conditions and are included in technical specification surveillance requirements to ensure their reliability and operability. Thus, consistent with the position established in NUREG-0138, Issue Number 1, the secondary MSIVs ensure that the blowdown is limited if a steamline were to break upstream of the MSIV. Conformance with PDC 34 is further discussed in Section 5.4.

The requirements of 10 CFR 20.1101(b) were considered in the design of the MSS. The MSS is not normally a radiation hazard in a pressurized water reactor. Radiological considerations do not affect access to system components during normal conditions. Therefore, no radiation shielding is provided for the MSS and associated components. It is only in the unlikely event of a primary-to-secondary system leak or SG tube failure that the steam could become contaminated. If a SG tube failure is detected, the secondary coolant is sampled and a radiation survey completed before performing maintenance or modification work on the system. Access to the areas containing the system is restricted, if required, based on the survey results. The requirements of 10 CFR 20.1406 were considered in the design of the MSS. Consistent with 10 CFR 52.47(a)(6), the MSS is designed to meet the requirements of 10 CFR 20.1406 as it relates to minimizing contamination of the facility.

Further discussion of the facility design features to protect against contamination is provided in Section 12.3.

The requirements of 10 CFR 50.63 were considered in the design of the MSS. The nonsafety-related portion of the MSS is not relied upon to operate in response to an SBO to satisfy 10 CFR 50.63. Rather, the DHRS operates in conjunction with the ultimate heat sink to fulfill the core cooling function in the event of an SBO. Successful operation of the DHRS relies on the safety-related MSIVs, which form part of the DHRS flowpath and pressure boundary. The secondary MSIVs provide backup to the MSIVs, thus are also required to fail closed during an SBO. This functionality is ensured with or without the availability of electrical power. Conformance with 10 CFR 50.63 and the guidelines of Regulatory Guide 1.155 are discussed in Section 8.4.2.

10.3.4 Inspections and Tests

The MSS components are inspected and tested as part of preoperational and startup tests, and are within the scope of the initial test program described in Section 14.2. Nonsafety-related MSS piping and components are inspected and tested in accordance with the requirements of ASME B31.1.

The proposed Inspections, Tests, Analyses, and Acceptance Criteria required by 10 CFR 52.47(b)(1) and 10 CFR 52.80(a) are discussed in Section 14.3.

10.3.5 Water Chemistry

10.3.5.1 Chemistry Control Program

The SG water and feedwater quality requirements are based on current water chemistry technology reflected in EPRI chemistry guidelines (Reference 10.3-1 and Reference 10.3-2) and NEI 97-06 (Reference 10.3-3).

Consistent with this guidance, the secondary water chemistry control program includes control and diagnostic parameters, and associated action limits. Additional control and diagnostic parameters have been included as appropriate based on industry experience and other available information.

The secondary water chemistry control program is implemented by plant operating procedures, which control the recording and management of data, and require appropriate corrective actions in response to abnormal chemistry conditions.

COL Item 10.3-1: A COL applicant that references the NuScale Power Plant design certification will provide a site-specific chemistry control program based on the EPRI PWR Secondary Water Chemistry Guidelines and NEI 97-06.

10.3.5.1.1 Chemistry Control Objectives and Basis

The objectives of the secondary water chemistry program are:

- to protect the steam generators, turbine, and FWS from general and localized corrosion caused by the ingress of oxygen and other chemical contaminants

- to minimize the metal release rate from the steam-water cycle materials in order to reduce the transport of corrosion products into the steam generators

The secondary chemistry program addresses these objectives by controlling system pH, controlling the amount of oxidants and minimizing the amount of contaminants in the system. Water chemistry recommendations for secondary systems invoke plant and operational philosophies that address the control of corrosion products and dissolved impurities by minimizing potential sources, and by implementing effective monitoring. Secondary system components and piping exposed to wet steam, flashing liquid flow, or turbulent single-phase flow where significant loss of material could occur use corrosion, erosion, and flow-accelerated corrosion (FAC) resistant materials. The degree of resistance of the material to FAC, corrosion, and erosion is consistent with specific conditions of the fluid stream involved.

Copper deposits are a major source of corrosion products in the steam generators in plants with copper alloys in their secondary system. The elimination of copper from the secondary system mitigates copper transport to the steam generators. The use of all ferrous materials allows the implementation of a higher feedwater pH target compared to systems that use copper. The use of a higher feedwater pH reduces iron corrosion and iron transport to the steam generators. Therefore, emphasis is placed on excluding copper and copper alloy pipe, valves, and components from the secondary chemistry environment.

10.3.5.1.2 Water Chemistry Treatment and Monitoring

The secondary water chemistry control program includes methods of treatment for corrosion control and proposed specification limits such that the barrier between the primary and secondary fluids maintains its integrity during operation (including design basis accidents), maintenance, and testing. Guidelines for secondary side water chemistry are addressed in Table 10.3-3a through Table 10.3-3d.

An all-volatile treatment amine, such as ammonium hydroxide is added to the feedwater to establish an optimum pH level. Hydrazine is also added to control the residual dissolved oxygen concentration and to maintain a passive protective film of magnetite on carbon steel surfaces.

10.3.5.1.3 Chemistry Sampling

The secondary system for each NPM is designed to allow for chemistry sampling and analysis, both continuous and grab samples, from selected locations to monitor water quality. Analyses of the chemistry samples are used to control the secondary side water chemistry and to permit corrective actions to be taken in the event of contaminant ingress or other chemistry excursion.

Design of the secondary sampling system considers sampling flow velocities, sample tubing length, and routing of the sample tubing to prevent impurities from settling out in the tubing and to obtain representative samples for analysis.

Continuous sampling flows have bypass flow provisions to maintain flow velocities sufficient to prevent settling of suspended solids in the sample lines.

10.3.5.2 Contaminant Ingress

There are several sources that may introduce contaminants into the secondary system during operation

- condenser cooling water in-leakage,
- poor quality makeup water,
- improperly regenerated condensate polishers,
- atmospheric leaks at the condenser or pump seals, and
- contaminated water treatment chemicals.

The contaminated water treatment chemicals as source of contaminants is controlled by the chemical use and control program.

The remaining sources of contaminants, described below, are detected by continuous monitoring or sample analysis, and appropriate action is taken following detection to locate and to correct the problem.

- Contaminants that enter the system through condenser tube leaks are detected by continuous process monitoring of the condenser hotwells for cation conductivity and sodium and the condensate pump discharge for straight conductivity, cation conductivity, and dissolved oxygen.
- The condensate polisher discharge is continuously monitored for cation conductivity, dissolved oxygen, and sodium when in use.
- Demineralized water is continuously monitored as it is being produced and the demineralized water storage is routinely sampled to verify makeup water quality.

Air inleakage is detected by monitoring the condensate pump discharge for excessive dissolved oxygen and by monitoring the condenser air removal rate.

Condensate polishers are used in the condensate system during plant startup and shutdown to remove both dissolved and particulate contaminants prior to admitting feedwater to the steam generators. This practice achieves the required water purity in a shorter time and prevents these contaminants from entering the steam generators.

Condensate polishers are intended to be used continuously during power operation. Their use is important in the event of an upset in chemistry conditions, for example, during periods of condenser cooling water leakage or when inadequate performance of the makeup water system would introduce impurities to the steam generators. They also assist in minimizing iron transport to the steam generators. Additional information on the condensate polishing system is provided in Section 10.4.6.

10.3.5.3 Primary-to-Secondary Leakage

Leakage of primary water into the SG tubes from through-wall tube defects would represent a source of radioactive iodine to the secondary system. The volatility of radioactive iodine is increased by acidic and oxidizing solutions. The secondary side chemicals added (Section 10.3.5.1.2) make the secondary side chemistry both basic and reducing. These conditions suppress the volatility of radioactive iodine species, thus minimizing release through the main condenser evacuation system.

The implications of detecting radioactivity in the secondary side are addressed by the requirements identified in Section 11.5.

10.3.5.4 Chemical Addition System

Equipment is provided to inject controlled quantities of treatment chemicals as part of the secondary water chemistry program. These treatment chemicals are injected into the condensate pump discharge header. See details for the feedwater treatment system in Section 10.4.11.

10.3.6 Steam and Feedwater System Materials

10.3.6.1 Fracture Toughness

The MSS and condensate and feedwater system (CFWS) are nonsafety-related and are not relied upon to perform a nuclear safety function. The quality group for the MSS and CFWS is quality group D, thus the piping is non-nuclear safety ASME Code B31.1 piping. All MSS and CFWS component materials meet ASME code requirements.

10.3.6.2 Materials Selection and Fabrication

Section 3.2 provides the material specification, grade, and classification for piping, valves, fittings, and weld filler material used in the MSS and CFWS.

Specifically, material selection and fabrication requirements for the MSS and CFWS conform to ASME Code B31.1 and are consistent with the quality group and seismic design classifications provided in Table 3.2-1.

The design, materials selection, fabrication, and operation of components mitigate susceptibility to intergranular stress corrosion cracking of the stainless steel and nickel-based materials used. See additional stress corrosion cracking information in Section 3.6.3.

10.3.6.3 Flow-Accelerated Corrosion

The design of the piping in the MSS and the CFWS incorporates considerations to prevent the occurrence of erosion and corrosion. These considerations include material selection, limits on flow velocity, inspection programs, and limits on water chemistry to reduce FAC, corrosion, and erosion of piping and piping components. The design meets the guidance contained in Generic Letter 89-08 and NSAC-202L-R3

(Reference 10.3-1) governing design considerations to minimize erosion and corrosion (including FAC) and acceptable FAC monitoring programs.

The MSS and CFWS design and layout incorporate appropriate provisions to minimize FAC. These provisions are applied to the high-energy, nonsafety-related portions that could adversely impact safety-related systems susceptible to FAC and other flow-induced degradation mechanisms. These provisions include:

- elimination of high turbulence points wherever possible (e.g., adequate straight pipe length downstream of flow orifice or control valve, etc.)
- use of long radius elbows
- smooth transition at shop or field welds
- selection of pipe diameter to have velocities within industry recommended values
- use of corrosion resistant materials

In addition to the design and layout provisions described above, erosion and corrosion is minimized by the implementation of a secondary water chemistry control program as described in Section 10.3.5.

COL Item 10.3-2: A COL applicant that references the NuScale Power Plant design certification will provide a description of the flow-accelerated corrosion monitoring program for carbon steel portions of the steam and power conversion systems that contain water or wet steam and are susceptible to erosion and corrosion damage.

10.3.7 Instrumentation

The main steam temperature, pressure, radiation, and flow instrumentation is designed to permit automatic plant operation, remote control, and continuous indication of system parameters. The remote instrumentation readouts required for monitoring the system are provided in the main control room. The ability to manually initiate MSS control actions is available in the main control room.

Table 10.3-4 shows the MSS instrumentation. A list of the instrumentation associated with DHRS actuation and operation (including MSIV and secondary MSIV closure) is provided in Section 7.1.

The instrumentation and controls associated with turbine bypass are described in Section 10.4.4.

10.3.8 References

10.3-1 Electric Power Research Institute, "Recommendations for an Effective Flow-Accelerated Corrosion Program (NSAC-202L-R3) Non-Proprietary Version," EPRI Report No.1015425, Final Report, August 2007.

10.3-2 Electric Power Research Institute, "Pressurized Water Reactor Secondary Water Chemistry Guidelines", Rev 7, February 17, 2009, Palo Alto, CA.

10.3-3 Nuclear Energy Institute, "Steam Generator Program Guidelines," Rev 3, Washington, DC, January 2011.

Table 10.3-1: Main Steam System Design Data (Single NuScale Power Module)

Design Parameter	Rated Conditions
Full power steam flow	
Total	532,100 lbm/hr
Design Conditions	
Design pressure upstream/downstream of the secondary MSIVs	2100 psia/ 1000 psia
Design temperature	650 °F
Operating Conditions	
Pressure at rated power	500 psia
Temperature at rated power	575 °F
Secondary Main Steam Isolation Valves	
Number per main steam line	1
Total number of valves / valve type	2/ gate valve
Valve size	12 in.
Design code	ASME B31.1
Seismic Category	I
Actuator System	hydraulic and/or pneumatic
Closure speed	Within 5 seconds
Secondary Main Steam Isolation Bypass Valves	
Number per main steam line	1
Total number of valves	2
Valve size	4 in.
Design code	ASME B31.1
Seismic Category	I
Actuator System	Air operated
Closure speed	Within 10 seconds
Main Steam Safety Valves	
Total number of valves	2
Valve size	4 in. (inlet), 6 in. (outlet)
Valve capacity	Greater than 50% of design steam flow

Table 10.3-2: Main Steam System Failure Modes and Effects Analysis (Isolation Functions)

Component Identification	Function	Failure Mode	Failure Mechanism	Effect on System	Method of Failure Detection	Remarks
Secondary MSIVs (nonsafety-related) XX*-MS-AOV-1003 XX*-MS-AOV-2003 (normally open, fail close) XX* reserved for module number (01 - 12)	Isolate steam generators from each other by isolating MSS headers due to a module control system (MCS) close signal.	Fails open (steam line break)	Mechanical Electrical / I&C (failure to close)	Valve MS-AOV-1003 (2003) remains open. 1) If the break is upstream of MS-AOV-1003(2003), then MS-ISV-1005(2005) and MS-ISV-1006(2006) close to isolate the steam line break. Both steam generators are isolated from the break. 2) If the break is downstream of MS-AOV-1003(2003), then MS-ISV-1005(2005) and MS-ISV-1006(2006) close to isolate the steam line break. Both steam generators are isolated from the break.	Main control panel valve position indication Steam header pressure Steam flow	For a break downstream of MS-ISV-1005/ 2005, the steam generators are isolated from the break and are available for heat removal via the DHRS.
		Fails open (steam generator tube failure)		Valve MS-AOV-1003(2003) remains open. If the failure is on SG2 (1) (the SG without the tube failure) and MS-AOV-2003(1003) remains open, then MS-ISV-1005(2005) and MS-ISV-1006(2006) closes to isolate the break. MS-ISV-2005(1005) and MS-ISV-2006(1006) isolate the non-affected SG2 (1). If the failure is on SG1 (the SG with the tube failure) and MS-AOV-1003(2003) remains open, then MS-ISV-1005(2005) and MS-ISV-1006(2006) isolate the break. MS-ISV-2005(1005) and MS-ISV-2006(1006) isolate the non-affected SG2 (1).	MS line radiation monitor Pressurizer level response Makeup flow ESFAS actuation	The failed SG tube fills up the steam line to the closed MSIV (affected SG). The non-affected SG is available for heat removal via the DHRS.
		Fails closed (during normal operation)	Mechanical Electrical / I&C (fails closed) Operator error	Valve MS-AOV-1003(2003) closes. Rapid decrease in steam flow and subsequent loss of reactor coolant heat removal capability. Bounded by turbine trip event.	Main control panel valve position indication Steam flow	The turbine trip event bounds this scenario.
		Fails partially closed (during normal operation)		Valve MS-AOV-1003/2003 partially closes. This could be seen as a small reduction in steam flow up to a large reduction in steam flow. For a small reduction in steam flow, the reactor follows steam demand and stabilizes at a lower reactor power. If the failure is significant enough, it is similar in response to the complete closure of the valve discussed above.	Main control panel valve position indication Steam flow	The turbine trip event bounds this scenario.
		Fails to close on demand	Mechanical Electrical / I&C	Valve MS-AOV-1003(2003) fails open when commanded to close. MS-ISV-1005(2005) and MS-ISV-1006(2006) close on redundant signal and isolate the steam generators.		The turbine trip event bounds this scenario.

Table 10.3-2: Main Steam System Failure Modes and Effects Analysis (Isolation Functions) (Continued)

Component Identification	Function	Failure Mode	Failure Mechanism	Effect on System	Method of Failure Detection	Remarks
Secondary MSIBVs (nonsafety-related) XX*-MS-AOV-1004 XX*-MS-AOV-2004 (normally closed, fail close) XX* reserved for module number (01 - 12)	Isolate steam generators from each other by isolating MSS headers due to MCS close signal.	Spuriously opens (steam line break)	Mechanical	There is no credible mechanism for this valve to mechanically fail open.	N/A	
			Electrical / I&C Operator error	Valve MS-AOV-1004(2004) fails open 1) If the break is upstream of MS-AOV-1004(2004), then MS-ISV-1005(2005) and MS-ISV-1006(2006) close to isolate the steam line break. Both steam generators are isolated from the break. 2) If the break is downstream of MS-AOV-1004(2004), then MS-ISV-1005(2005) and MS-ISV-1006(2006) close to isolate the steam line break. Both steam generators are isolated from the break.	Main control panel valve position indication Steam header pressure Steam flow	For a break downstream of MS-ISV-1005(2005), the steam generators are isolated from the break and are available for heat removal via the DHRS.
		Spuriously opens (steam generator tube failure)	Electrical / I&C Operator error	Valve MS-AOV-1004(2004) opens. If the failure is on SG2 (the SG without the tube failure) and MS-AOV-2004(1004) opens, then MS-ISV-1005(2005) and MS-ISV-1006(2006) isolate the break. MS-ISV-2005(1005) and MS-ISV-2006(1006) isolate the non-affected SG2 (1). If the failure is on SG1 (the SG with the tube failure) and MS-AOV-1004(2004) opens, then MS-ISV-1005(2005) and MS-ISV-1006(2006) isolate the break. MS-ISV-2005(1005) and MS-ISV-2006(1006) isolate the non-affected SG2 (1).	MS line radiation monitor Pressurizer level response Makeup flow ESFAS actuation	The failed SG tube will fill up the steam line to the closed MSIV (affected SG). The non-affected SG is available for heat removal via the DHRS.

Table 10.3-2: Main Steam System Failure Modes and Effects Analysis (Isolation Functions) (Continued)

Component Identification	Function	Failure Mode	Failure Mechanism	Effect on System	Method of Failure Detection	Remarks
MSSVs (nonsafety-related) XX*-MS-PSV-0019 XX*-MS-PSV-0020 Normally closed XX* reserved for module number (01 - 12)	Provide overpressure protection for steam lines downstream of secondary isolation valves (MS-AOV-1003/ 2003)	Spuriously opens	Mechanical (spring failure)	Valve MS-PSV-0019(0020) opens. Each MSSV has a flow rate of greater than 50 percent flow. Therefore, this failure causes a plant response that is similar to a steam line break event. This failure is bounded by the steam line break event	Steam header pressure Decrease in turbine output due to loss of flow	
Feedwater heater isolation valve (nonsafety-related) XX*- MS-MOV-0035 XX*- MS-MOV-0039 XX*- MS-MOV-0043 Normally closed, fails closed XX* reserved for module number (01 - 12)	Direct steam to feedwater heaters	Spuriously closes	Electrical / I&C Operator error	Valve MS-MOV-0035 or 0039 or 0043 fails closed This failure would result in a loss of feedwater heating and a colder feedwater temperature to the steam generators. This is bounded by the decrease in feedwater temperature event.	Main control panel valve position indication Feedwater temperature	

Table 10.3-3a: Steam Generator (Reactor Coolant System ≤ 200°F)

Parameter	Normal Value	Value Necessary Prior to Heatup Above >200°F
pH @ 25°C	≤9.8	-
Hydrazine[a], ppm	<25	>3 x oxygen (ppm)
Sodium, ppb	>1000	≤100
Chloride, ppb	>1000	≤100
Sulfate, ppb	>1000	≤100
Diagnostic Parameters		**Analysis Basis**
Nitrogen overpressure, psig		Minimize oxygen ingress to the SGs
Hideout return Analysis (Na, Cl, SO_4, SiO_2, K, Mg, Ca, Al)		Assessment of steam generator impurity deposition

Notes:

a) Alternative oxygen scavenger to hydrazine (if used) must be qualified by the utility prior to use. Revised limits applicable to the hydrazine alternative will be used.

Table 10.3-3b: Feedwater Sample (Reactor Coolant System > 200°F to <15% reactor power)

Control Parameters	Normal Value
pH agent	(a)
Dissolved oxygen, ppb	
200°F < RCS ≤ 350°F	≤ 100
RCS >350°F, Reactor-not-critical	≤ 10
Reactor critical at <15% Reactor power	≤ 5
Hydrazine, ppb	≥ 8 x condensate pump discharge (CPD)(O_2), ≥ 50
Suspended solids, ppb	
200°F < RCS ≤ 350°F	≤100
RCS >350°F and <15% power	≤10
Silica, ppb (Reactor Critical)	≤10
Diagnostic Parameters	**Analysis Basis**
pH at 25°C	Minimize system corrosion
Sodium, ppb	Minimize contaminant transport to the steam generators
Sulfate, ppb	Minimize contaminant transport to the steam generators
Chloride, ppb	Minimize contaminant transport to the steam generators
Cation conductivity, μS/cm at 25°C	Minimize contaminant transport to the steam generators

Notes:

a) Normal value is determined by the site specific chemistry control program.

Table 10.3-3c: Feedwater Sample (≥15% reactor power)

Control Parameters	Normal Value
pH Agent	(a)
Hydrazine, ppb	≥ 8 x CPD O_2, ≥ 50 ppb
Dissolved oxygen, ppb	≤5
Sodium, ppb	≤1
Chloride, ppb	≤3
Sulfate, ppb	≤1
Silica, ppb	≤10
Total iron, ppb	≤5
Diagnostic Parameters	**Analysis Basis**
Specific conductivity, μS/cm at 25°C	Consistent with pH amine concentration
Cation conductivity, μS/cm at 25°C	Monitor increase in anion concentration
Fluoride, ppb	Contribution to cation conductivity
Copper, ppb	Baseline analysis
Lead, ppb	Impact on Alloy 690 corrosion
Reducible metal oxides, ppb	Corrosion product impact on SG tubing
Integrated corrosion product transport	Assessment of corrosion product transport to the SG

Notes:

a) Normal value is determined by the site specific chemistry control program.

Table 10.3-3d: Condensate Sample (≥ 15% reactor power)

Control/Diagnostic Parameters	Normal Value
Dissolved O_2, ppb	≤ 10[a]

Notes:

a) Measured at the condensate polisher effluent

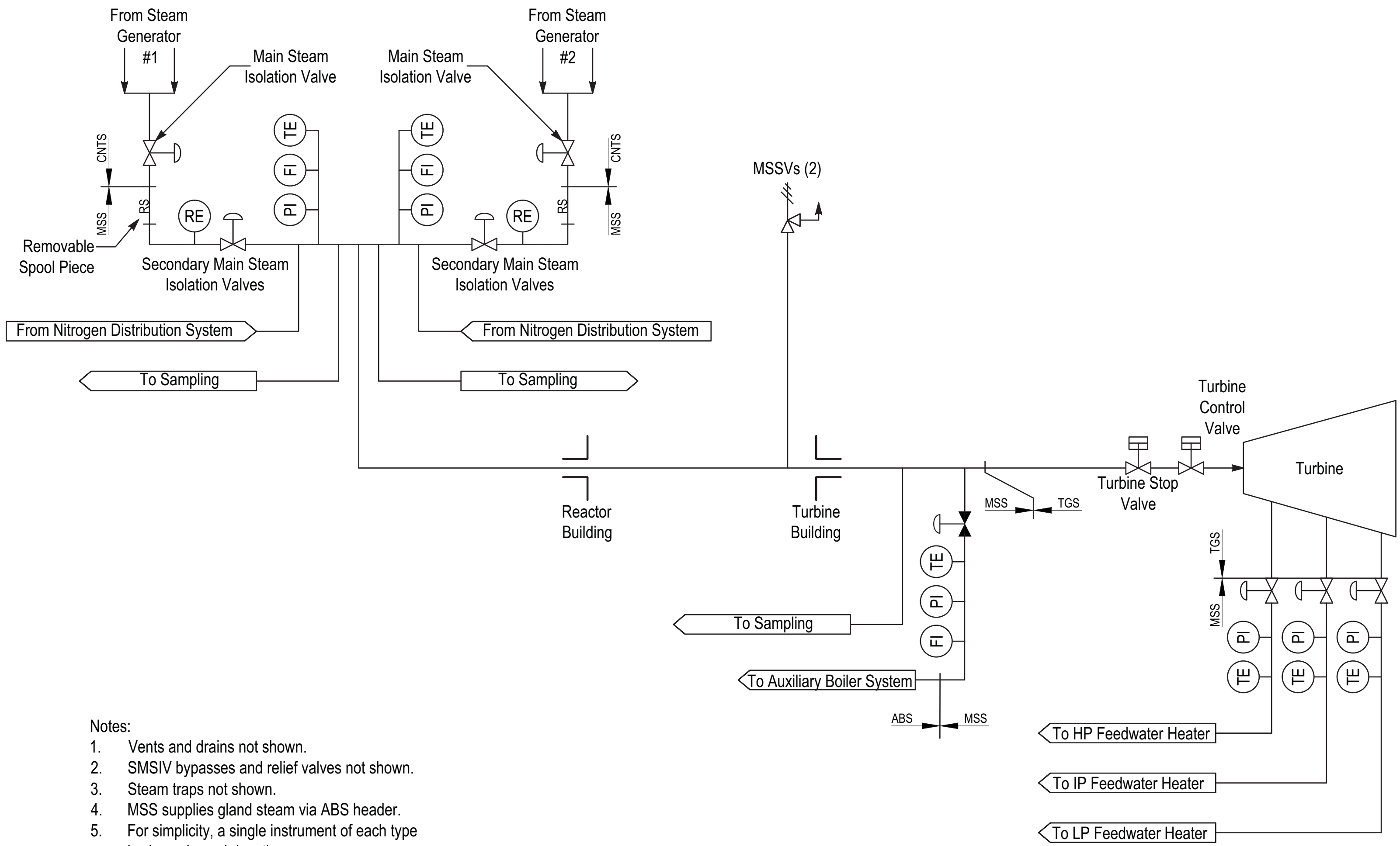
Table 10.3-4: Main Steam System Instrumentation

Equipment Name	Monitored Parameter	Local Display	Signal To MCS
MSS radiation transmitters	Radiation	Yes	Yes
Secondary MSIV limit switches	Valve position, open	No	Yes
Secondary MSIV limit switches	Valve position, percent	No	Yes
Secondary MSIV limit switches	Valve position, closed	No	Yes
Secondary MSIV bypass valve limit switches	Valve position, open	No	Yes
Secondary MSIV bypass valve limit switches	Valve position, percent	No	Yes
Secondary MSIV bypass valve limit switches	Valve position, closed	No	Yes
Secondary MSIV bypass isolation valve limit switches	Valve position, open	No	Yes
Secondary MSIV bypass isolation valve limit switches	Valve position, closed	No	Yes
N_2 valve limit switches	Valve fully open	No	Yes
N_2 valve limit switches	Valve fully closed	No	Yes
MSS pressure transmitters	Pressure	Yes	Yes
MSS flow transmitters	Mass flow rate	Yes	Yes
MSS pressure gauges	MSS pressure	Yes	No
MSS thermal elements	MSS temperature	NA	Yes
Vent valve limit switch	Valve fully open	No	Yes
Vent valve limit switch	Valve fully closed	No	Yes
Auxiliary steam supply valve position transmitter	Valve position, percent	No	Yes
Auxiliary steam flow transmitters	Mass flow rate	Yes	Yes
Auxiliary steam pressure gauge	Pressure	Yes	No
Auxiliary steam thermal elements	Temperature	NA	Yes
Auxiliary steam warm-up valve position transmitter	Valve position, percent	No	Yes
Low pressure extraction steam pressure transmitter	Pressure	Yes	Yes
Low pressure extraction steam thermal element	Temperature	NA	Yes
Intermediate pressure extraction steam pressure transmitter	Pressure	Yes	Yes
Intermediate pressure extraction steam thermal element	Temperature	NA	Yes
High pressure extraction steam pressure transmitter	Pressure	Yes	Yes
High pressure extraction steam thermal element	Temperature	NA	Yes
Extraction steam check valve limit switches	Valve fully open	No	Yes
Extraction steam check valve limit switches	Valve fully closed	No	Yes
Extraction steam isolation valve limit switches	Valve fully open	No	Yes
Extraction steam isolation valve limit switches	Valve fully closed	No	Yes
Steam trap drip leg level transmitters	Level	No	Yes

Table 10.3-4: Main Steam System Instrumentation (Continued)

Equipment Name	Monitored Parameter	Local Display	Signal To MCS
Steam trap drip leg level switches	Level	No	Yes
Steam trap drain valve limit switches	Valve fully open	No	Yes
Steam trap drain valve limit switches	Valve fully closed	No	Yes

Figure 10.3-1: Main Steam System Piping and Instrumentation Diagram



Notes:
1. Vents and drains not shown.
2. SMSIV bypasses and relief valves not shown.
3. Steam traps not shown.
4. MSS supplies gland steam via ABS header.
5. For simplicity, a single instrument of each type is shown in each location.

10.4 Other Features of Steam and Power Conversion System

10.4.1 Main Condenser

Each NuScale Power Module (NPM) has a main condenser (MC), which is part of the condensate and feedwater system described in Section 10.4.7. Each MC functions to condense and deaerate the exhaust from the main turbine and the turbine bypass system (TBS).

10.4.1.1 Design Basis

This section identifies the MC required or credited functions, the regulatory requirements that govern the performance of those functions, and the controlling parameters and associated values that ensure that the functions are fulfilled. Together, this information represents the design bases, defined in 10 CFR 50.2, as required by 10 CFR 52.47(a) and (a)(3)(ii).

The MC serves no safety-related functions, is not credited for mitigation of a design basis accident (DBA), and has no safe shutdown functions. General Design Criteria (GDC) 2, 3, 4, and 5 were considered in the design of the MC. No safety-related structures, systems, and components (SSC) are affected by the effects of natural phenomena such as earthquakes. The design of the MC protects SSC from the effects of fire and explosion, and minimizes the probability of fire and explosion. The design of the MC provides protection of safety-related SSC from the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents. The components in the MC are not shared among NPMs; therefore, the MC does not significantly impair the ability of other NPMs to perform their safety functions. See Section 10.4.1.3 for the MC safety evaluation.

Consistent with GDC 60, the design of the MC ensures the capability to control releases of radioactive materials to the environment. Consistent with 10 CFR 20.1101(b), the MC design supports keeping radiation exposures as low as reasonably achievable (ALARA). The MC is designed to meet the requirements of 10 CFR 20.1406 as it relates to minimization of contamination of the facility.

10.4.1.2 System Description

10.4.1.2.1 General Description

The MC is part of the condensate and feedwater system (CFWS), which is described in Section 10.4.7. A simplified diagram of the condenser is shown in Figure 10.4-1. The MC includes all components and equipment from the turbine exhaust to the connections and interfaces with the CFWS and other systems such as turbine bypass, feedwater heater vents and drains, and gland sealing steam spillover and drains. The main condenser design data are provided in Table 10.4-1.

The primary functions of the MC are to:

- condense exhaust steam from the turbine exhaust using circulating water
- provide a heat sink for the turbine bypass system

The MC components include:

- condenser
- deaerator
- instrumentation
- hotwell
- inlet and outlet connections

The MC is designed to deaerate the condensate. The condenser air removal system (CARS) removes the dissolved oxygen as well as other non-condensable gases as described in Section 10.4.2.

10.4.1.2.2 System Operation

For system startup, the CARS is used to establish vacuum in the condenser. Steam from the auxiliary steam header is used to deaerate the condensate water. The auxiliary steam header is supplied steam from either the auxiliary boiler system (ABS) or from the main steam system (MSS). The deaerated condensate is routed through the condensate polishers to adjust CFWS water chemistry within limits, then to a spray line in the condenser to facilitate cleaning of the condenser hotwell.

During normal power operation, exhaust steam from the turbine is directed into the MC where the steam is expanded, condensed, and collected in the MC hotwell. The MC also receives auxiliary system flows, such as turbine bypass, feedwater heater vents and drains, and gland sealing steam spillover and drains. The condenser hotwell receives primary makeup from the condensate storage tank (CST). The condensate pumps transfer the condensate from the hotwell to the condensate polishing system.

The MC operates under a vacuum that is maintained by the CARS. Non-condensable gases and air inleakage are collected in the MC and removed by the CARS to control contaminants and maintain the secondary water chemistry within an acceptable range as described in Section 10.3.5. The system has sampling lines provided to monitor for radioactivity and water chemistry as described in Section 9.3.2.

For off-normal operations, the condenser hotwell provides excess capacity. The MC hotwell is designed to store extra full-load condensate system operating flow during normal operation. In addition, the hotwell has a standby surge storage capacity. See additional information in Table 10.4-1.

During anticipated operational occurrences (AOOs), the MC is capable of accepting full-load steam flow from the TBS in conjunction with residual turbine exhaust while maintaining a vacuum. Operation of the TBS is discussed in Section 10.4.4. To protect the MC from superheated steam from the turbine bypass, a desuperheater is installed that is capable of cooling the 100 percent turbine bypass flow of superheated steam to saturated conditions.

Air leakage is monitored and minimized to maintain acceptable water chemistry. Continuous deaeration is performed. The CARS discharge is also monitored to detect radiation in the system. In the unlikely event of a primary-to-secondary side leak due to a steam generator tube failure (SGTF), it is possible for the steam and the resulting condensate to become contaminated. In the event of an SGTF, the MSS and CFWS provide secondary isolation capabilities to minimize contamination.

Several methods are used to detect, control, and facilitate correction of leakage of cooling water into the condensate. The condenser is constructed of materials expected to prevent inleakage, and the module control system (MCS) is used to monitor the CFWS for inleakage. The permitted inleakage rate based on the capacity of the CPS is specified in Table 10.4-13.

To monitor for circulating water ingress, cation conductivity is measured in a number of locations in the hotwell and in the condensate lines with in-line samples.

Condensate water egress to the environment is monitored by radiation monitors on the balance-of-plant drain system (BPDS), providing a positive means of ensuring that inadvertent radioactive discharges to the environment do not occur.

The MC hotwell has water level control that provides automatic makeup or rejection of condensate water to maintain water levels within the normal operating ranges. On low water level, the makeup control valves automatically open and condensate water is gravity fed to the hotwell from the CST. On high water level the condensate reject control valves automatically open to divert water from the condensate pump discharge to the CST. Makeup and overflow needs are provided on a normal basis, with redundant emergency makeup and overflow provisions for rapid condensate level requirements during abnormal situations. The condensate storage tank is further discussed in Section 10.4.7.

The MC tubes and tubesheet overlay are constructed of materials to help prevent corrosion and erosion, compatible with the chemistry requirements for the feedwater treatment system (FWTS) and condensate polishing system (CPS). Other methods used to reduce the corrosion and erosion of MC tubes and components include:

- chemical treatment of the circulating water system as addressed in Section 10.4.5
- use of main condenser tube cleaning as described below
- control of secondary side water chemistry as described in Section 10.3.5

The condensers have two separate tube bundles with separate inlet and outlet connections for circulating water. This allows for potential inservice maintenance of the tubes (plugging or cleaning) at reduced operating power. Provision is made for the addition of a condenser tube cleaning system to mechanically scrub the circulating water side of the main condenser tubes. The circulating water chemical treatment may need the assistance of site-specific mechanical tube cleaning to

reduce deposits and maintain condenser thermal efficiency. Adequate space is provided for pulling tubes in the condenser.

Discussion of the MC design features to protect against contamination is provided in Section 12.3.

10.4.1.3 Safety Evaluation

The MC serves no safety-related functions, is not credited for mitigation of a design basis accident (DBA), and has no safe shutdown functions. General Design Criterion 2 was considered in the design of the MC. No safety-related structures, systems, or components are affected by this system from the effects of natural phenomena such as earthquakes. The design and layout of the MC include provisions that ensure that a failure of the system will not adversely affect the functional performance of safety-related systems or components. The MC meets RG 1.29 in that it is not located in areas that contain safety-related components and is not required to operate during or after an accident. The MC is non-seismic, Seismic Category III.

General Design Criterion 3 was considered in the design of the MC. The design of the MC protects SSC from the effects of fire and explosion, and minimizes the probability of fire and explosion. The MC has no hydrogen buildup. A negligible amount of dissolved oxygen is present in the condensate and MC hotwell inventory in comparison to the amount of gas and vapor being evacuated by the CARS. There is no potential for explosive mixtures within the MC. The fire protection program is described in Section 9.5.1.

General Design Criterion 4 was considered in the design of the MC. The design of the MC provides protection of safety-related SSC from the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents. A failure of the MC hotwell that releases the water inventory and the resulting flooding does not prevent the operation of a safety-related system because no such systems are located in the Turbine Generator Buildings (TGBs). The flooding evaluation is addressed in Section 3.4.

General Design Criterion 5 was considered in the design of the MC. The components in the MC are not shared among NPMs; therefore, the MC does not significantly impair the ability of other NPMs to perform their safety functions.

General Design Criterion 60 was considered in the design of the MC. The MC design satisfies GDC 60 with regard to control of radioactive material releases to the environment. The MC is anticipated to contain negligible quantities of radioactive contaminants during power operation and during shutdown. To control the releases of radioactive contaminants, the air and non-condensable gases in the condenser are removed by the condenser air removal system. There is no buildup of non-condensable gases in the MC during normal operations because the liquid ring vacuum pump operates continuously during operation of the MC. The CARS has process radiation monitors on the gaseous effluent lines that discharge to atmosphere capable of detecting radioactivity in the gaseous effluent. Primary-to-secondary leakage contamination and the radiological monitoring instrumentation are addressed in

Section 11.5. Leakage from the hotwell is collected and retained by a leakage detection system.

There is no potential for explosive mixtures within the MC that would result in the release of radioactivity above the regulatory limits. Therefore, the MC design satisfies GDC 60 and is not required to be designed to withstand the effects of an explosion. The fire hazards analysis for the MC and component area is described in Section 9.5.1.

Consistent with 10 CFR 20.1101(b), the MC design supports keeping radiation exposures ALARA. To maintain the radiation exposure to operating and maintenance personnel ALARA, the MC is designed to facilitate maintenance, inspection, and testing in accordance with the guidance in Regulatory Guide (RG) 8.8.

The MC design satisfies the requirements of 10 CFR 20.1406 as it relates to minimization of contamination of the facility and such that the release of radioactive materials is ALARA. The CARS monitors the removed gases for radioactivity and can be isolated. The steam source can isolate upon loss of condenser vacuum. Further discussion of the facility design features to protect against contamination is provided in Section 12.3.

10.4.1.4 Inspection and Testing

The MC components are inspected and tested as part of the initial testing and startup program as described in Section 14.2.

Inspections, tests, analyses, and acceptance criteria (ITAAC) are addressed in Section 14.3.

10.4.1.5 Instrumentation

The hotwell is equipped with level control devices for control of automatic makeup and rejection of condensate. Water level in the hotwell is indicated in the main control room (MCR) and alarms on high-water level or low-water level.

The MC pressure is indicated in the MCR and alarms on high level. Also, pressure instrumentation is provided to alarm prior to reaching the maximum turbine operating backpressure limit. Pressure devices are provided to trip the turbine on high-turbine exhaust pressure. Conductivity sensors are installed to detect high conductivity.

Temperature sensors are provided for monitoring MC performance. MC instrumentation is listed in Table 10.4-2.

10.4.2 Condenser Air Removal System

Each NuScale Power Module (NPM) has a condenser air removal system designed to establish and maintain main condenser vacuum, and to monitor for radioactive material.

10.4.2.1 Design Bases

This section identifies the CARS required or credited functions, the regulatory requirements that govern the performance of those functions, and the controlling parameters and associated values that ensure that the functions are fulfilled. Together, this information represents the design bases, defined in 10 CFR 50.2, as required by 10 CFR 52.47(a) and (a)(3)(ii).

The CARS serves no safety-related functions, is not credited for mitigation of a design basis accident, and has no safe shutdown functions. General Design Criteria (GDC) 2, 3, 4, and 5 were considered in the design of the CARS. No safety-related structures, systems, and components (SSC) are affected by the effects of natural phenomena such as earthquakes. The design of the CARS protects SSC from the effects of fire and explosion, and minimizes the probability of fire and explosion. The design of the CARS provides protection of safety-related SSC from the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents. The components in the CARS are not shared among NPMs; therefore, failure of the CARS does not significantly impair the ability of other NPMs to perform their safety functions.

Consistent with GDC 60, the design of the CARS ensures the capability to control releases of radioactive materials to the environment. Consistent with GDC 64, the CARS design provides radioactive effluent monitoring in potential discharge pathways to the environment and is designed to meet the requirements of 10 CFR 20.1406 as it relates to minimization of contamination of the facility. See Section 10.4.2.3 for the CARS safety evaluation.

10.4.2.2 System Description

10.4.2.2.1 General Description

The condenser air removal system is used to remove air from the main condenser. Each MC is provided with two 100 percent capacity condenser air removal systems in parallel. If one system is unavailable due to maintenance issues or lost during normal operation, the redundant system is started to prevent a loss of condenser vacuum.

The CARS primary functions are to:

- remove air and non-condensable gases from the MC during plant startup, cooldown, and normal operation
- provide initial system vacuum for NPM startup
- maintain MC vacuum to support operation of the turbine at various turbine loads and during AOOs

Components of the CARS include:

- liquid ring vacuum pump
- heat exchanger
- seal water separator

- gaseous effluent discharge radiation monitor

The condenser air removal system is located near each main condenser. The CARS design data are provided in Table 10.4-3 and a simplified functional arrangement is provided in Figure 10.4-2.

Systems interfacing with the CARS have isolation capabilities to reduce the potential for cross-contamination between systems.

The CARS materials are based on compatibility with temperature, pressure, and secondary loop water chemistry. The system piping complies with ASME B31.1 requirements.

The quality group for the CARS is Quality Group D as described in Section 3.2. The seismic category is Seismic Category III. Quality group and seismic category designations are in accordance with the guidance provided in RG 1.26 and RG 1.29. In accordance with the guidance provided in RG 1.26, piping, components, and instruments that are Quality Group D correspond to non-nuclear safety piping that is not relied upon to perform a nuclear safety function.

10.4.2.2.2 Component Description

Liquid Ring Vacuum Pump

The liquid ring vacuum pump (LRVP) removes gases and non-condensables from the MC and discharges the exhausted gases into the seal water separator. The LRVP is provided as part of a vendor skid and is designed based on HEI performance standards (Reference 10.4-1).

Seal Water Heat Exchanger

The process side of the seal water heat exchanger is supplied from the seal water separator tank. The seal water heat exchanger supplies cooled flow to the seal water connection on the LRVP. The seal water is cooled by site cooling water.

Seal Water Separator

The seal water separator takes discharge from the LRVP and separates the water from the exhaust gases. The gases are monitored and vented directly to atmosphere. The seal water separator returns excess water to the MC when a high seal water tank level is detected. Initial fill of the seal water separator and liquid ring pumps is provided by the demineralized water system.

10.4.2.2.3 System Operation

For system startup, both condenser air removal systems are used to pull the initial vacuum on an offline main condenser. Using the liquid ring vacuum pump from both CARS rapidly reduces the pressure in the MC. Once the MC has achieved the desired vacuum pressure, one LRVP is switched off.

During normal operation, only one CARS is operating. The primary flow path consists of piping from the MC to the LRVP. The LRVP continuously removes gases, including non-condensable gases from the MC, while maintaining a vacuum at the desired setpoint. The gases are exhausted through piping connected to the seal water separator tank, in which moisture and gases are separated. The separated moisture is recycled as seal water for the LRVP. The gases are routed through piping connected to a silencer and then exhausted to the atmosphere.

The MC vacuum conditions are monitored during normal operation. If the vacuum decreases below the setpoint, the LRVP on the second skid is started to maintain a vacuum in the MC. The connection of the MC to the vacuum pumps is controlled by valves at the inlet of each vacuum pump.

Level is maintained in the seal water separator tank by makeup from the demineralized water system or letdown back to the MC. Tank level and LRVP level are equalized when the equipment is not in operation. When the LRVP is started, seal water flow is initiated and tank level controlled to provide adequate seal water in the LRVP.

The CARS is supplied with drains to the balance-of-plant drain system, which provides the capability during or after a contamination event to route liquid to the radioactive waste drain system. Before the air is exhausted, the radioactivity of the exhausted air is monitored. Instrumentation is provided for monitoring radiation levels at the discharge of the CARS by the radiation monitoring system as described in Section 11.5.

For system shutdown, the LRVP is stopped and the CARS is isolated from the MC.

Off-normal system operation is indicated by high system exhaust radiation or by degrading or lost condenser vacuum. Radiation indication is provided in the main control room. High level radiation may require NPM shutdown, including stopping the LRVP and closing the CARS isolation valves. The allowable radioactivity high-level alarm in the CARS exhaust is set in accordance with 10 CFR 50, Appendix I. Process effluent radiation monitoring and sampling is discussed in Section 11.5.

Degrading MC vacuum conditions initiate operator action to start the idle LRVP to augment or replace the original running pump as applicable. Loss of condenser vacuum is an anticipated operational occurrence discussed in Section 15.2.3.

10.4.2.3 Safety Evaluation

The CARS serves no safety-related functions, is not credited for mitigation of a design basis accident, and has no safe shutdown functions. General Design Criterion 2 was considered in the design of the condenser air removal system. No safety-related structures, systems, or components are affected by this system from the effects of natural phenomena such as earthquakes. The design and layout of the CARS include provisions that ensure that a failure of the system will not adversely affect the functional performance of safety-related systems or components.

The CARS meets RG 1.29 in that it is not located in areas that contain safety-related components and is not required to operate during or after an accident. The CARS is Seismic Category III.

General Design Criterion 3 was considered in the design of the condenser air removal system. The design of the CARS protects SSC from the effects of fire and explosion, and minimizes the probability of fire and explosion. The condenser exhaust gas consists mainly of air and ammonia. Ammonia concentrations may be considered minimal since the source is from pH control of the condensate and feedwater system and from hydrazine reactions with oxygen in the CFWS. The source of the hydrazine is the feedwater treatment chemical skid. For a pressurized water reactor, no hydrogen buildup is anticipated and only trace amounts of oxygen are released in the condenser. The amount of hydrogen and other potential explosive gases released in the condenser is negligible compared to the amount of air and steam being evacuated by the system. Therefore, the potential for explosive mixtures within the condenser air removal system does not exist. The fire protection program is described in Section 9.5.1.

General Design Criterion 4 was considered in the design of the condenser air removal system. The design of the CARS provides protection of safety-related SSC from the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents. A failure of the CARS does not prevent the operation of a safety-related system because no safety-related systems are located in the TGB.

General Design Criterion 5 was considered in the design of the condenser air removal system. The components in the CARS are not shared among NPMs; therefore, failure of the CARS does not significantly impair the ability of other NPMs to perform their safety functions.

General Design Criterion 60 was considered in the design of the condenser air removal system. Radiation monitoring equipment continuously monitors gaseous effluent with indication and high radiation alarms in the main control room. Isolation valves at the discharge of the seal water separator tank can be controlled from the main control room. A negligible amount of dissolved oxygen is present in the condensate and MC hotwell inventory in comparison to the amount of gas and vapor being evacuated by CARS. There is no potential for explosive mixtures within CARS that would result in the release of radioactivity above the regulatory limits. Therefore, the CARS design satisfies GDC 60 and is not required to be designed to withstand the effects of an explosion.

Design Criterion 64 was considered in the design of the condenser air removal system. The CARS meets the requirements of GDC 64 for continuous monitoring for radioactivity in the effluent discharge. Instrumentation is provided at the discharge as described in Section 11.5. The non-condensable gases and vapor mixture discharged from the CARS normally contain negligible amounts of radioactivity during normal plant operation. However, it is possible for the discharged mixture to become contaminated in the event of primary-to-secondary system leakage, and provision is made to detect and isolate this flow and manually route it to BPDS.

Consistent with 10 CFR 20.1101(b), the MC design supports keeping radiation exposures ALARA. To maintain the radiation exposure to operating and maintenance

personnel ALARA, the condenser air removal system is designed to facilitate maintenance, inspection, and testing in accordance with the guidance in RG 8.8.

The CARS design satisfies the requirements of 10 CFR 20.1406 as it relates to minimization of contamination of the facility. The CARS monitors the removed gases for radioactivity and transfers detected radioactive materials to the radwaste processing systems. Further discussion of the facility design features to protect against contamination is provided in Section 12.3.

Detected radioactive material at or above the limits established in 10 CFR 50, Appendix I is isolated in the CARS. The CARS uses the balance-of-plant drain system to route liquid to the liquid radioactive waste drain system for appropriate processing during or after a contamination event.

The CARS has redundant components to ensure that a single component failure does not lead to a loss of condenser vacuum and a subsequent turbine trip. A failure of the CARS does not impact the safe operation of the NPM nor affect safety-related equipment. The CARS has no direct impact on the primary system or the secondary systems. A failure of the CARS results in a slow increase in MC pressure. The loss of MC vacuum trip setpoint is designed so that a turbine trip is initiated before a reactor trip. The loss of MC vacuum condition is described in Section 15.2.3.

10.4.2.4 Inspection and Testing

The CARS and its components are inspected and tested as part of the initial testing and startup program as described in Section 14.2. Plant startup testing and inspection is performed prior to plant operation. The CARS design provides for on-line testing to determine the amount of exhaust flow and monitor MC performance and leakage rates. Flow measuring instrumentation is provided to determine the exhaust flow from the NPM.

The ITAAC are addressed in Section 14.3.

10.4.2.5 Instrumentation

The following instrumentation and controls are provided to monitor and control the system and components of the CARS. Details are shown in Table 10.4-4.

- Temperature monitors are provided for the seal water loop at the inlet side of the LRVP to maintain the temperature below the MC temperature.
- Pressure monitors are provided at the suction of the LRVP with differential pressure provided at the flow control valve.
- The seal water separator tank is provided with level monitoring and level control for tank makeup and letdown. This controls the water for the seal in the LRVP as well.
- A flow gauge is attached to the separator tank for manual measurement of the LRVP exhaust flow. It is used to quantify inleakage and gas, including non-condensable gas removed from the MC.

- Indication is provided at the supply breaker and at the main control room for the LRVP for pump on or off verification.

10.4.3 Turbine Gland Sealing System

The turbine gland sealing system (TGSS) is part of the turbine generator system (TGS) described in Section 10.2 and is shown on Figure 10.2-1. The primary function of the TGSS is to prevent air leakage into the turbine under vacuum and prevent steam leakage out of the turbine under pressure for all load conditions.

10.4.3.1 Design Bases

This section identifies the TGSS required or credited functions, the regulatory requirements that govern the performance of those functions, and the controlling parameters and associated values that ensure that the functions are fulfilled. Together, this information represents the design bases, as defined in 10 CFR 50.2, as required by 10 CFR 52.47(a) and (a)(3)(ii).

The TGSS is part of the TGS, serves no safety-related function, is not credited for mitigation of a DBA, and has no safe shutdown functions. See Section 10.2 for the discussion on how General Design Criteria 2, 4 and 5 were considered in the design of the TGS.

Consistent with GDC 60, the design of the TGSS ensures the capability to control releases of radioactive materials to the environment. Consistent with GDC 64, the TGSS design provides radioactive effluent monitoring in potential discharge pathways to the environment and is designed to meet the requirements of 10 CFR 20.1406 as it relates to minimization of contamination of the facility. See Section 10.4.3.3 for the TGSS safety evaluation.

10.4.3.2 System Description

10.4.3.2.1 General Description

The TGSS performs the following functions:

- prevents air leakage into the turbine under vacuum
- prevents steam leakage out of the turbine under pressure
- provides for the use of redundant steam supplies and controlling devices

The TGSS is part of the TGS, and consists of the following components:

- gland steam condenser
- two gland seal condenser exhauster blowers
- condenser drain hold tank
- desuperheater
- relief valves

- gland steam regulator

The TGSS design details are provided in Table 10.4-5.

10.4.3.2.2 Component Description

Gland Steam Condenser

The gland steam condenser cools the gland steam using feedwater. It is equipped with high-point vents and a drain. Water level in the condenser is monitored.

Gland Seal Condenser Exhauster Blowers

The gland seal condenser exhauster blowers maintain a partial vacuum in the gland steam condenser to prevent the entrainment of air in the gland steam condensate.

Desuperheater

The gland seal desuperheater uses feedwater to cool the steam fed to the TGSS to saturated conditions.

Relief Valves

The relief valves provide overpressure protection to the TGSS.

Gland Steam Regulator

The gland steam regulator maintains seal steam pressure.

10.4.3.2.3 System Operation

The gland seal steam prevents the escape of steam from the turbine shaft and casing penetrations and the glands of large turbine valves. Sealing steam is distributed to the turbine shaft seals through the steam-seal header. This sealing steam is supplied from either the auxiliary boiler system or from the main steam system extracted ahead of the turbine control valves. Steam flow to the header is controlled by the steam-seal feed valve, which responds to maintain the steam-seal supply header pressure. The gland seal desuperheater uses feedwater to cool the steam fed to the TGSS to saturated conditions.

During plant startup, the ABS provides steam until sufficient steam flow is available from the MSS. The TGSS steam pressure is automatically maintained by pressure-regulating valves provided in both the MSS and auxiliary steam system supply piping. Excess steam is returned to the gland steam condenser through the spillover control valve, which automatically opens to bypass excess steam from the TGSS. Automatic and manual controls are provided to regulate gland steam pressure and temperature.

At the outer ends of the turbine glands, collection piping routes the mixture of air and excess seal steam to the gland steam condenser. The gland steam condenser internal pressure is maintained at a slight vacuum by motor driven blowers. Condensate from the steam-air mixture drains to the MC while non-condensables are exhausted to the vents, drains, and relief system through a common discharge line shared by the vapor extractor blowers.

The mixture of non-condensable gases discharged from the gland steam condenser blower is not normally radioactive; however, in the event of significant primary-to-secondary system leakage due to an SGTF, it is possible to discharge radioactively contaminated gases. The TGSS effluents are monitored by a radiation monitor and grab sample point located on the exhaust line to the gland seal steam vent.

10.4.3.3 Safety Evaluation

The turbine gland sealing system is part of the turbine generator system and has no safety-related functions, is not credited for mitigation of a DBA, and has no safe shutdown functions. General Design Criterion 60 and 64 were considered in the design of the turbine gland sealing system. The TGSS design satisfies GDC 60 with regard to control of radioactive material releases to the environment and GDC 64 with regard to monitoring radioactive releases, and is designed to meet the requirements of 10 CFR 20.1406 as it relates to minimizing contamination of the facility. The TGSS is anticipated to contain negligible quantities of radioactive contaminants. However, in the event of significant primary-to-secondary system leakage due to a SGTF, the leakage can be isolated. The TGSS effluent duct is equipped with a radiation monitor and provision for grab sampling. The radiation monitor alarms at high and high-high levels in the MCR and the gland seal exhaust has remote manual isolation capabilities.

10.4.3.4 Inspection and Testing

The TGSS is inspected and tested prior to plant operation as described in Section 14.2.

The ITAAC are addressed in Section 14.3.

10.4.3.5 Instrumentation

Instrumentation is detailed in Table 10.4-6. Gland seal pressure is monitored and a pressure controller is provided to maintain the steam-seal supply header pressure by providing signals to the steam-seal supply valve. Control valves are used to regulate the appropriate pressure to the turbine glands.

10.4.4 Turbine Bypass System

The turbine bypass system is provided as part of the turbine generator system described in Section 10.2 and is shown on Figure 10.2-1. The TBS provides main steam directly from the steam generators to the main condenser in a controlled manner to remove heat from the NPM following a reduction or loss of electrical load.

10.4.4.1 Design Bases

This section identifies the TBS required or credited functions, the regulatory requirements that govern the performance of those functions, and the controlling parameters and associated values that ensure that the functions are fulfilled. Together, this information represents the design bases, as defined in 10 CFR 50.2, as required by 10 CFR 52.47(a) and (a)(3)(ii).

The TBS serves no safety-related function is not credited for mitigation of a DBA, and has no safe shutdown functions. It is part of the TGS discussed in Section 10.2. See Section 10.2 for discussion of GDC 2, 4, and 5 and additional design bases.

Although not credited for compliance with PDC 34, the TBS can be used to provide a residual heat removal function for normal NPM shutdown, eliminating the need to rely solely on safety systems or components. The decay and residual heat removal safety function per PDC 34 is performed by the decay heat removal flowpath and the containment isolation function of the containment system, that is, the main steam isolation valves (MSIVs) and the feedwater isolation valves. Conformance with PDC 34 is further discussed in Section 5.4.

The TBS is designed to

- transfer steam to the condenser, bypassing the turbine,
- bypass steam automatically as needed,
- bypass steam for load rejection without additional release mechanisms,
- bypass steam to accommodate step-load changes at the required speeds, and
- provide NPM cooldown by steam bypass.

The TBS has the capacity to bypass the rated power steam flow to the MC at full power operation. The TBS total flow capacity, in combination with bypass valve opening time, pressurizer (PZR) size, and the reactor power control system is sufficient to sustain a rated power normal load rejection (electrical load), without generating a reactor trip, and without requiring actuation of the main steam safety valve.

The NPM design is capable of step load changes from steady state conditions, as described in Section 10.2.2, dumping the steam from the main steam header directly to the condenser. The turbine bypass valve is automatically controlled to protect the reactor during turbine load transients or loss of electrical load. For these load rejections, the TBS operates in conjunction with the control systems used for the load change to meet the design basis requirements without generating a reactor trip.

10.4.4.2 System Description

10.4.4.2.1 General Description

The TBS is part of the turbine generator system described in Section 10.2 and is shown on Figure 10.1-1.

Turbine bypass components include:

- turbine bypass valve
- turbine bypass desuperheater

The TBS consists of a line connected to the main steam combined header, downstream of the MSIVs and upstream of the turbine stop valve, with a regulating valve and an inline desuperheater discharging to an MC.

For load rejections, the TBS operates in conjunction with the control systems used for the load change to meet the design basis requirements without generating a reactor trip.

Quality group standards and seismic design information for the TBS are provided in Section 3.2.

10.4.4.2.2 Component Description

Table 10.4-7 provides the TBS component details.

Turbine Bypass Valve

The turbine bypass valve dumps steam from the main steam header, through the desuperheater to the condenser. It is located near the turbine and is capable of throttling the full bypass flow from the turbine to the condenser.

Desuperheater

The desuperheater is downstream of the turbine bypass valve to reduce the steam temperature because highly superheated steam directly entering the condenser could damage the condenser tubes. The desuperheater cooling water is directly injected into the bypassed steam from the CFWS.

10.4.4.2.3 System Operation

For NPM startup, the turbine bypass valve is open. The turbine bypass valve is used to control the steam generator (SG) pressure, which determines the highest achievable primary side temperature during heatup operations. The bypass valve pressure setpoint is adjusted during startup to control steam flow as required. Operation during power descent is the reverse of power ascent. Decay heat and sensible heat is removed by the TBS to cool the plant and bring it to safe shutdown. During normal operation, the TBS is not used.

The TBS is designed to reduce the possibility of reactor transients during off-normal operation. A turbine or generator trip causes the turbine stop valve to quickly isolate, causing an increase in steam pressure. The bypass valve then opens either on an anticipatory signal or on high steam line pressure. While the bypass line and MC are sized for bypass flow to prevent a reactor trip, continuous operation with high bypass flow is not desirable. Depending on the cause of the event and

expected time to return to normal operation, the NPM can either be shut down or remain operating on bypass flow at full or reduced power.

A loss of circulating water flow or condenser vacuum triggers the control system to block opening the bypass valves and can trip the reactor.

An unintentional opening of the turbine bypass valve could cause an overcooling event and an increase in reactor power. Refer to Section 15.1.3 for more information.

10.4.4.3 Safety Evaluation

The TBS has no safety-related function, is not credited for mitigation of a DBA, and has no safe shutdown functions. The TBS is part of the TGS. Refer to Section 10.2 for discussion concerning GDC 2, 4, and 5.

Compliance of the turbine bypass system with BTP 3-3 and BTP 3-4 is discussed in Section 3.6.1. A discussion of the effects of the TBS equipment malfunctions on the reactor coolant system (RCS) is provided in Table 10.3-3.

Principal Design Criterion 34 was considered in the design of the turbine bypass system. Although not credited for PDC 34 compliance, the TBS can be used to provide a residual heat removal function for normal NPM shutdown, eliminating the need to rely solely on safety systems or components. The requirements of PDC 34 are performed by the decay heat removal flowpath and the containment isolation function of the containment system. Conformance to PDC 34 is further discussed in Section 5.4. The turbine bypass system design supports the intent of PDC 34 as it can provide a residual heat removal function for NPM shutdown, eliminating the need to rely solely on safety systems or components. The TBS can be used cool the NPM to safe shutdown heat levels. The TBS design also satisfies the requirements of 10 CFR 20.1406 as it relates to minimization of contamination of the facility.

10.4.4.4 Inspection and Testing

Before the TBS is initially placed in service, the turbine bypass valve is tested as described in Section 14.2 to verify proper function. The TBS piping and valves are accessible for inspection. Inservice inspection or testing is not required except for the turbine bypass valve, which is included in the inservice inspection program.

The ITAAC are addressed in Section 14.3.

10.4.4.5 Instrumentation and Control

Table 10.4-8 lists the instrumentation used to control the TBS. Pressure and valve position indications are also provided in the MCR.

The module protection system and module control system are used to control flow rate for warming of the MSS lines and establishing steam flow during startup. The bypass valve can divert main steam during normal operation while maintaining the required load operational backpressure at the SG. The MCS logic provides the ability to bypass

low RCS average temperature control in order that the turbine bypass valve can be used to cool down the plant. Interlocks block actuation of the turbine bypass valve on high condenser pressure (low vacuum) or on a circulating water system trip.

10.4.5 Circulating Water System

The principal function of the circulating water system (CWS) is to provide cooling water to the main condensers. The CWS consists of two duplicate cooling water subsystems, each designed to deliver cooling water to six main condensers. A single subsystem is discussed unless otherwise noted.

10.4.5.1 Design Bases

This section identifies the CWS required or credited functions, the regulatory requirements that govern the performance of those functions, and the controlling parameters and associated values that ensure the functions are fulfilled. Together, this information represents the design bases, defined in 10 CFR 50.2, as required by 10 CFR 52.47(a) and (a)(3)(ii).

The CWS serves no safety function, is not credited for mitigation of a DBA, and has no safe shutdown functions. General Design Criteria 2, 4, and 5 were considered in the design of the CWS. No safety-related SSC are affected by the effects of natural phenomena such as earthquakes. The design of the CWS provides protection of safety-related SSC from the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents.

There are no safety-related components in the CWS that are shared among NPMs; therefore, failure of the CWS does not impair the ability of other NPMs to perform their safety functions. See Section 10.4.5.3 for the CWS safety evaluation.

Consistent with GDC 60, the design of the CWS ensures the capability to control releases of radioactive materials to the environment. Consistent with 10 CFR 20.1101(b), the CWS design supports keeping radiation exposures as low as reasonably achievable (ALARA). Consistent with 10 CFR 20.1406, the CWS is designed to meet the requirements as it relates to minimization of contamination of the facility. Further discussion of the facility design features to protect against contamination is provided in Section 12.3.

The CWS design parameters are provided in Table 10.4-9.

10.4.5.2 System Description

10.4.5.2.1 General Description

The CWS is a nonsafety-related system that provides a continuous supply of cooling water to the main condensers and rejects heat to the environment. The CWS is the normal heat sink for the NuScale Power Plant. For the 12-NPM design, the CWS is composed of two identical circulating water subsystems, each responsible for delivering cooling water to the main condensers of six condensate

and feedwater systems. There is no interconnected piping between the two subsystems. The CWS is shown in Figure 10.4-3.

The components of the CWS consist of:

- three circulating water pumps
- three traveling screens (one per pump)
- chemical injection system
- mechanical draft cooling tower banks and basin
- cooling tower makeup and blowdown

The CWS is a moderate energy fluid system. Design considerations based on the effects of failures of moderate energy fluid systems on safety-related systems are addressed in Section 3.6.

10.4.5.2.2 Component Description

The CWS component design parameters are provided in Table 10.4-9.

Circulating Water Pumps

Three 33 percent capacity circulating water pumps take suction, through a traveling screen, from dedicated CWS pump bays that are connected directly to the cooling tower basin. The pump discharge lines supply circulating water to two headers. Each header is responsible for maintaining circulating water flow to the two water boxes in each of three condensers. Each pump discharge line has a valve located between the pump discharge and the common header to permit two-pump operation during pump maintenance. The alpha pump of each subsystem has a minimum flow valve that returns flow to the cooling tower basin. This valve is used during system filling.

Traveling Screens

Continuously moving traveling screens located at the entrance to each individual pump bay prevent debris from entering the CWS pump bay from the cooling tower basin water.

Cooling Tower

The CWS uses a single cooling tower arrangement to reject heat to the atmosphere, consisting of mechanical, induced-draft, counterflow cooling tower cells. Each of the cells includes a motor-driven, mechanical-draft fan and isolation valve. Each tower is sized to support the full-power operation of up to six NPMs during the summer months with one tower segment (cell) not operating during all but the three warmest summer months. The number of cooling tower cells and the horsepower of each cell's fan is site-specific, dependent on the design ambient temperature.

The tower cells may be bypassed, partially bypassed, or fully utilized as needed depending on the desired configuration, heat load, and ambient conditions. During cold weather operations, the CWS provides the capability to reverse cooling tower airflow.

The cooling tower basin serves for collection and storage of the circulating water inventory, and is sized to provide surplus inventory for several hours of extended operation without makeup.

The cooling towers are physically located so that their failure has no physical interaction with other plant structures.

Cooling Tower Makeup and Blowdown

Makeup water to the cooling tower basin is supplied by the utility water system (Section 9.2.9). Automatic makeup to the cooling tower basin is actuated by water level instrumentation.

Makeup to and blowdown from the CWS is controlled by the makeup and blowdown throttling control valves. These valves, along with a chemical feed system, provide chemistry control in the CWS in order to maintain a noncorrosive, nonscale-forming condition and limit biological growth in CWS components. Five cycles of concentration for fresh water has been designed for sizing the cooling tower makeup and blowdown rates. The cycles of concentration is site-specific, dependent on makeup water quality.

The site's single point discharge to the environment accepts the cooling tower blowdown, and is located to prevent recirculation to the makeup water intake.

Chemical Treatment

The CWS chemistry is maintained by a chemical treatment system located adjacent to the cooling tower basin, which includes tanks, pumps, and associated piping and components to inject biocide, dispersant chemical, and scale inhibitor into the cooling tower basin to maintain acceptable chemistry.

The chemicals used are dependent upon site selection and subsequent water analyses. Site selection determines the restrictions on the discharge of biocide.

Connections to the process sampling system (PSS) (Section 9.3) are provided for grab samples to monitor total dissolved solids, pH, conductivity, and biocide effectiveness. Chemistry control is maintained manually during startup, and with automated injection in the cooling tower basin during operation, adjusted through feedback from chemical analyzers in the cooling tower basin and in the CWS blowdown line.

Piping and Valves

The underground portions of the CWS piping are constructed of pre-stressed concrete-lined pipe designed to AWWA standards. The remainder is carbon steel

designed to ASME B31.1. The CWS piping is designed to withstand the maximum operating discharge pressure of the circulating water pumps. Piping includes the expansion joints, valves, condenser water boxes, and tube bundles.

Valves are provided in each of the circulating water lines at the inlet to and exit from the condenser waterboxes to allow isolation of portions of the condenser. Provision is made for the addition of a site-specific condenser tube cleaning system. Throttling control valves regulate cooling tower blowdown and makeup.

10.4.5.2.3 System Operation

Startup is accomplished with valve lineup and single pump initiation, followed by venting and chemistry adjustment as needed.

After startup, the CWS is designed for continuous operation with minimal operator involvement. The system is designed such that one circulating water pump is in operation for every two operating main condensers.

Operating circulating water pumps take suction from dedicated pump intake bays and circulate the water through the tube side of six operating main condensers and then back through a piping network to the cooling tower. A mechanical forced-draft cooling tower, described above, cools the circulating water by discharging the water over a network of baffles, called fill. The water then cascades through fill material to the basin beneath the tower and, in the process, rejects heat to the atmosphere primarily via evaporation.

During normal operation, when five or six main condensers are in operation, three circulating water pumps provide full-rated flow to each main condenser to maintain adequate condenser vacuum for turbine operation. The rated flow to each condenser is site-specific, dependent on the design ambient temperature.

The CWS flow to the cooling tower can be diverted directly to the tower basin, through a cooling tower bypass valve, bypassing cooling tower cells to maintain basin temperatures during cold weather operations.

Makeup water to replace water losses due to evaporation, wind drift, and blowdown is supplied by the utility water system.

The CWS chemistry is monitored routinely during operation and controlled by the chemical injection and blowdown systems. A portion of the CWS flow is continuously blown down and replenished with makeup water to maintain acceptable chemistry levels.

During plant shutdown as total system heat load is reduced, portions of the CWS may be removed from service by shutting down cooling tower cells, fans, and circulating water pumps.

The three circulating water pumps are manifolded together and feed into two distribution lines. Each distribution line feeds three main condensers. If one pump trips, the remaining two pumps increase flow on pump runout and can continue to

support six condensers at 70 to 80 percent of normal CWS flow. If two pumps trip, the remaining pump increases flow on pump runout to only 40 percent of normal CWS flow. To maintain adequate condenser backpressure for turbine operation, the six NPMs reduce power. If the three circulating water pumps trip, condenser backpressure is lost and the six NPMs associated with that circulating water subsystem trip.

If the circulating water pumps, the cooling tower, or the circulating water piping malfunctions such that condenser backpressure rises above the maximum allowable value, the MC is no longer able to adequately support NPM operation. Because each loop of the CWS is shared by six NPMs a malfunction within a loop affects the operational capability of all six associated NPMs.

A trip of one of the six NPMs served by the circulating water subsystem does not affect the other five. The design requires one CWS pump for every two main condensers that are online to provide full flow.

To accommodate flooding due to rain or makeup valve malfunction, basin overflow is piped to the single point discharge to the environment.

The circulating water pumps are not required during a DBA.

10.4.5.3 Safety Evaluation

The CWS serves no safety function, is not credited for mitigation of a DBA, and has no safe shutdown functions.

General Design Criterion 2 was considered in the design of the circulating water system. No safety-related structures, systems, or components are affected by this system from the effects of natural phenomena such as earthquakes. The design and layout of the CWS include provisions that ensure that a failure of the system will not adversely affect the functional performance of safety-related systems or components. The CWS system meets RG 1.29 in that the CWS is not located in areas that contain safety-related components and is not required to operate during or after an accident.

General Design Criterion 4 was considered in the design of the circulating water system. The design of the CWS provides protection of safety-related SSC from the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents.

The TGB does not contain safety-related equipment; thereby eliminating the possibility of damage as a result of CWS line break. Water from a circulating water pipe or expansion joint leak would drain through the building doors and vent openings, and then away from other buildings as controlled by the site grading. The soil around the TGB and the cooling towers is sloped away from structures, thus a failure of the water basin of the cooling towers has no effect on other structures. The flooding evaluation is addressed in Section 3.4.

General Design Criterion 5 was considered in the design of the circulating water system. The sharing of the CWS across six NPMs does not impair the ability of the other

NPMs to perform their safety functions. The use of common CWS equipment to accomplish the cooling of six or less condensers does not have a significant effect on system availability and operability as described in Section 10.4.5.2.3.

General Design Criterion 60 was considered in the design of the circulating water system. Consistent with GDC 60, the CWS design controls radioactive material releases to the environment. The CWS is anticipated to contain negligible quantities of radioactive contaminants during power operation and during shutdown. Blowdown from the circulating water system is sent to the utility water system site liquid effluent release point. The discharge from this release point is monitored for radioactivity before discharge to the environment. If high radiation is detected at the single point effluent discharge path to the environment, the radiation monitoring system for the UWS provides an alarm in the main control room and locally.

Consistent with 10 CFR 20.1101(b), the CWS design supports keeping radiation exposures ALARA. To maintain the radiation exposure to operating and maintenance personnel ALARA, the CWS is designed to facilitate maintenance, inspection, and testing in accordance with the guidance in RG 8.8.

The CWS design satisfies 10 CFR 20.1406 requirements relating to minimization of contamination of the facility. Further discussion of the facility design features to protect against contamination is provided in Section 12.3.

The CWS provides cooling water to the tube side of the main condensers. In the event of a SG tube leak, radioactive fluid would infiltrate the secondary loop, which would be detected in the MSS. There would have to be a simultaneous failure of the SG tubes and MC tube leak for radiation to leak into the CWS. However, during normal operation the CWS is kept at higher pressure than the condenser shell side, which keeps the leakage into the condenser rather than to the environment. Grab sample locations are checked and blowdown is monitored for radiation.

10.4.5.4 Inspection and Testing

Components of the CWS are accessible for inspection during plant operation or during NPM refueling.

Performance, hydrostatic, and leakage tests associated with pre-installation and preoperational testing are performed on the CWS as described in Section 14.2. The system performance, structural and leaktight integrity of system components are demonstrated by continuous operation.

A test coupon exposure rack is provided in the pump basin for monitoring material performance in the CWS.

A full-power performance test of the CWS is performed prior to initial full-power operation in accordance with ASME PTC 23 (Reference 10.4-2). Inservice inspection is performed of the CWS components as described in Chapter 13.

The ITAAC are addressed in Section 14.3.

10.4.5.5 Instrumentation

System operating parameters are monitored locally and in the MCR as part of the MCS. Main control room alarms are also provided. The operating parameters include cooling tower and pump sump water levels, temperature, pump pressure, and system flow. Instrumentation details are provided in Table 10.4-11. Alarm details are listed in Table 10.4-12.

The motor-operated valve at each pump discharge is interlocked with the pump so that the pump trips if the discharge valve fails to reach the full-open position shortly after starting the pump. Water chemistry is manually adjusted during startup, and monitored routinely during operation with the PSS (Section 9.3). Automatic chemical injection is adjusted with instrumentation in the cooling tower basin and blowdown line. Appropriate PSS indications and alarms are provided in the MCR.

10.4.6 Condensate Polishing System

The condensate polishing system is part of the condensate and feedwater system. The condensate polishing system treats and cleans the feedwater to remove corrosion products and ionic impurities. The feedwater treatment system (Section 10.4.11), a separate part of the condensate and feedwater system, manages chemical addition for pH control and oxygen scavenging.

10.4.6.1 Design Basis

The condensate polishing system (CPS) serves no safety-related functions, is not credited for mitigation of a DBA, and has no safe shutdown functions. See Section 10.4.7 for discussion of GDC 2, 4, and 5.

Consistent with GDC 14, the design of the CPS provides the means to maintain acceptable secondary water chemistry as discussed in the EPRI report series, "PWR Secondary Water Chemistry Guidelines" (Reference 10.4-3) as discussed in Section 10.3.5. This supports the overall objective of maintaining the reactor coolant pressure boundary integrity with an extremely low probability of abnormal leakage, rapidly propagating failure, or gross rupture.

Consistent with GDC 60, the design of the CPS ensures the capability to control releases of radioactive materials to the environment. Consistent with 10 CFR 20.1101(b), the CPS design supports keeping radiation exposures as low as reasonably achievable (ALARA). The CPS is designed to meet the requirements of 10 CFR 20.1406 as it relates to minimization of contamination of the facility.

The operating parameters for the CPS are listed in Table 10.4-13.

10.4.6.2 System Description

10.4.6.2.1 General Description

The CPS is nonsafety related, is part of the condensate and feedwater system (CFWS), and is located in the TGB. The CPS removes corrosion products and ionic

impurities from the CFWS system, provides adequate capacity to treat feedwater at plant startup, and provides adequate capacity for treatment during a condenser leak that may contaminate the CFWS system. The CPS is supported by the condensate polisher resin regeneration system, which restores resin quality to polisher requirements for reuse.

The CPS consists of two skids near the turbine: one condensate polishing skid and one rinse recycle pump skid.

The CPS includes the following major equipment:

- two condensate inlet filters
- condensate polishers (mixed bed deionizers)
- resin filters
- spent resin tanks
- resin supply tank
- resin replacement equipment (valves, hoppers, controls, etc.)

The CPS is Quality Group D, ASME B31.1. The system is designed to Seismic Category III requirements. Input to the CPS equipment is received from downstream of the condensate pumps. Processed flow is returned to the gland steam condenser. A full flow bypass path is provided around the CPS.

The CPS maintains water quality to the parameters shown in Table 10.4-14, to avoid corrosion-induced failure of the reactor coolant pressure boundary. The system is designed to control flow through the condensate polishers to avoid hydraulic surges and additional hydraulic loads due to flow as discussed in Section 10.4.6.2.3. The adequacy of the design to withstand breaks and cracks in high-energy and moderate-energy system piping is discussed in Section 3.6.1.

Corrosion, erosion, and flow-accelerated corrosion (FAC) resistant materials are used for components exposed to wet steam, flashing liquid flow, or turbulent single phase flow where significant loss of material could occur. The degree of corrosion, erosion, and FAC resistance of the material is consistent with specific conditions of the fluid stream involved. A corrosion allowance is included on the design of carbon steel CFWS piping.

The system is designed such that the condensate temperature at the condensate polishers does not exceed the design temperature limit of the resin during normal operation or planned transients.

The PSS and CFWS monitor the CFWS for dilution due to condenser cooling water leakage.

10.4.6.2.2 Component Description

Condensate Filter

Two 100 percent flow condensate filters are upstream of the condensate polishers. They have rinse piping for manual cleaning based on the differential pressure indication.

Condensate Polishers

Two 100 percent redundant condensate polisher trains are provided per NPM. The condensate polisher is a mixed bed deionizer. The polishing capacity meets the feedwater chemistry requirements as specified in Section 10.3.5. CPS components are mounted on the condensate polishing skid and the rinse recycle pump skid. Connections are provided for resin transfer with the resin regeneration equipment, condensate rinse, compressed air, drainage to balance of plant drains, and sampling.

Resin Trap

The resin trap is located downstream of the condensate polisher and collects resin fines that have escaped the polisher.

Resin Filter

The resin filter is located on the condensate polishing skid to filter out potential foreign materials. Plugging is monitored with pressure differential measurement.

Spent Resin Tanks

The spent resin tank is used to store spent resin for shipment offsite.

Resin Supply Tank

The resin supply tank is used to store new resin for use onsite.

COL Item 10.4-1: A COL applicant that references the NuScale Power Plant design certification will determine the size and number of new and spent resin tanks in the condensate polishing system.

Resin Replacement Equipment

The resin replacement equipment is automated to minimize operator involvement. The system is designed to allow use at each CPS through temporary connections. One condensate polisher regeneration system is provided to service up to six CPS in each TGB.

Valves

Ion exchanger isolation valves are designed to permit slow, controlled opening to minimize hydraulic surges on the resin bed, which could damage the resin.

10.4.6.2.3 System Operation

The CPS cleans the CFWS water during startup to meet the secondary water chemistry specifications listed in Section 10.3.5. The water is recirculated between the MC hotwell and the CPS until the water quality is within the specifications. The FWTS (Section 10.4.11) manages chemical addition for pH control and oxygen scavenging. The remainder of the CFWS is described in Section 10.4.7.

During normal operation, the condensate pumps move 100 percent of the condensate flow from the hotwell through the CPS and into the gland steam condenser (Section 10.4.3). Several sampling points provide input to the PSS to monitor CPS performance. The CPS is capable of reducing anticipated impurity levels to the acceptable feedwater levels in Table 10.4-14.

Condensate polishing system bypass piping is provided.

The spent resin is removed from the polishers and replaced with new or regenerated resin. The replacement of resin is done with the polisher out of service. The CPS uses demineralized water for transfer, flushing, and other resin regeneration processes. Spent resin is normally not radioactive. If primary-to-secondary leakage occurs, the CPS resin is transferred into a high integrity container (HIC) or another suitable container and transported to a storage area of the RWB for offsite disposal. No direct piping exists between the turbine building and RWB for this purpose. The resin replacement equipment is instrumented and valves can be remotely operated to allow automation of the entire process.

The Process Control Program (Section 11.4) governs the handling of spent resins and their removal from the site.

Condensate polisher regenerant waste is discharged to the BPDS where it is monitored for contamination. If radioactivity is detected above a predefined set point the regenerant waste is sent to the liquid radioactive waste system for treatment, else it is sent to the plant's single point of discharge to the environment.

The condensate polishers are expected to also be used in abnormal conditions such as MC tube leaks. This allows the plant to continue operation for a short time at full power before shutting down to repair the condenser tube leaks. The flow through the CPS is controlled by the condensate bypass valve.

Design features ensure that in the event of condenser tube leaks, concentrations of chloride and other contaminants are limited to allowable values until the CFWS is isolated.

10.4.6.3 Safety Evaluation

The condensate polishing system (CPS) serves no safety-related functions, is not credited for mitigation of a DBA, and has no safe shutdown functions.

The CPS functions to remove impurities and corrosion products to maintain water quality as specified in the Secondary Water Chemistry Program described in Section 10.3.5.

General Design Criterion 14 was considered in the design of the condensate polishing system. Consistent with GDC 14, the design of the CPS provides the means to maintain acceptable secondary water chemistry as discussed in the EPRI report series, "PWR Secondary Water Chemistry Guidelines." (Reference 10.4-3) as discussed in Section 10.3.5. This supports the overall requirements of GDC 14 of maintaining the reactor coolant pressure boundary integrity with an extremely low probability of abnormal leakage, rapidly propagating failure, or gross rupture. By controlling the water chemistry to avoid corrosion-induced failure of the reactor pressure boundary.

General Design Criterion 60 was considered in the design of the condensate polishing system. Consistent with GDC 60, the CPS design controls radioactive material releases to the environment. The CPS is anticipated to contain negligible quantities of radioactive contaminants during power operation and during shutdown. The system leakage, which may contain radioactivity, is collected and contained in the condensate sump. The leakage collected in the sump is monitored for radioactivity and routed if needed from the BPDS to the liquid waste management system for processing as described in Section 11.2.

The effect of CPS on fission and corrosion product concentrations, and the effect of the quantity of spent resin and regenerant solution on radwaste system requirements is discussed in Sections 11.2, 11.3, and 11.4.

Consistent with 10 CFR 20.1101(b), the CPS design supports keeping radiation exposures ALARA. To maintain the radiation exposure to operating and maintenance personnel ALARA, the (system) is designed to facilitate maintenance, inspection, and testing in accordance with the guidance in RG 8.8. As the CPS is not normally a radiation hazard, no radiation shielding is provided for the CPS components. Consistent with 10 CFR 20.1406, the CPS design supports minimization of contamination of the facility and the environment. Chapters 11 and 12 discuss the potential radiation of a primary to secondary coolant leak.

10.4.6.4 Inspection and Testing

The CPS components are inspected and tested as part of the initial testing and startup program as described in Section 14.2.

The ITAAC are addressed in Section 14.3.

10.4.6.5 Instrumentation

Instrumentation is provided to measure the pressure drop, flow, and outlet conductivity from each polisher to monitor performance. See instrumentation in Table 10.4-15, and see alarms in Table 10.4-16.

10.4.7 Condensate and Feedwater System

The primary function of the CFWS is to supply feedwater with the necessary chemistry, temperature, and pressure to the SG.

Each NPM is supplied with a separate CFWS not shared with other NPMs.

The containment penetrating systems are divided into three portions: internal to containment, the containment and safety-related isolation valve(s), and the nonsafety-related portion external to the NPM.

The CFWS boundary extends from the MC to the flange immediately upstream of the SG feedwater isolation valves (FWIVs). The FWIVs are a part of the containment system (CNTS).

10.4.7.1 Design Bases

This section identifies the CFWS required or credited functions, the regulatory requirements that govern the performance of those functions, and the controlling parameters and associated values that ensure the functions are fulfilled. Together, this information represents the design bases, as defined in 10 CFR 50.2, as required by 10 CFR 52.47(a) and (a)(3)(ii).

Specific feedwater components provide a nonsafety-related, not risk-significant backup to plant safety features. One feedwater regulating valve (FWRV) is located upstream of each CNTS feedwater isolation valve (FWIV), as a means of backup isolation to the containment system FWIV as outlined in Section 6.2.4. Likewise, the feedwater check valve is used as a backup to the FWIV integral check valve to prevent SG backflow. Use of these valves as backup to plant safety features is discussed in Section 15.0.0.

General Design Criteria 2, 4, and 5 were considered in the design of the CFWS. No safety-related SSC are affected by the effects of natural phenomena such as earthquakes. The design of the CFWS provides protection of safety-related SSC from the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents. There are no safety-related components in the CFWS shared among NPMs, therefore failure of the CFWS does not significantly impair the ability of other NPMs to perform their safety functions. See Section 10.4.7.3 for the CFWS safety evaluation.

Consistent with PDC 44, the CFWS is capable of supporting heat removal from the NPM by providing feedwater to the SG for heat transfer to an ultimate heat sink under both normal operating and accident conditions. See Chapter 15 for description of the CFWS functions during accident conditions.

Consistent with GDC 45, the design contains provisions to permit periodic inservice inspection of CFWS system components and equipment.

Consistent with GDC 46, the CFWS design contains provisions to permit appropriate functional testing to ensure structural integrity and leaktightness, operability and performance of active CFWS components, and capability of the integrated CFWS system to function as intended during normal, shutdown, and accident conditions. See Chapter 15 for description of the CFWS functions during accident conditions.

Consistent with GDC 60, the design of the CFWS ensures the capability to control releases of radioactive materials to the environment. Consistent with 10 CFR 20.1101(b), the CFWS design supports keeping radiation exposures as low as reasonably achievable (ALARA). The CFWS is designed to meet the requirements of 10 CFR 20.1406 as it relates to minimization of contamination of the facility.

10.4.7.2 System Description

10.4.7.2.1 General Description

The containment penetrating systems are divided into three portions: internal to containment, the containment and safety-related isolation valve(s), and the nonsafety-related portion external to the NPM. The three portions of the system are shown on Figure 10.1-1. The CFWS provides the upstream nonsafety-related portion.

The CFWS includes the following equipment and components:

- condenser (Section 10.4.1)
- condenser hotwell (Section 10.4.1)
- condensate storage tank
- condensate pumps
- feedwater pumps
- feedwater heaters (closed-type)
- feedwater regulating and check valves
- condensate polishing subsystem (Section 10.4.6)
- FWTS (Section 10.4.11) providing pH and oxygen control

The CFWS boundary extends from the MC to the upstream flanges of the FWIVs. The CFWS is nonsafety-related and is primarily located within the TGB and RXB, with the exception of some piping and the CST located outside.

The MC condenses turbine exhaust steam and collects it in the hotwell. The condenser hotwell can also receive makeup from the demineralized water system or the CST. The condensate pumps move the condensate from the hotwell through the condensate polishing subsystem (Section 10.4.6) and into the gland steam condenser (Section 10.4.3). After exiting the gland steam condenser, the water is

treated by the FWTS (Section 10.4.11) to adjust the pH and to scavenge oxygen. Following treatment, the condensate continues on into the feedwater portion of the system.

The system sends the feedwater through the FWHs, with the feedwater pumps raising system pressure prior to entry to the SGs. The feedwater continues into the SGs or returns to the condenser hotwell through the feedwater recirculation line. During plant startup, the recirculation path facilitates system chemical cleanup and adjustment of water quality prior to initiating feed to the SGs. Feedwater chemistry is maintained per the guidelines described in EPRI TR-1008224, Rev. 7 (Reference 10.4-3).

Downstream of the high-pressure feedwater heater (HP-FWH), the feedwater header divides into two lines. The feedwater flow in each line then passes through the FWRV, a check valve, the interface flanges, and the containment system FWIV. See Figure 10.1-1.

Downstream of the FWIVs, each feedwater line penetrates the containment vessel (CNV) top head through separate CNV feedwater nozzles. Inside the CNV, each feedwater line is divided into two feedwater lines that connect to the respective SG feedwater plenums through reactor pressure vessel feedwater nozzles.

The redundant decay heat removal system (DHRS) return lines connect with each feedwater line upstream of the junction for the SG inlet lines inside the CNV.

Quality classification of the CFWS equipment and components is provided in Section 3.2. Components, piping, and structures are designed in accordance with applicable codes and standards as described in Sections 3.9.1 through 3.9.3.

Risk-significant equipment is addressed in Section 17.4. Regulatory treatment of nonsafety systems equipment is described in Section 19.3. Quality assurance is addressed in Chapter 17.

10.4.7.2.2 Component Description

Component design data is provided in Table 10.4-17.

Condenser and Condenser Hotwell

A detailed description of the condenser and hotwell is provided in Section 10.4.1.

Condensate Storage Tank

The CST is located external to the TGB. The CST provides a volume for makeup and rejection of condensate to and from the condenser hotwell based on hotwell level. The CST includes the tank, piping, valves, and tank level instrumentation, and is maintained full with the demineralized water system. The necessary vents, drains, and piping connections to the hotwell are included.

Condensate Strainer

A condensate strainer is located upstream of each condensate pump to filter out potential foreign materials.

Condensate Pumps

Condensate pumps are located near the condenser hotwell. The condensate pumps are designed with positive shaft seals to minimize air inleakage. The seals are vented and drained to the MC.

The condensate pumps and pump control system are designed so that loss of one condensate pump does not result in trip of a feedwater pump.

Condensate pump flow is monitored for each pump with minimum flow protection provided through a common recirculation line to prevent pump damage. The recirculation line is sized to support the minimum required flow for two condensate pumps and the gland seal steam exhauster in operation.

The condensate pumps are protected from running with very low net positive suction head (NPSH) without tripping on short transient low levels in the hotwell.

Condensate Polishers

The CPS maintains CFWS water quality in conjunction with the FWTS. The CPS is described in Section 10.4.6.

Gland Seal Condenser

The gland seal condenser cools the gland sealing steam with condensate, and drains it to the condenser. The gland seal condenser is discussed in Section 10.4.3.

Feedwater Treatment System

The FWTS maintains water quality in conjunction with the CPS. The FWTS is described in Section 10.4.11.

Feedwater Heaters

Feedwater heaters preheat the feedwater before returning to the steam generators. This improves the thermodynamic efficiency of the system, reduces plant operating costs, and helps reduce thermal stress on the steam generators.

Condensate is progressively warmed in the tube side of successive FWHs by turbine extraction steam. The FWHs can be isolated and have a full-flow bypass.

Level in each of the FWHs is automatically controlled using a modulating drain control valve on the downstream heater.

Feedwater Heater Vents and Drains

The heater vents and drains subsystem manages the condensing extraction steam flow through the shell side of the FWHs. Cascading drains flow by gravity to the condenser. Drain coolers are used to remove excess heat. Each FWH is individually vented to the condenser.

Feedwater Pumps

Three feedwater pumps are located downstream of the low-pressure feedwater heater (LP-FWH) and the intermediate-pressure FWH (IP-FWH), and upstream of the HP-FWH. Feedwater pump flow is monitored for each pump with minimum flow protection provided through a dedicated recirculation line sized for the pump required minimum flow. The feedwater pumps and pump control system are designed so that the trip of one feedwater pump does not result in a turbine generator trip or reactor trip. Standby feedwater pumps are provided with autostart capability on low pressure or pump trip.

Feedwater Regulating Valves

The FWRVs are used during normal and transient operation to control and equalize feedwater flow to the steam generators. The FWRVs are located in the RXB and are upstream of the FWIVs.

Normal control of the FWRVs is through the MCS. In off-normal conditions the MPS overrides normal control of the valves and can force closure. Each FWRV is designed to fail closed on loss of power or control signal, regardless of the operating mode, and performs a feedwater isolation function as a backup to the FWIV.

Feedwater Check Valves

Two check valves are installed in each feedwater line. Both feedwater check valves prevent reverse flow from the steam generators whenever the feedwater system is not in operation and are designed to withstand the forces of closing after a CFWS line rupture.

The first check valve is upstream of and integral with the FWIV, providing backflow prevention. The second is downstream of the FWRV and is provided for secondary backflow prevention.

Condensate and Feedwater Piping

The CFWS piping layout between components is shown in Figure 10.1-1. The CFWS and SG design include features that minimize the potential for water hammer and subsequent effects. Additional detail is provided in Section 3.6.3.

The CFWS piping meets ASME B31.1 (Reference 10.4-5) requirements. CFWS piping materials are further described in Section 10.3.6 and descriptions of piping and support design are provided in Section 3.6.

The design of the CFWS incorporates considerations to prevent the occurrence of erosion and corrosion. These considerations include material selection, limits on flow velocity, inspection programs, and limits on water chemistry to reduce FAC, erosion, and corrosion of piping and piping components. See Section 10.3.6 for a discussion of FAC.

10.4.7.2.3 System Operation

Following refueling and reconnection of the NPM, the SG is placed in a startup cleanup mode using a condensate pump to circulate condensate through the condensate polishers, the feedwater system, the SG, into the steam lines and back to the condenser hotwell through a steam line low point drain. This alignment serves to fill the SG and set chemistry conditions in the SG and feedwater system. The DHRS isolation valves are opened simultaneously to also fill and clean the DHRS heat exchanger.

Startup and normal operation of the CFWS is an automated process. During plant startup, the CFWS is operated in several different configurations. Two standard recirculation configurations, short-cycle and long-cycle cleanup, are provided to allow for system cleanup and adjustment of water chemistry prior to initiating feed to the SG, as described above.

In the short-cycle cleanup alignment, condensate pumps supply condensate through the polishers, gland seal condenser, low-pressure feedwater heaters, intermediate-pressure feedwater heaters, and back to the condenser through the short-cycle recirculation valve, which is also the condensate pump minimum flow line. During short-cycle cleanup operation, the performance of the condensate polishers is verified, hotwell inventory is deaerated, and CFWS chemistry is brought into specification. In the long-cycle cleanup alignment, the short-cycle cleanup alignment is extended to bypass the feedwater pumps and flow is allowed to pass through the HP-FWH by opening the long-cycle cleanup recirculation valve to the condenser and closing the short-cycle cleanup recirculation valve.

While in long-cycle cleanup, the first feedwater pump is started with the FWIV remaining closed. In this lineup, with at least one condensate and feedwater pump operating and flow directed to the condenser, the CFWS is ready to be placed in service supplying feed to the SG.

Reactor startup can commence after the CFWS has been operating in long-cycle cleanup and chemistry is within allowable limits. The FWIVs are opened and FWRVs placed in service. As feedwater flow through the SGs increases, the long-cycle recirculation valve is closed.

The introduction of steam and roll of the turbine provide extraction steam to the shell side of the FWHs, raising feedwater temperature as CFWS flow through the tube side of the heater increases. Condensate from condensed extraction steam is drained to the condenser as FWH level is stabilized and heater startup vents are closed.

An additional condensate pump and feedwater pump is placed in service to support SG flow requirements (Table 10.4-17). The third condensate and feedwater pumps are set to automatically start (standby).

The CFWS is capable of 100 percent power operation with two condensate pumps and two feedwater pumps in service. The CFWS is able to accommodate the step load changes (Section 10.2.2) without significant deviation from programmed SG water level or a major effect on the feedwater system. The CFWS has the capability of accommodating the necessary changes in feedwater flow to the SG with the steam pressure increase resulting from a 100 percent load rejection.

During normal operation, two condensate pumps take suction from the hotwell providing flow through the CPS, gland sealing steam condenser, low-pressure feedwater heaters, and intermediate-pressure feedwater heaters to the suction of the feedwater pumps. The feedwater pumps take suction from the discharge of the IP-FWH driving flow through the HP-FWH to the FWRVs.

For normal operating conditions between 0 and 100 percent load, system operation is primarily automatic. Automatic level controls maintain inventory levels in the condenser hotwell, FWHs, and the condensate storage.

The CFWS also provides cooling flow to the turbine bypass desuperheater to cool the up to 100 percent superheated bypass steam to saturated conditions.

The PSS (Section 9.3.2) continuously monitors pH, conductivity, and oxygen concentration through sample points within the FWS. The PSS also provides the capability to pull and analyze grab samples.

The FWTS (Section 10.4.11) provides pH and oxygen control. In conjunction with the CPS. The FWTS maintains CFWS and SG water quality when connected to the NPM. Secondary water chemistry is discussed in more detail in Section 10.3.5.

Shutdown and cooldown of the NPM is an automated process accomplished through coordinated turbine control, feedwater control, and reactivity control. As NPM power is lowered, the FWRV and feedwater pump speed control modulate consistent with SG feed demand as power is reduced.

The automated shutdown lowers power to a hold point, when one feedwater and condensate pump can be secured. Automated shutdown is continued to a second hold point when the turbine is tripped, diverting steam flow through the bypass valve to the condenser. Following turbine trip, the automated shutdown is continued with control rod insertion until the reactor is tripped. Subsequently, a second feedwater pump is shut down when it is no longer needed to support SG feed demand and pressure.

As the reactor is cooled down, feedwater flow is adjusted by condensate pump operation to maintain SG inventory. As the RCS cools and steam generation diminishes SG feed, demand lowers to the SG switchover point, at which feedwater flow is raised to fill the SG and overflow the steam line with flow back to the condenser through the steam line drip leg trap.

The condenser hotwell capacity, CST inlet to the hotwell, and the demineralized makeup water inlet to the CST provide capacity for additional feedwater to the SG to maintain inventory during an off-normal reduction of inventory. The CFWS is designed and operated to prevent transients that could allow steam to enter the feedwater piping.

The condensate pumps are configured to provide redundancy to ensure operations are not interrupted or reduced in the event of a pump failure or trip. Upon loss of an operating condensate pump a standby pump is aligned to start automatically in sufficient time that steady flow to the SG is maintained and no trip of a feedwater pump occurs.

The feedwater pumps are configured with a standby pump that starts automatically on a running feedwater pump trip with sufficient response time to maintain steady system flow. The loss of a single feedwater pump does not result in a turbine generator or reactor trip.

Loss of normal AC power results in a loss of feedwater to the SG. A reactor trip occurs on low steam pressure or low feedwater flow as a result. The sudden loss of feedwater flow and termination of steam flow to the turbine causes the SG heat removal rates to decrease, which results in an increase in the reactor coolant temperature. As a result, the reactor coolant expands and surges into the PZR. The DHRS initiates and establishes decay heat removal. The RCS pressure and temperature are maintained within required limits. See Section 15.2.7 for a discussion of the loss of normal feedwater.

An excessive feedwater flow malfunction causes an increase in feedwater flow resulting in a reduction of steam superheat, increased SG inventory, and reduction in outlet temperature. If overcooling of the RCS occurs, a negative moderator temperature coefficient causes an increase in reactor power and potentially leads to a reactor trip occurs on a high steam pressure or power increase signal. See Section 15.1.2 for a discussion of an increase in feedwater flow.

The loss of feedwater heating malfunction causes a decrease in feedwater temperature that increases heat removal from the RCS and lowers the RCS temperature. A negative moderator temperature coefficient causes a positive reactivity insertion that increases the reactor power and potentially leads to a reactor trip on a power increase signal. See Section 15.1.1 for a discussion of a loss of feedwater heating.

A feedwater line break outside of containment is isolated by the FWIVs. The FWRVs provide a backup isolation to the FWIVs. See Section 15.2.8 for a discussion of feedwater line breaks.

Inadvertent DHRS actuation causes closure of the MSIV and MFIV on the affected side of the secondary system. This increases the secondary side pressure on the affected SG. The RCS pressure and temperature increases at a lower rate. The unaffected SG train steam production is lower than the turbine steam demand. The reactor trips on high steam pressure, high PZR pressure, or high PZR level. See Section 15.6.1 for the inadvertent opening of a reactor safety valve.

A steam line break event refers to a main steam line break ranging from a small break to a double-ended rupture of a main steam line. Initially, the steam flow is increased before the affected steam line is isolated and depressurizes. After a short time of overcooling, the RCS temperature and pressure increase. If the steam line break is inside the containment, the reactor trips on high containment pressure. If the steam line break is outside the containment, the reactor trips on low steam pressure or low PZR level or pressure. For breaks outside containment, the break flow is terminated by closure of the MSIV on the affected SG or after CFWS is isolated and the SG boils dry. For breaks inside the containment, the break flow is terminated after feedwater flow is isolated and the SG dries out. A steam line break is discussed in Section 15.1.5.

The SGTF is defined as a double-ended rupture of a single SG tube. Primary coolant from the RCS enters the secondary system, driven by the pressure difference between the RCS and the secondary side of the SG. As a result, the inventory, pressure, and activity in the affected SG increase. The break flow depressurizes the RCS and decreases the PZR level. On the secondary side, the FWIVs and FWRVs isolate on a low-low PZR level containment isolation signal to prevent excessive loss of RCS inventory. The reactor trips on high steam pressure, low PZR pressure, or low PZR level. An SGTF is discussed in Section 15.6.3.

The sudden loss of CFWS flow at power causes the SG heat removal rates to decrease, which causes the reactor coolant temperature to increase. The RCS fluid expands, flows into the PZR, thereby increasing the pressure. The SG liquid levels decrease following the termination of feedwater flow. The reactor trips on high PZR level and pressure, or low feedwater flow. This event results in the closure of the MSIVs and the actuation of the DHRS. The DHRS initiates and establishes decay heat removal and control RCS pressure and temperature within required limits. A loss of feedwater flow is discussed in Section 15.2.7.

10.4.7.3 Safety Evaluation

The portion of the feedwater piping from the SG feedwater nozzles to the outermost FWIV flange is classified as safety-related Quality Group B. This portion of the system is designed to ensure feedwater system isolation in accident situations, such as a feedwater line break, and containment isolation in cases in which the feedwater system could potentially become a containment bypass pathway (e.g., SGTF) and is included in the containment system described in Section 6.2. One FWRV is located upstream of each containment system FWIV as back up for the performance of the FWIV design bases functions. Likewise, the feedwater check valve is used as a back up to the FWIV integral check valve to prevent SG backflow. Both valves are nonsafety-related and not risk significant.

General Design Criterion 2 was considered in the design and arrangement of the condensate and feedwater system. No safety-related structures, systems, or components are affected by this system from the effects of natural phenomena such as earthquakes. The isolation backup portions of CFWS are contained in the RXB, which is a Seismic Category I structure designed to withstand the effects of natural phenomena, such as earthquakes, tornadoes, hurricanes, floods, tsunamis and seiches. The adequacy of the structural design of the RXB to withstand these phenomena is further

described in Section 3.3 for wind and tornadoes, Section 3.4 for flooding, Section 3.5 for missile protection, and Section 3.7 for earthquakes. Thus, these backup portions of CFWS are designed to remain functional during and after a safe shutdown earthquake and meet the guidelines of RG 1.29. The RXB is designed as an engineered barrier to withstand a postulated design basis missile. Consistent with RG 1.117, this satisfies GDC 2 by the proper design and use of missile barriers (i.e., the RXB) to protect essential SSC against potential missiles generated by tornado or hurricane winds.

The nonsafety-related portions of the CFWS are not located in areas that contain safety-related components and are not required to operate during or after an accident. No safety-related SSC are affected by the effects of natural phenomena such as earthquakes. The seismic and quality classifications of CFWS components are described in Section 3.2. Flooding is evaluated in Section 3.4.1.

General Design Criterion 4 was considered in the design and arrangement of the condensate and feedwater system. The design of the CFWS provides protection of safety-related SSC from the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents. Internally generated missiles, pipe whip, and jet impingement forces associated with pipe breaks do not prevent the CFWS from performing safety functions. Isolation backup portions of the CFWS are protected from pipe whip and jet impingement forces resulting from breaks in nearby systems (including the CFWS of adjacent NPMs) by the piping design layout. These portions of the CFWS are physically separated from safety-related systems in the RXB and have no adverse impacts on safety functions. Refer to Section 3.12 for a description of the design of piping systems and piping supports used in Seismic Category I, Seismic Category II and non-seismic systems. Feedwater components and piping located outside of the RXB are classified Quality Group D and Seismic Category III. The analysis of a postulated high-energy line failure is provided in Section 3.6.1 and Section 3.6.2.

Isolation backup portions of the CFWS which are located within the RXB are protected from the effects of missiles generated by plant equipment failures outside the RXB. See Section 3.5 for the discussion of missile protection.

Refer to Section 3.6.3 for a description of SG design features implemented to prevent fluid flow water hammer. The potential for water hammer in the CFWS is minimized by design features such as pipe slope, the use of available drains before startup, and adjustment of valve closure timing.

General Design Criterion 5 was considered in the design of the condensate and feedwater system. The components in the CFWS are not shared among NPMs; therefore, failure of the CFWS does not impair the ability of other NPMs to perform their safety functions.

The condensate and feedwater system is designed to avoid FAC:

- feedwater piping and components are constructed using material resistant to FAC
- flow velocity and changes in flow direction is limited consistent with the guidance of NSAC-202L (Reference 10.4-4)

- feedwater chemistry is continuously monitored and controlled

The CFWS and supporting systems monitor and control secondary water chemistry to maintain water quality specifications during normal operation and AOOs. Flow-accelerated corrosion is discussed further in Section 10.3.6.3.

Principal Design Criterion 44 was considered in the design of the condensate and feedwater system. Consistent with PDC 44, the CFWS is capable of supporting heat removal from the NPM by providing feedwater to the SG for heat transfer to an ultimate heat sink under both normal operating and accident conditions. The CFWS provides nonsafety-related FWRVs and check valves as backup to the safety-related containment system FWIVs. The FWIVs are designed to isolate components, subsystems, or piping to support operation of the DHRS and maintain SG inventory during all plant conditions. See Section 5.4.3 for a discussion of the DHRS. Isolation capability, redundancy, and leak detection is provided to ensure that the safety function can be accomplished.

General Design Criterion 45 was considered in the design of the condensate and feedwater system. Consistent with GDC 45, the design contains provisions to permit periodic inservice inspection of CFWS system components and equipment. The CFWS system is designed to permit appropriate periodic inspection of components, such as heat exchangers and piping, to ensure the integrity and capability of the system.

General Design Criterion 46 was considered in the CFWS design. Consistent with GDC 46, the CFWS design contains provisions to permit appropriate functional testing to ensure structural integrity and leaktightness, operability and performance of active CFWS components, and capability of the integrated CFWS system to function as intended during normal, shutdown, and accident conditions. The CFWS system is nonsafety-related. Each FWRV is designed to provide backup to the FWIV safety function. Both valves are designed to fail closed on loss of motive force or loss of control signal.

General Design Criterion 60 was considered in the design of the condensate and feedwater system. Consistent with GDC 60, the CFWS design controls radioactive material releases to the environment. Consistent with 10 CFR 20.1101(b), the CFWS design supports keeping radiation exposures ALARA. To maintain the radiation exposure to operating and maintenance personnel ALARA, the CFWS is designed to facilitate maintenance, inspection, and testing in accordance with the guidance in RG 8.8. The CFWS design satisfies the requirements of 10 CFR 20.1406 in that it supports minimization of contamination of the facility and the environment. Primary-to-secondary leakage from an SGTF has the potential to introduce radioactive material into the CFWS. Main steam and condensate monitoring with MSS and CFWS isolation capabilities minimize the contamination and release to the environment. The CFWS drains to the BPDS, which discharges to the radioactive waste drain system should the CFWS become contaminated.

Detected radioactive material in the condenser is managed by the CARS (Section 10.4.2). Radiation monitors are also provided on the exhaust from the gland seal condenser (Section 10.4.3).

The results of the CFWS failure modes and effects analysis is presented in Table 10.4-18.

10.4.7.4 Inspection and Testing Requirements

The CFWS is inspected and tested prior to plant operation as described in Section 14.2. Because the CFWS is in use and essential parameters are monitored during normal plant operation, the satisfactory operation of the system components demonstrates system operability.

The ITAAC are addressed in Section 14.3.

10.4.7.5 Instrumentation Requirements

Feedwater instrumentation is designed to facilitate automatic operation, remote control, and monitoring of system parameters. Instrumentation and controls are provided in the MCS to monitor variables and control CFWS operation over its anticipated range of normal operation, AOOs, and accident conditions to ensure adequate safety. Feedwater parameters monitored and instrumentation details are listed in Table 10.4-19.

Positioning of the FWRVs and speed control of the feedwater pumps are functions of the MCS. For each SG, the feedwater control system maintains the feedwater flow supply. The MCS is able to accommodate specified step load changes without a significant deviation from the programmed control band or major effect on the feed system. See Table 10.4-17. Chapter 7 describes the MCS.

10.4.8 Steam Generator Blowdown System

This section is applicable only to pressurized water reactor SG designs that incorporate a blowdown system. As described in Section 5.4.1, the NuScale Power Plant SG design does not use a blowdown system. Therefore, this section is not applicable to the NuScale design.

10.4.9 Auxiliary Feedwater System

The NuScale Power Plant design neither requires nor uses an auxiliary feedwater system. Therefore, this section is not applicable to the NuScale design.

The DHRS (Section 5.4.3) performs some functions similar to an auxiliary feedwater system. However, as compared to an auxiliary feedwater system, the DHRS differs substantially in its design, operation, and relationship to the small break loss-of-coolant accident (LOCA) plant response.

10.4.10 Auxiliary Boiler System

The ABS is a nonsafety-related non-seismic system designed to supply steam to systems where main steam is not available or not preferred. The system is supplied by the COL applicant.

10.4.10.1 Design Bases

This section identifies the ABS required or credited functions, the regulatory requirements that govern the performance of those functions, and the controlling parameters and associated values that ensure that the functions are fulfilled. Together, this information represents the design bases, as defined in 10 CFR 50.2, as required by 10 CFR 52.47(a) and (a)(3)(ii).

The ABS serves no safety function, is not credited for mitigation of a DBA, and has no safe shutdown functions.

General Design Criteria 2, 4, and 5 are considered in the design of the ABS. No safety-related SSC are affected by the effects of natural phenomena such as earthquakes. The design of the ABS provides protection of safety-related SSC from the environmental conditions associated with normal operation, maintenance, testing and postulated accidents. There are no safety-related components in the ABS that are shared among NPMs; therefore, failure of the ABS does not significantly impair the ability of other NPMs to perform their safety functions.

Consistent with GDC 60, the design of the ABS ensures the capability to control releases of radioactive materials to the environment. Consistent with GDC 64, the system is monitored for radioactivity that may be released from normal operations, including anticipated operational occurrences, and from postulated accidents.

Consistent with 10 CFR 20.1101(b), the (system) design supports keeping radiation exposures as low as reasonably achievable (ALARA). Consistent with 10 CFR 20.1406, the ABS is designed to preclude contamination of connecting systems, and thus minimize contamination of the associated systems, facility, and the environment.

The ABS component design parameters are shown in Table 10.4-20.

10.4.10.2 System Description

The ABS is a nonsafety-related non-seismic system designed to supply steam to systems where main steam is not available or not preferred. The ABS consists of two separate systems. The high-pressure system is dedicated to supplying steam to the MHS heat exchangers during startup and shutdown. The primary functions of the low-pressure system are to provide steam to the turbine gland seals, the MC for deaeration, and to the condensate polishing resin regeneration system.

The high-pressure and low-pressure system configurations are depicted on Figure 10.4-4a and Figure 10.4-4b and are comprised of vendor-supplied boiler skid packages. The ABS provides 18,000 lb/hr of 575-degree steam at 1100 psig and 4600 lb/hr of 575-degree steam at 500 psig at the required chemistry quality, during all modes of plant operation including AOOs, for the following functions:

- module heatup system (MHS), described in Section 9.3.4, to heat the primary coolant to initiate natural circulation during startup and shutdown
- turbine gland sealing

- sparging steam for MC deaeration at lower loads
- resin regeneration for the CPS

10.4.10.2.1 General Description

The high-pressure ABS supply header is protected by pressure relief valves and monitored by pressure and temperature transmitters. Supply lines off the header distribute the steam to the MHS. Two high-pressure boilers (one primary and one redundant) supply steam to the MHS. One boiler supports heatup of a single NPM. The simultaneous heatup of an NPM from each group of up to six NPMs can be supported using both high-pressure auxiliary boilers.

The pressure of the returning MHS steam is reduced by a pressure control valve and a flash tank, and collected as condensate in a condensate collection tank with relief valve. Excess steam pressure is vented. The demineralized water system feeds makeup water as needed, and the outlet of the CST flows to the inlet suction of redundant boiler feedwater pumps. Upstream of the feedwater pumps, a chemical addition system injects chemicals for water quality. Feedwater pumps supply redundant ABS boilers with water at the required pressure, and check valves downstream of each pump prevent backflow through the idle pump.

Boiler blowdown is monitored with a flow meter control valve, and the common blowdown header is cooled by a heat exchanger and discharged to the BPDS. Each blowdown stream has a sampling line routed to the PSS to monitor and maintain water quality for the ABS.

A line off the high-pressure steam header is routed to the low-pressure steam header for when the low pressure boiler is out of service. Protected by double blocking valves, a pressure reducer and relief valves, the pressure and temperature downstream of the pressure reducing valve is monitored.

The ABS has provisions for chemical addition for chemistry control of the steam from the auxiliary boiler. During boiler operations, water makeup is provided from a non-radioactive demineralized water source. In order to maintain the chemistry requirements of the system, appropriate additives are used to control oxygen and pH. Each boiler system (low-pressure and high-pressure) has a blowdown line connected to the BPDS. The blowdown is cooled by a heat exchanger after entering the BPDS. Each boiler system has a sample line from the steam supply and the blowdown to the PSS.

COL Item 10.4-2: A COL applicant that references the NuScale Power Plant design certification will describe the site-specific auxiliary boiler system, the chemistry requirements, chemistry maintenance program, and how the system meets the design requirements.

During operation, the low-pressure ABS supply header provides steam to the turbine gland seals during NPM startup, the MC, and the CPS for resin regeneration. It is protected by triple pressure relief valves and monitored by pressure and temperature transmitters. During NPM startup, the MSS flow is not established, and

thus the ABS must supply gland seal steam to the TGSS. This function is transferred to the individual NuScale Power Module MSS when sufficient supply is generated.

For the low-pressure ABS, the flow is monitored by a flow transmitter which is used to control the amount of steam fed to the gland seals. The backup steam supply from the high-pressure boiler system is isolated by double block valves and a pressure-reducing valve. The supply line downstream of the pressure-reducing valve is protected by double pressure relief valves. The pressure and temperature downstream of the pressure-reducing valve is monitored by a pressure transmitter and a temperature transmitter.

The steam to the gland seals is routed to the MC, and does not return to the ABS. The condensate tank is protected by a pressure relief valve. The pressure-regulating valve vents steam to maintain pressure which is monitored by a pressure transmitter.

The level inside the tank is measured and monitored by a level transmitter. The demineralized water system, through a level control valve, feeds makeup water into the condensate tank to compensate for the blowdown out of the boiler or boiler drum and the gland seal steam. The outlet of the condensate tank flows to the inlet suction of redundant boiler feedwater pumps. Upstream of the feedwater pumps, a chemical addition system injects essential chemicals required for water quality.

The redundant feedwater pumps supply the boiler and boiler drum with water at the required pressure.

Blowdown from the boiler and boiler drum is measured by an inline flow meter and controlled by a flow control valve. The blowdown from the low-pressure boiler flows into a single header and is discharged to the BPDS. The blowdown stream has a sampling line routed to the PSS to monitor and maintain water quality for the ABS.

The ABS is designed to the requirements of Quality Group D and Seismic Category III. Section 3.2 shows the seismic design and quality group classifications for each major component.

10.4.10.2.2 Component Description

For both the high-pressure and low-pressure portions, the major ABS components include boiler skids, a condensate collection tank, and chemical addition skids. Specific components include:

- packaged boiler with:
  - redundant feedwater pumps
  - deaerator
  - pressure relief
  - fuel supply

- valves
- steam supply piping and fittings
- flash tank
- condensate return tank, piping and fittings
- associated controls

The ABS component design parameters are shown in Table 10.4-20.

Material selection is compatible with operating conditions. See Table 10.4-20 for ABS material.

Boiler

Each ABS boiler generates steam with a site-specific design and fuel supply.

Feedwater Pumps

For each system, the ABS feedwater pumps provide sufficient capacity for the maximum expected steam makeup from the ABS boiler with sufficient reserve. A redundant pump allows for component service during operation.

Deaerator

A deaerator is provided in each ABSs to remove excess gases during operation of the system.

Pressure Relief

A pressure-relief valve is installed on each ABS boiler. It maintains the system pressure below the design maximum and can manage the maximum expected flow from the worst transient.

Valves

The ABS valves are provided on serviced components to allow component selection and servicing during operation. Valves are also provided to seamlessly integrate the use of ABS steam with main steam as desired.

Flash Tank and Condensate Return Tank

A flash tank is used to vaporize and condense hot condensate before returning the liquid to the system. A condensate return tank is provided for each boiler system. It is sized to accommodate the condensate return from the maximum expected number of simultaneous components.

10.4.10.2.3 System Operation

Operations are described as those supporting a single NPM operation status, even if a single NPM is shutdown while the other NPMs are running.

During normal operation, the low-pressure ABS supplies steam to the TGSS gland seals during NPM startup, the MC, and the CPS for resin regeneration. During NPM startup and shutdown when the MSS flow is not established, the ABS supplies gland seal steam to the TGSS. This function is transferred to the MSS of the individual NPM when sufficient supply is generated. The high-pressure ABS supplies steam to the MHS for NPM heatup and shutdown. When the NPM temperature reaches a set point, the ABS supply to the heat exchangers is discontinued and the inlet valve to the MHS heat exchanger isolated. The high pressure ABS can supply steam to the low-pressure header if needed (for backup only) through a pressure-reducing valve.

The ABS does not run continuously, but is brought online when needed. The system is monitored locally and in the MCR. Pressure, temperature, level, flow, remotely-operated valve position transmitters supply the operators with necessary system information.

The ABS is equipped with protective features that activate should the pressure increase beyond allowable limits. Pressure-relief valves automatically vent steam if the pressure increases above a set point to protect the system and prevent overpressure failure. If the water level in the boiler or condensate tank is too high or too low, or if flow rates or temperatures are out of safe operating limits, alarms sound locally in the auxiliary boiler building and in the MCR to alert the operator that attention or action is required. Level transmitters monitor the condensate level inside the condensate collection tanks. If the level falls below a lower limit, the level control valve in the demineralized water supply line modulates open to add water to the tank. If the water level rises above an upper limit, the level control valve modulates closed to allow the boiler feedwater pumps to lower the level in the condensate tank. Flow transmitters on the blowdown of the boilers modulate the downstream flow control valve to regulate the volume of blowdown of the boilers.

The ABS does not need to maintain essential functions in the event of adverse environmental phenomena, pipe breaks, or loss of normal AC power. The ABS is nonsafety-related and is not needed post-DBA.

The system shutdown procedure for the ABS is provided by the equipment manufacturer. The equipment manufacturer provides the sequencing and required checks to shutdown the boiler and accessories safely.

10.4.10.3 Safety Evaluation

The ABS serves no safety function, is not credited for mitigation of a DBA, and has no safe shutdown functions.

GDC 2 was considered in the design and arrangement of ABS components. The ABS is nonsafety-related, but portions of the ABS are contained in the RXB, which is a Seismic

Category I structure, designed to withstand the effects of natural phenomena, such as earthquakes, tornadoes, hurricanes, floods, tsunamis and seiches. Thus the portions of the ABS inside the RXB are designed to remain functional during and after a safe shutdown earthquake (SSE) and meet the guidelines of Regulatory Guide 1.29. The RXB is designed as an engineered barrier to withstand a postulated design basis missile. Consistent with Regulatory Guide 1.117, this satisfies the criteria of GDC 2 by the proper design and use of missile barriers (i.e., the RXB) to protect essential SSC against potential missiles generated by tornado or hurricane winds.

The portions of ABS that are housed in the TGB are nonsafety-related and are not located in areas that contain safety-related components and are not required to operate during or after an accident. No safety-related SSC are affected by the effects of natural phenomena such as earthquakes on the ABS.

General Design Criterion 4 was considered in the design of the auxiliary boiler system. The design of the ABS provides protection of safety-related SSC from the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents. A failure of the ABS that releases the water inventory and the resulting flooding does not prevent the operation of safety-related SSC. The plant flooding evaluation is addressed in Section 3.4. The dynamic impacts from missiles, water and steam system failures are addressed in Sections 3.5 and 3.6, respectively.

General Design Criterion 5 was considered in the design of the auxiliary boiler system. There are no safety-related components in the ABS that are shared among NPMs; therefore, failure of the ABS does not significantly impair the ability of other NPMs to perform their safety functions.

General Design Criteria 60 and 64 were considered in the design of the auxiliary boiler system. Consistent with GDC 60, the design of the ABS ensures the capability to control releases of radioactive materials to the environment. Consistent with GDC 64, the system is monitored for radioactivity that may be released from normal operations, including anticipated operational occurrences, and from postulated accidents.

Process radiation monitors on each high-pressure return line from the MHS heat exchangers monitor the steam or condensate exiting, and a process radiation monitor on the vent of the pressure regulating valve on the high-pressure condensate collection tank monitors the steam venting from the tank. If radiation is detected in the ABS that is greater than the high-high radiation isolation or if system power is lost, the ABS flash tank pressure regulating valve and the steam supply valves from both boilers isolate.

An adjacent-to-line radiation detector monitors the cross-tie line from the high-pressure to low-pressure ABS and isolates the high-pressure to low-pressure ABS cross-tie valve if the high-high radiation isolation setpoint is exceeded or if system power is lost.

Blowdown from the ABS is delivered to the BPDS south turbine building drain tank. This tank provides a means to monitor for radioactive contaminants in the ABS blowdown line. If a high radiation condition is detected, an alarm is initiated in the MCR, the north waste water sump pumps and north oily waste pump automatically

shut down and the discharge flow path to the balance of plant drain system collection tanks automatically isolates. Sufficient holdup capacity is provided for retention of liquid effluents containing radioactive materials in the 25,000 gallon BPDS south turbine building drain tank.

Consistent with 10 CFR 20.1101(b), the (system) design supports keeping radiation exposures ALARA. The ABS is normally a non-radioactive system; however, ABS interfaces with the MHS heaters which contain radioactive fluid. To maintain the radiation exposure to operating and maintenance personnel ALARA, the auxiliary boiler system is designed to facilitate maintenance, inspection, and testing in accordance with the guidance in RG 8.8. The ABS returns from the MHS heaters are equipped with radiation monitoring equipment and provisions for sampling by the Process Sampling System. The radiation monitors have high and high-high set points, both of which alarm in the MCR. Remote manual isolation capabilities of the gland steam exhaust system are available in the MCR. The PSS provides a safe means of sampling of condensate return from the MHS heaters for radiological contamination. Where there is a risk of high radiation at interfaces with the ABS, shielding, pipe and valve galleries and/or labyrinth pathways are incorporated into pipe routes as needed.

Consistent with 10 CFR 20.1406, the auxiliary boiler system design supports minimization of contamination of the facility and the environment. The steam or condensate return from the module heatup system heat exchangers has radiation monitors that send a signal to the CVCS to isolate the affected module heatup system heat exchanger to prevent the flow of contamination and protect the remaining ABS from becoming contaminated. Additionally, the cross-tie line from the high-pressure to the low-pressure ABS and the blowdown line to the BPDS have radiation monitors to isolate the flowpath to prevent contamination of downstream components. Leaks and spills in the ABS are minimized and contained.

The design features addressing the provisions of RG 4.21 are discussed in Section 12.3.6.

10.4.10.4 Inspection and Testing

The ABS components are inspected and tested as part of the initial testing and startup program as described in Section 14.2.

The ABS is designed to be tested and inspected per the original equipment manufacturer inservice inspection and testing plan.

The ITAAC are addressed in Section 14.3.

10.4.10.5 Instrumentation

Instrumentation is described in Table 10.4-21.

Pressure, temperature, flow, tank level, and valve position are provided on both the high-pressure and low-pressure ABS components.

A single adjacent-to-line radiation monitor is located on the cross-tie line from the high-pressure to low-pressure ABS. If radiation is detected in the ABS greater than the high radiation alarm setpoint, the system initiates a MCR alarm notifying the operators to investigate and initiate mitigating actions. If radiation is detected in the ABS that is greater than the high-high radiation isolation setpoint or if system power is lost, the high-pressure to low-pressure ABS cross-tie valve isolates. There are process radiation monitors on each high-pressure return line from the MHS heat exchangers to monitor the steam or condensate exiting, and a process radiation monitor on the vent of the pressure regulating valve on the high-pressure condensate collection tank to monitor the steam venting from the tank. If radiation is detected in the ABS that is greater than the high-high radiation isolation setpoint or if system power is lost, a signal is sent to the CVCS to isolate the affected module heatup system heat exchanger.

10.4.11 Feedwater Treatment System

The FWTS treats and cleans the feedwater in conjunction with the CPS (Section 10.4.6) to maintain secondary water quality. The FWTS is part of the CFWS.

10.4.11.1 Design Basis

This section identifies the FWTS required or credited functions, the regulatory requirements that govern the performance of those functions, and the controlling parameters and associated values that ensure the functions are fulfilled. Together, this information represents the design bases, as defined in 10 CFR 50.2, as required by 10 CFR 52.47(a) and (a)(3)(ii).

The FWTS is designed to provide for chemical addition and feedwater sampling during all plant modes (except NPM transport), to maintain feedwater pH and dissolved oxygen levels.

The FWTS serves no safety-related functions, is not credited for mitigation of a DBA, and has no safe shutdown functions. General Design Criteria 2, 4, and 5 were considered in the design of the FWTS. No safety-related SSC are affected by the effects of natural phenomena such as earthquakes. The design of the FWTS provides protection of safety-related SSC from the environmental conditions associated with normal operation, maintenance, testing and postulated accidents.

There are no safety-related components in the FWTS shared among modules; therefore, the FWTS does not significantly impair the ability of other systems to perform their safety functions.

Consistent with GDC 60, the design of the FWTS ensures the capability to control releases of radioactive materials to the environment. Consistent with 10 CFR 20.1101(b), the FWTS design supports keeping radiation exposures as low as reasonably achievable (ALARA). Consistent with 10 CFR 20.1406, the FWTS is designed to preclude contamination of connecting systems, and thus minimize contamination of the associated systems, facility, and the environment.

10.4.11.2 System Description

10.4.11.2.1 General Description

The FWTS is part of the CFWS described in Section 10.4.7 and is designed to control erosion and corrosion of CFWS components by monitoring and maintaining feedwater pH and dissolved oxygen levels during all plant modes except NPM transport. See Section 10.4.7 for a discussion of seismic and quality group, equipment qualification, and applicable codes and standards for the FWTS.

Two chemical injection points are provided downstream of the CFWS condensate pumps. The FWTS includes separate equipment for pH control and oxygen scavenger injection. The equipment includes tanks, valves, piping, pumps, and instrumentation for each chemical addition.

The FWTS operating parameters are shown in Table 10.4-22.

10.4.11.2.2 Component Description

The FWTS component design data is provided in Table 10.4-23.

Feedwater Treatment Tanks

The FWTS has one tank for pH control and one tank for oxygen control that service up to six turbine generators in each TGB. Each tank is constructed of corrosion-resistant material for the chemical service and conditions (See Section 10.3.6). Each chemical addition tank includes connections for chemical fill, demineralized water supply, pump suction, pump relief valve return, level instrumentation, drain and loop seal overflows.

Chemical injection equipment is capable of independently injecting controlled amounts of oxygen scavenger and pH agent. The chemical addition portions of the CFWS system have capacity for at least 24 hours of continuous chemical injection at normal feed rates. Chemical addition tank overflows, drains, etc. are routed to the BPDS' chemical waste collection sumps.

COL Item 10.4-3: A COL applicant that references the NuScale Power Plant design certification will provide a secondary water chemistry analysis. This analysis will show that the size, materials, and capacity of the feedwater treatment system equipment and components satisfies the water quality requirements of the secondary water chemistry program described in Section 10.3.5, and that it is compatible with the chemicals used.

Feedwater Treatment Pumps

The FWTS pumps are diaphragm simplex-type pumps with the wetted parts, except for the diaphragm, constructed of the appropriate grade of stainless steel for the chemical service and conditions. Redundant pumps are provided to support isolation for maintenance. Each pump or common line has a filter (or strainer) to filter out foreign materials. Each chemical addition pump has a discharge pressure

greater than the condensate pump shutoff head. A pulsation dampener oil trap is provided in the discharge line of each chemical addition pump.

Feedwater Treatment Valves and Piping

The FWTS valves and piping are designed to preclude water hammer.

10.4.11.2.3 System Operation

10.4.11.2.3.1 Startup

Recirculation capability back to the condenser after the FWTS chemical addition is provided by the feedwater system. Reactor startup may commence after the CFWS system is operating in long-cycle cleanup and chemistry is within allowable limits.

10.4.11.2.3.2 Normal Operation

The PSS continuously monitors the feedwater. When the feedwater quality is outside the parameters specified in the secondary water program described in Section 10.3.5, the FWTS provides chemical injections from the treatment tanks as appropriate to control water chemistry.

The chemical tanks receive concentrated chemicals that are diluted to normal service levels, as determined by the secondary water chemistry program, in the tanks by the addition of demineralized water.

Components are constructed out of materials compatible with higher concentrations of the chemicals used.

10.4.11.2.3.3 Shutdown

The FWTS maintains water quality suitable for long-term plant operation for all plant conditions, including power operation, startup, shutdowns, and extended outages.

10.4.11.2.3.4 Off-Normal Operation - Extended Outages

Connections are provided to allow for wet-storage or dry-storage of the condenser based upon water chemistry effects during short-term or long-term condenser shutdown.

10.4.11.3 Safety Evaluation

The FWTS serves no safety-related functions, is not credited for mitigation of a DBA, and has no safe shutdown functions.

General Design Criterion 2 was considered in the design of the feedwater treatment system. No safety-related structures, systems, or components are affected by this system from the effects of natural phenomena such as earthquakes. The design and

layout of the FWTS include provisions that ensure that a failure of the system will not adversely affect the functional performance of safety-related SSC.

The FWTS meets RG 1.29 in that it is not located in areas that contain safety-related or risk-significant components and is not required to operate during or after an accident. The FWTS is Seismic Category III.

General Design Criterion 4 was considered in the design of the feedwater treatment system. The design of the FWTS provides protection of safety-related SSC from the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents. The FWTS has been designed for the dynamic effects associated with possible fluid flow instabilities (e.g., water hammer) by having the FWTS designed in accordance with the guidance contained in NUREG-0927 and thereby eliminating or reducing the possibility of water hammer in SGs. See Section 3.6 for discussion of high-energy and moderate-energy pipe breaks.

GDC 5 was considered in the design of the feedwater treatment system. The FWTS has no safety-related components shared among modules and the FWTS does not impair the ability of other systems to perform their safety functions.

The FWTS functions to control pH and scavenge free oxygen to maintain water quality as specified in the secondary water chemistry program described in Section 10.3.5.

General Design Criterion 60 was considered in the design of the feedwater treatment system. Consistent with GDC 60, the FWTS design controls radioactive material releases to the environment. The FWTS is anticipated to contain negligible quantities of radioactive contaminants during power operation and during shutdown.

Consistent with 10 CFR 20.1101(b), the (system) design supports keeping radiation exposures ALARA. To maintain the radiation exposure to operating and maintenance personnel ALARA, the FWTS is designed to facilitate maintenance, inspection, and testing in accordance with the guidance in RG 8.8. The FWTS design satisfies the requirements of 10 CFR 20.1406. Release of radioactivity to the environment by the CFWS (Section 10.4.7) is precluded in the event of a pipe leak, or break, or degradation of the integrity of safety-related equipment by monitoring and isolation valves. The FWTS portion is not expected to receive backflow, so should not become contaminated. Further discussion of the facility design features to protect against contamination is shown in Section 12.3.

10.4.11.4 Inspection and Testing

The FWTS components are inspected and tested as part of the initial testing and startup program as described in Section 14.2. Preservice inspection requirements are discussed in Section 6.6.

The inservice testing program of FWTS pumps and valves is performed per Section 3.9.6.

The ITAAC are addressed in Section 14.3.

10.4.11.5 Instrumentation

The pumps of the FWTS have controls to allow for automatic and manual operation. Instrumentation provides tank level indication for proper water inventory and pump pressure to ensure the proper discharge pressure for chemical injection into the feedwater lines. See Table 10.4-24.

Samples are monitored to adjust chemical feed.

10.4.12 References

10.4-1 Heat Exchange Institute, "Performance Standards for Liquid Ring Vacuum Pumps," HEI-2854, 4th Edition, 2011.

10.4-2 ASME PTC 23, "Atmospheric Water Cooling Requirement," 2003 (R2009).

10.4-3 Electric Power Research Institute, "Pressurized Water Reactor Secondary Water Chemistry Guidelines – Revision 7," TR-1008224, Palo Alto, CA.

10.4-4 Electric Power Research Institute (EPRI) Report No. 1015425 (NSAC-202L-R3) "Recommendations for an Effective Flow-Accelerated Corrosion Program," August 2007.

10.4-5 American Society of Mechanical Engineers, Code for Pressure Piping, B31, Section B31.1, "Power Piping," New York, NY.

Table 10.4-1: Main Condenser Design Data

Parameter	Data
Condenser type	Single pass
Hotwell storage capacity	Equivalent to at least three minutes of full-load condensate system operating flow during normal operation and a standby surge storage capacity equivalent to two minutes of full-load normal condensate flow
Heat transfer duty	See heat balance in Figure 10.1-2
Shell design pressure / temperature	5 psig / 250°F
Tube design pressure / temperature	150 psig / 150°F
Tube-side inlet temperature	See heat balance in Figure 10.1-2
Approximate tube-side temperature rise	See heat balance in Figure 10.1-2
Condenser outlet temperature	See heat balance in Figure 10.1-2
Condenser tube data	
Tube material (main section)	High alloy of stainless steel or titanium (based on site circulating water conditions)
Tube sheet material	Carbon steel-clad with the same material composition used for tube materials

Table 10.4-2: Main Condenser System Instrumentation

Equipment Name	Monitored Parameter (Units)	Local Display	Signal to MCS
MC pressure indicating transmitters A/B/C	MC pressure (psia)	Yes	Yes
MC temperature indicating transmitter A/B/C	MC temperature (°F)	Yes	Yes
MC hotwell level indicating transmitter A/B/C	MC level (inches of H_2O)	Yes	Yes
MC condensate emergency makeup line flow element	Condensate flow (gpm)	N/A	No
MC condensate makeup emergency line flow transmitter	Condensate flow (gpm)	No	Yes
MC emergency makeup level control valve position indicating transmitter	Level control valve position (%)	No	Yes
MC normal makeup level control valve position indicating transmitter	Level control valve position (%)	No	Yes
MC condensate normal makeup line flow element	Condensate flow (gpm)	N/A	No
MC condensate makeup normal line flow transmitter	Condensate flow (gpm)	Yes	Yes
MC hotwell cation conductivity analyzer	Hotwell cation conductivity (microsiemens per centimeter @ 25°C)	No	Yes
MC hotwell sodium analyzer	Parts per billion (ppb)	No	Yes
Main steam deaeration isolation valve position switch open	Valve not fully open	No	Yes
Main steam deaeration isolation valve position switch closed	Valve not fully closed	No	Yes
Main steam deaeration flow control valve position indicating transmitter	Valve position	No	Yes
Main steam deaeration flow element	Flow rate (lb/hr)	No	Yes
Main steam deaeration flow indicating transmitter	Flow rate (lb/hr)	Yes	Yes
Auxiliary boiler system sparging steam isolation valve position switch open	Valve not fully open	No	Yes
Auxiliary boiler system sparging steam isolation valve position switch closed	Valve not fully closed	No	Yes
Auxiliary boiler system sparging steam flow control valve position indicating transmitter	Valve position	No	Yes
Auxiliary boiler system sparging steam flow element	Flow rate (lb/hr)	No	Yes
Auxiliary boiler system sparging steam flow indicating transmitter	Flow rate (lb/hr)	Yes	Yes

Table 10.4-3: Condenser Air Removal System Design Data (Nominal)

Liquid Ring Vacuum Pumps	
Number	2
Capacity	100%
Operating capacity	12.5 SCFM of gas at an inlet pressure of 2.5 inches HgA
Startup capacity	350 SCFM during condenser evacuation in preparation for operation
Input	75 horsepower
Seal water heat exchangers	
Number	2
Capacity / duty cycle	350,000 BTU/hr / 100%
Cooling input	60 gpm cooling water flow at 90°F or below
Cooling capacity	30 gpm flow
Seal water separator tanks	
Number	2
Size	100 gal

Table 10.4-4: Condenser Air Removal System Instrumentation

Type	Location	Local	Main Control Room
Temperature indication	Seal water inlet to LRVP	Yes	No
Pressure gauge (vacuum)	LRVP suction	Yes	Yes
Differential pressure	Across LRVP inlet control valve	Yes (control panel)	No
Level gauge	Seal water separator tank	Yes	No
Level switch (low)	Seal water separator tank	Yes	Yes
Flow gauge (rotometer)	Seal water separator tank	Yes	Yes
Motor power (on/off)	Power breaker	Yes	Yes
Radiation monitor	Radioactive contamination CARS gaseous effluent	Yes	Yes

Table 10.4-5: Gland Seal Steam Skid Design Data

Gland seal flow	Sufficient for 1.5 to 2 times the normal gland clearances and maximum allowable auxiliary steam supply pressure
Gland steam condenser	
Type	Shell-and-tube type heat exchanger
Gland seal condenser exhauster blowers	
Capacity	100%
Number	2

Table 10.4-6: Gland Sealing System Instrumentation

Equipment Name	Monitored Parameter	Local Display	Signal to MCS
GS desuperheater feedwater supply isolation valve limit switch	Valve fully open	No	Yes
GS desuperheater feedwater supply isolation valve limit switch	Valve fully closed	No	Yes
GS desuperheater feedwater supply pressure transmitter	Pressure psig	Yes	Yes
GS desuperheater feedwater supply flow control valve (FCV) position transmitter	Valve position %	Yes	Yes
GS desuperheater feedwater supply FCV position transmitter	Valve position %	Yes	Yes
GS desuperheater feedwater supply pressure transmitter	Pressure psig	Yes	Yes
GS desuperheater steam supply pressure transmitter	Pressure psig	Yes	Yes
GS desuperheater steam supply pressure transmitter	Pressure psig	Yes	Yes
GS desuperheater steam supply temperature transmitter	Temperature °F	Yes	Yes
GS desuperheater steam supply temperature transmitter	Temperature °F	Yes	Yes
GS supply pressure transmitter	Pressure psig	Yes	Yes
GS supply flow element	Steam flow lb/hr	No	Yes
GS supply flow transmitter	Steam flow lb/hr	No	Yes
GS supply temperature transmitter	Temperature °F	Yes	Yes
GS condenser condensate flow element	Steam flow lb/hr	No	Yes
GS condenser condensate flow transmitter	Steam flow lb/hr	No	Yes
GS condenser condensate FCV position transmitter	Valve position %	Yes	Yes
GS condenser isolation valve limit switch	Valve fully open	No	Yes
GS condenser isolation valve limit switch	Valve fully closed	No	Yes
TG lube oil supply pressure transmitter	Pressure psig	Yes	Yes
GS condenser condensate level indicator/ transmitter	Level indication	Yes	Yes
GS desuperheater feedwater supply FCV position transmitter	Valve position %	Yes	Yes
GS desuperheater feedwater supply FCV position transmitter	Valve position %	Yes	Yes

Table 10.4-7: Turbine Bypass System Component Details

Turbine bypass valve	
Number	1 (per NPM)
'Normal' capability	10% step load change from steady state conditions in 60 seconds when the power level is in the range of 50 to 100 percent without necessitating a turbine trip.
Normal load rejection	100 percent
Turbine bypass desuperheater	
Capacity	Reduce full power steam flow 532,100 lbm/hr, normal pressure 500 psia, normal temperature 575°F to saturation

Table 10.4-8: Turbine Bypass System Instrumentation

Equipment Name	Monitored Parameter	Local Display	Signal to MCS
MSS desuperheater steam supply FCV position transmitter	Valve position %	Yes	Yes
MSS pressure transmitter (downstream of turbine bypass line)	Pressure psig	Yes	Yes
Turbine bypass pressure transmitter (after DSH)	Pressure (psig)	Yes	Yes
MSS desuperheater feedwater supply pressure transmitter (before DSH)	Pressure (psig)	Yes	Yes
DSH feedwater isolation valve limit switch	Valve fully closed	No	Yes
MSS desuperheater feedwater FCV position transmitter	Valve position (%)	Yes	Yes

Table 10.4-9: Circulating Water System Design Parameters

Circulating Water Pumps, per six NPMs	
Number	3 pumps per loop
Capacity	[[76353 gpm]] / 33% capacity
Type	Vertical, wet pit
Motor horsepower (nameplate)	[[1750 hp]]
Limitations	3 pumps are sufficient when assuming loss of a single pump
Traveling Screens	
Type	Continuously moving
Number	1 per pump
Cooling Tower	
Cells per tower	[[14]]
Type	Mechanical draft, induced
Wet bulb	[[80°F]]
Range	[[20°F]]
Approach	[[10°F]]
Flow, each CWS loop	[[228,000 gpm]]
Construction code	ACI 318 standards
Testing standard	Cooling tower performance standard ASME PTC 23
Cooling Tower Makeup and Blowdown	
Rate	[[5320 gpm per loop]]
Cycles of concentration	[[5]]
Chemical Treatment	
Materials	[[biocide (typically sodium hypochlorite), algaecide, pH adjuster, corrosion inhibitor, scale inhibitor, and dispersant.]]
Piping, including the expansion joints, butterfly valves, condenser water boxes, and tube bundles.	
Size	[[9-foot diameter]]
Material	Prestressed concrete lined pipe (underground); carbon steel pipe (above ground).
Code	ASME B31.1 (above ground)

Table 10.4-10: Circulating Water System Interfaces

Condensate and feedwater system (CFWS)	Removes heat from the MCs, which are part of the CFWS
Utility water system (UWS)	Provides makeup water and receives blowdown water
Site drainage system (SDS)	Receives drain water from the cooling tower basin
Process sampling system (PSS)	Takes samples from the CWS to monitor for pH, free chloride, total dissolved solids, and other chemical concentrations
Electrical systems	Provide power to components
Control systems	Control individual and shared component operation

Table 10.4-11: Circulating Water System Instrumentation

Instruments		Indication	
Type	Location	Local	Main Control Room
Level Transmitter	Cooling tower basin, the common intake structure, and each individual pump bay	Yes	Yes
Pressure Differential Indicating Transmitter	Across the condensers	No	Yes
Pressure Indicating Transmitter	CWS piping	Yes	Yes
Temperature Indicating Transmitter	CWS water temperature	Yes	Yes
Flow Indicating Transmitter	CWS supply header	No	Yes
Flow Indicating Transmitter	Blowdown line	Yes	Yes
Flow Indicating Transmitter	CWS Cooling Tower Startup Flow Confirmation	No	Yes
Valve Position Switch -- Open	On MOVs responsible for equipment isolation	Yes	Yes
Valve Position Switch -- Closed	On MOVs responsible for equipment isolation	Yes	Yes
Position Indicating Transmitter	Flow Control Valve Percent Open	Yes	Yes
Level Gauges	Condenser water boxes	Yes	Yes
Chlorine Monitor	Cooling tower basin	No	Yes
Total Dissolved Solids Monitor	Cooling tower basin	No	Yes
Total pH Monitor	Cooling tower basin	No	Yes
Chlorine Monitor	CWS blowndown line	No	Yes

Table 10.4-12: Circulating Water System Alarms

Instruments		Indication	
Type	Location	Local	Main Control Room
Level alarm low/high	Cooling tower basin	No	Yes
Temperature alarm low/high	Cooling Tower Basin	No	Yes
Flow alarm low/high	Circulating water pump discharge common header	No	Yes
Flow alarm low/high	Blowdown line	No	Yes
Pressure differential alarm high	Across condensers	No	Yes
Level alarm low	Condenser waterbox	No	Yes
Temperature alarm high (2)	Cooling tower inlet	No	Yes

Table 10.4-13: Condensate Polishing System Operating Parameters

Condensate polisher	
Type	Ion exchange
Number of trains	2 at 100% capacity per NPM
Flow total	Full (100%) condensate flow in each train
Flow per NPM	100% of the condensate and feedwater flow at the design operating pressure and temperature
Operating limits	Freshwater plant: maintain chemistry with a continuous condenser tube leak of 0.001 gpm, or an increased leak rate of 0.2 gpm until repaired Brackish or seawater plant: maintain water chemistry during an orderly shutdown (8 hours) with a leak rate of 0.1 gpm
Resin Regeneration Subsystem	
Number	1 per TGB to service up to 6 NPMs

Table 10.4-14: Condensate Polishing System Impurity Limits

Item	Limit
Sodium	< 1 ppb
Chloride	< 3 ppb
Sulfate	< 1 ppb
Silica	< 10 ppb
Total iron	< 5 ppb

Table 10.4-15: Condensate Polishing System Instrumentation

Equipment Name	Monitored Parameter (Units)	Local Display	Signal To MCS
Condensate polishing system bypass air operated valve open position switch	Valve not fully open	No	Yes
Condensate polishing system bypass air operated valve closed position switch	Valve not fully closed	No	Yes
Condensate polishing system filter pressure differential indicating transmitter	Equipment pressure drop (psid)	Yes	Yes
Condensate polishing system inlet flow meter	Condensate flow rate (gpm)	No	Yes
Condensate polishing system inlet flow indicator/ transmitter (redundant)	Condensate flow rate (gpm)	Yes	Yes
Condensate polishing system inlet temperature indicating transmitter	Condensate temperature (°F)	Yes	Yes
Condensate polishing system rinse inlet flow meter	Condensate flow rate (gpm)	No	No
Condensate polishing system rinse inlet flow indicator/transmitter	Condensate flow rate (gpm)	Yes	Yes
Condensate polishing system verification flow control valve position indicating transmitter	Flow control valve position (%)	No	Yes

Table 10.4-16: Condensate Polishing System Alarms

Instruments	**Indication**	
Type	Local	Main Control room
Condensate polishing system high inlet temperature	Yes	Yes
Condensate polishing system inlet filter high pressure differential	Yes	Yes

Table 10.4-17: Condensate and Feedwater System Component Design Data

Condenser	
	See Section 10.4.1.
Condensate storage tank	
Size	1000 ft^3
Material/code	stainless steel / API 620
Location	site yard, see Figure 1.2-4
Condensate strainer	
Detail	1/8 inch stainless steel mesh
Condensate pumps	
Number	Three, 50% capacity
Type	vertical, single speed, multistage,
	(480vac) motor driven
Use	1 pump used below 50% power 2 pumps used between 50% and 100% power One pump set to autostart (standby)
Condensate filter	
Condensate polishers	See Section 10.3.5
Storage capacity	24 hours of continuous chemical injection at the normal feed rates
Gland seal condenser - see Section 10.4.3	
Type	shell and tube design condenser
Condensate	On the tube side
Gland sealing steam	on the shell side
Feedwater treatment system (See Section 10.4.11)	
Storage capacity	for 24 hours of continuous chemical injection at the normal feed rates
Feedwater heaters (closed type)	
Number	3 (high-, intermediate-, and low-pressure)
Type	horizontal shell and tube design
Material	constructed of carbon steel with stainless steel tubes
Condensate	Tube side
Extraction steam	Shell side
Final outlet temperature	300°F
Feedwater pumps	
Use	1 pump used below 50% power 2 pumps used between 50% and 100% power One pump set to start automatically (standby)
Number	3, 50% capacity
Type	Horizontal, multistage 480V with variable frequency drive
Feedwater regulating valves	
Number of valves	2
Closure type	air-operated
Design spec	in accordance with ASME BP&V Code 2010, 2011 Addenda, Section VIII and Heat Exchanger Institute 2622, 8th Edition

Table 10.4-18: Condensate and Feedwater System Failure Modes and Effects Analysis

Component Identification	Function	Failure Mode	Failure Mechanism	Effect on the Condensate and Feedwater System	Method of Failure Detection	Remarks
Main Condenser xx*-FW-CND-0001 *reserved for module number (01 - 12)	1) The main condenser is responsible for condensing low pressure exhaust steam from the turbine.	A) Slow Loss of Condenser Vacuum	Mechanical	Condenser vacuum pressure plays an integral part in turbine performance and energy production. There are multiple innate chronic problems that can develop in the condenser over normal power production operations. These problems include, but are not limited to, air ingress, tube plugging, and tube bundle corrosion. As these problems develop the amount of vacuum the condenser can pull decreases, reducing the efficiency of the system. Small decreases in condenser vacuum do not detrimentally effect plant operation; loss of vacuum above the required turbine back pressure causes a turbine trip. As condenser backpressure increases it is possible to start the standby condenser air removal system to reduce vacuum.	Failure is identified by high pressure measurements from PIT-0002 A/ B/C	If the turbine trips due to a loss of condenser vacuum, the main steam header pressure increases rapidly. This results in a reactor trip due to high steam line pressure or high pressurizer pressure. The loss of condenser vacuum prevents the condenser from being used to remove heat generated by the reactor. The turbine bypass valve closes, and the DHRS actuates to remove decay heat after control rod insertion. No safety-related components are affected by loss of condenser vacuum. This is an anticipated operational occurrence (AOO) for a reactor module.
		B) Immediate Loss of Condenser Vacuum	Mechanical Electrical/ I&C Operator Error	Condenser vacuum pressure plays an integral part in turbine performance and energy production. Loss of vacuum above the required turbine back pressure causes a turbine trip. Causes of this type of trip are loss of normal heat sink, loss of condenser air removal system. This results in a loss of condenser vacuum, and a turbine trip.		

Table 10.4-18: Condensate and Feedwater System Failure Modes and Effects Analysis (Continued)

Component Identification	Function	Failure Mode	Failure Mechanism	Effect on the Condensate and Feedwater System	Method of Failure Detection	Remarks
Main Condenser xx*-FW-CND-0001 *reserved for module number (01 - 12) (cont)	2) Maintain purity of the condensate	A) Minor Leak of Condenser Tubes	Mechanical	Circulating water enters the CFWS contaminating the system. Condensate polishers remove the contaminants. Leaky tube is identified by taking tube bundles off line one at a time to determine leak source. Leaking tube is identified and repaired. Operating with one water box offline requires a module to be operated at a reduced load, but does not result in a turbine trip.	Failure detected by measurements from analyzers AIT-0235 for conductivity and AIT-0236 for sodium concentration.	None
		B) Major Leak of Condenser Tubes	Mechanical	A major leak of the condenser tubes results in a higher condensate level in the hotwell and an increase in condenser back pressure as circulating water enters the condenser. A major leak of the condenser tubes introduces significant quantities of contaminants which may overwhelm the CPS and foul the CFWS.	Also, high main condenser level is measured by instruments LIT-0004 A/B/C in the main condenser hotwell. Failure detected by measurements from analyzers AIT-0235 for conductivity and AIT-0236 for sodium concentration. AIT 0026 detects resin depletion and breakthrough occurring.	A major condenser tube leak results in a turbine trip and reactor trip due to detection of contamination in the CFWS. Operators are responsible for locating the damaged tubes for replacement.

Table 10.4-18: Condensate and Feedwater System Failure Modes and Effects Analysis (Continued)

Component Identification	Function	Failure Mode	Failure Mechanism	Effect on the Condensate and Feedwater System	Method of Failure Detection	Remarks
Main Condenser xx*-FW-CND-0001 *reserved for module number (01 - 12) (cont)	3) Designed for full flow bypass following a turbine trip.	A) Failure of Bypass valve to open. B) Failure of Bypass valve to close when needed.	Mechanical	The effect is dependent on the reason for the valve open requirement. If the valve open requirement is because of a need to reduce power output (for example load following etc), a different reactor need to be selected for power reduction. If the valve open requirement is due to a turbine generator trip then the reactor needs to be tripped and steam pressure controlled by main steam safety valve. Failure of bypass valve to close results in loss of power generation. The valve needs to be either manually closed or repaired.	Bypass valve position indicator shows valve failed to respond when valve fails to open/close. The turbine either fails to start/stop.	Bypass valve failure has no impact on safety-related components.

Table 10.4-18: Condensate and Feedwater System Failure Modes and Effects Analysis (Continued)

Component Identification	Function	Failure Mode	Failure Mechanism	Effect on the Condensate and Feedwater System	Method of Failure Detection	Remarks
Condensate Pumps xx*-FW-P-0011 A/B/C *reserved for module number (01 - 12)	1) Draws suction from the main condenser. Delivers condensate to the feedwater pumps with adequate pressure.	A) Fail to Start	Mechanical Electrical/ I&C	Failure of a condensate pump to start upon the trip of one of the operational condensate pumps results in a decreased supply pressure to the feedwater pumps. If adequate supply pressure and flow rate to the feedwater pumps is not achieved then one or both of the feedwater pumps trip due to low suction pressure. This event results in a loss of feedwater flow to the SGs.	Failure would be detected by downstream instruments PIT-0014 A/B/C and FE/FIT-0012 A/B/C.	A decrease in feedwater flow to the SGs because of a condensate pump trip causes the RCS temperature to increase. This leads to the feedwater pump variable frequency drives (VFDs) increasing their motor output to increase the flow. If one condensate pump is not able to supply adequate pressure to the inlet of the feedwater pumps, one or both of the feedwater pumps trip and this incident is consistent with a loss of feed water flow. A loss of feed water flow results in a reactor trip due to high pressurizer pressure. Loss of feedwater is an AOO for a NuScale module.
		B) Pump Trip	Mechanical Electrical/ I&C Operator Error	If one condensate pump trips during normal operation the STANDBY condensate pump starts with enough response time to avoid feedwater pump trip.	Failure would be detected by downstream instruments PIT-0014 A/B/C and FE/FIT-0012 A/B/C.	There is a temporary decrease in feedwater flow rate to the SGs. The remaining online pump runs out on its pump curve, but is not capable of supplying the full load flow rate requirements. As the standby condensate pump comes online, the system returns to normal operation.

Table 10.4-18: Condensate and Feedwater System Failure Modes and Effects Analysis (Continued)

Component Identification	Function	Failure Mode	Failure Mechanism	Effect on the Condensate and Feedwater System	Method of Failure Detection	Remarks
Condensate Polishing System Bypass Valve xx*-FW-AOV-0017 (normally closed, fail open) *reserved for module number (01 - 12)	1) Bypasses condensate polishing system upon high condensate temperature.	A) Failure to Open	Mechanical Electrical/ I&C	A failure of the condensate polishing bypass valve to open upon a high condensate temperature signal causes the resin in the condensate polisher to be damaged.	Limit switches ZSO-0017 and ZSC-0017 position indication.	Failure of the condensate polishing system bypass valve could cause damage to the polishing resin. The effect this transient would have on the primary side is dependent on the cause of the increased condensate temperature. If condensate temperature is too high and there is a risk of damaging polishing resin, operators can make the choice to shutdown the module, preserving the integrity of the polishers.
		B) Partial Opening		Partial opening of the bypass valve causes condensate to bypass the polishers resulting in degrading water chemistry.		Analyzers downstream of the condensate polishing system show increased amounts of contaminants in the CFWS. Operators are responsible for diagnosing the problem and making the correct actions to fix.
		C) Spurious Opening	Mechanical Electrical/ I&C Operator Error	Spurious opening causes condensate to bypass the polishers resulting in degrading water chemistry.	Limit switches ZSO-0017 and ZSC-0017 position indication. Reduced flow rate through FE-0020.	Large amount of condensate bypassing the condensate polishers could result in the CFWS being operated outside of water chemistry limits. Operators are responsible for making the decision to remain in operation based on water chemistry.
Condensate Polishing Skid xx*-FW-SKD-0022 *reserved for module number (01 - 12)	1) Maintains water chemistry limits by removing dissolved solids and by products of hydrazine reactions.	A) Failure resulting in polishing resin entering the feedwater system.	Mechanical	Failure of the condensate polishing system resulting in resin entering the CFWS is captured in a downstream filter. A high pressure drop reading across the filter alerts operators to this occurrence and prompts a switch to the standby unit. The condensate polishing system is designed with two 100 percent capacity ion exchangers, so this switch does not result in a reactor trip.	Filters are located downstream of each condensate polisher. A high differential pressure indication across the filters indicates resin carry over from the polishers.	CFWS and primary side experience a temporary transient as flow is transferred from the online polisher to the standby polisher. As flow is returned to normal through the condensate polishing system, the CFWS and primary side return to steady state operations.

Table 10.4-18: Condensate and Feedwater System Failure Modes and Effects Analysis (Continued)

Component Identification	Function	Failure Mode	Failure Mechanism	Effect on the Condensate and Feedwater System	Method of Failure Detection	Remarks
Gland Steam Condenser xx*-TG-CND-0003 *reserved for module number (01 - 12)	1) Uses condensate to condense the low-pressure steam supplied to the turbine seals.	A) Tube Failure	Mechanical	Actions taken during a gland steam condenser (GSC) tube failure are dependent on the severity of the leak. For minor leaks, operators may decide to remain in operation. Major tube failure of the GSC requires a turbine trip to prevent water from entering the turbine seals. For a failure of the gland steam condenser the reactor module is taken offline through the use of the DHRS.	Level indication on the shell side of the gland steam condenser is the primary means of detecting gland steam condenser tube failure.	For a minor leak, the feedwater system is available and operating under normal conditions. As the leak increases in severity the decision to trip the turbine is an operator decision. A substantial tube failure of the GSC results in the inability to supply steam to the turbine seals. Without this capability the turbine and the reactor are tripped. The condenser is also isolated from potential steam sources. This incident is consistent with a loss of feedwater flow transient.

Table 10.4-18: Condensate and Feedwater System Failure Modes and Effects Analysis (Continued)

Component Identification	Function	Failure Mode	Failure Mechanism	Effect on the Condensate and Feedwater System	Method of Failure Detection	Remarks
Low-Pressure Feedwater Heater xx*-FW-HX-0038 *reserved for module number (01 - 12)	1) Heats condensate to increase reactor module thermal efficiency.	A) Shell Side Failure High.	Mechanical Electrical/ I&C Operator Error	Failure of the LP FWH shell side in the high causes high level notifications. If the normal level control valve is not capable of reducing the water level in the heater, the emergency level control valve attempts to reduce level. At some high-high liquid level turbine water induction interlocks are initiated protecting the turbine from damage. Turbine water induction protection includes isolating the heater from its steam supply source. If this is done the temperature delivered to the SG is decreased. If level control of the heater cannot be established operators make the decision to bypass the LP FWH on the condensate side. This reduces the temperature of the feedwater entering the SGs.	Level indication on the shell side of the feedwater heater is the primary means of detecting level fluctuations on the shell sided of the LP FWH.	Decreasing feedwater temperature being supplied to the SGs results in the SG going through a power transient. The higher level of heat removal from the SGs causes a decrease in primary side temperature. As the colder temperatures pass over the core the reactivity increases as does the reactor power level. If the temperature drops low enough the reactor trips based on a high reactor power set point. Decrease in feedwater supply temperature is an AOO for a NuScale module.
		B) Shell Side Failure Low		Failure of the LP FWH shell side in the low causes low level notifications. The emergency level control valve and the normal level control valve modulate closed in an effort to increase the liquid level in the feedwater heater. Without an established water level in the heater, the feedwater supply temperature decreases. If the problem persists operators are responsible for determining the problem and deciding the best course of action.		

Table 10.4-18: Condensate and Feedwater System Failure Modes and Effects Analysis (Continued)

Component Identification	Function	Failure Mode	Failure Mechanism	Effect on the Condensate and Feedwater System	Method of Failure Detection	Remarks
Intermediate-Pressure Feedwater Heater xx*-FW-HX-0044 *reserved for module number (01 - 12)	1) Heats condensate to increase reactor module thermal efficiency.	A) Shell Side Failure High	Mechanical Electrical/ I&C Operator Error	Failure of the IP FWH shell side in the high causes high level notifications. If the normal level control valve is not capable of reducing the water level in the heater, the emergency level control valve attempts to reduce level. At some high-high liquid level turbine water induction interlocks are initiated protecting the turbine from damage. Turbine water induction protection includes isolating the heater from its steam supply source. If this is done the temperature delivered to the SG is decreased. If level control of the heater cannot be established operators make the decision to bypass the IP FWH on the condensate side. This reduces the temperature of the feedwater entering the SGs.	Level indication on the shell side of the feedwater heater is the primary means of detecting level fluctuations on the shell sided of the IP FWH.	Decreasing feedwater temperature being supplied to the SGs results in the SG going through a power transient. The higher level of heat removal from the SGs causes a decrease in primary side temperature. As the colder temperatures pass over the core the reactivity increases as does the reactor power level. If the temperature drops low enough the reactor trips based on a high reactor power set point. Decrease in feedwater supply temperature is an AOO for a NuScale module.
		B) Shell Side Failure Low		Failure of the IP FWH shell side in the low causes low level notifications. The emergency level control valve and the normal level control valve modulate closed in an effort to increase the liquid level in the feedwater heater. Without an established water level in the heater, the feedwater supply temperature decreases. If the problem persists operators are responsible for determining the problem and deciding the best course of action.		

Table 10.4-18: Condensate and Feedwater System Failure Modes and Effects Analysis (Continued)

Component Identification	Function	Failure Mode	Failure Mechanism	Effect on the Condensate and Feedwater System	Method of Failure Detection	Remarks
Short-Cycle Recirculation Flow Control Valve xx*-FW-FCV-0049 (normally closed, fail closed) *reserved for module number (01 - 12)	1) Provides condensate pump minimum flow protection.	A) Failure to Open	Mechanical Electrical/ I&C	Short-cycle recirculation flow control valve acts as the primary means of minimum flow protection for the condensate pumps during normal operation. A failure of the short-cycle recirculation flow control valve causes the redundant condensate pump minimum flow protection lines to open.	Low flow rate measured by FE-0012 A/B/C Position switches ZSO-0222 A/B/C and/or ZSC-0222 A/B/C indicating PIT-0050 A/B/C measuring low suction pressure. ZT-0049 shows incorrect valve position vs expected position.	If this valve is being commanded to open, then a plant transient is taking place that is forcing the condensate pump to approach minimum flow conditions. This incident is consistent with a loss of feedwater flow if the reactor is at full power. During a loss of feedwater flow, the primary side temperature and pressure increases as the amount of heat removed decreases. The reactor trips due to a high primary side pressure set point. Loss of feedwater is an AOO for a NuScale module.
		B) Partial Opening		Partial opening of the short-cycle recirculation valve could cause the redundant condensate pump minimum flow protection lines to open.		
		C) Spurious Closure	Mechanical Electrical/ I&C Operator Error	Spurious closure of the short-cycle recirculation valve during condensate pump protection operations causes the redundant condensate pump minimum flow protection lines to open.		
		D) Spurious Opening		Spurious opening of the short-cycle recirculation valve during normal operation results in condensate being diverted back to the condenser. This reduces the flow rate and the suction pressure supplied to the feedwater pumps. There is a reduced feedwater flow rate to the steam generators.	PIT-0050 A/B/C measuring low suction pressure. Flow rate through FE-0012 A/B/C shows an increase over normal amount. ZT-0049 shows incorrect valve position vs expected position.	As the feed flow rate and pressure supplied to the feedwater pumps decreases the VFDs on the feedwater pumps begin to speed the pumps up to maintain normal flow to the SGs. If supply pressure drops to the set point for low supply pressure protection of the feedwater pumps the feedwater pumps trip. This results in a loss of feedwater, and the tripping of both the reactor module and the turbine. Loss of feedwater is an AOO for a NuScale module.

Table 10.4-18: Condensate and Feedwater System Failure Modes and Effects Analysis (Continued)

Component Identification	Function	Failure Mode	Failure Mechanism	Effect on the Condensate and Feedwater System	Method of Failure Detection	Remarks
Feedwater Pump xx*-FW-P-0052 A/B/C *reserved for module number (01 - 12)	1) Delivers feedwater to the SGs with adequate pressure to maintain steam generation.	A) Failure to Start	Mechanical Electrical/ I&C	Failure of a feedwater pump to start after one of the two operational pumps trip could result in a reactor trip due to high pressurizer pressure. If feedwater flow to the reactor can be maintained via the online feedwater pump and reactor automation controls primary side parameters correctly, safety-related portions of the NSSS should not be affected. If the reactor trips due to decreased feedwater flow, the safety systems are available for decay heat removal.	Low pressure reading on feedwater pump discharge PIT-0053 A/B/C Low feedwater flow rate at downstream flow instrument FE-0054 A/B/C Decreased feedwater flow rate as measured by FE-1005 and FE-2005.	If the primary side temperature and pressure result in a reactor trip due to the high pressurizer pressure set point cause DHRS actuation/SG isolation, decay heat is removed via the DHRS exchanger. No safety-related NSSS equipment is prevented from performing its safety function by a feedwater pump trip. Loss of feedwater is an AOO for a NuScale module.
		B) Pump Trip	Mechanical Electrical/ I&C Operator Error	Pump trip causes a temporary reduced flow rate to the SGs while the standby feedwater pump starts up.		The standby feedwater pump is designed to startup without causing a reactor trip. DHRS is not actuated and no safety-related portions of the NSSS are affected.
		C) VFD failure of both operating VFDs resulting in increased pump speed operations.	Mechanical Electrical/ I&C	Increased feedwater flow rate to the SGs increases the amount of heat removed from the RCS via the secondary side.	High feedwater flow rate at instruments FE-0054 A/B/C Increased feedwater flow rate as measured by FE-1005 and FE-2005. Low primary side temperature.	Decreased RCS temperature causes the core reactivity to increase, in turn increasing the reactor output. If reactor power increases above some set point without actions being taken (e.g., reduced turbine load, increased pressurizer spray) reactor trips due to high reactor power output. DHRS, FWIV and MSIV are available to maintain SG water level and remove decay heat following a reactor trip. Increase in feedwater flow is an AOO for a NuScale module.

Table 10.4-18: Condensate and Feedwater System Failure Modes and Effects Analysis (Continued)

Component Identification	Function	Failure Mode	Failure Mechanism	Effect on the Condensate and Feedwater System	Method of Failure Detection	Remarks
Feedwater Pump xx*-FW-P-0052 A/B/C *reserved for module number (01 - 12) (cont)	1) Delivers feedwater to the SGs with adequate pressure to maintain steam generation. (cont)	D) VFD failure increasing the pumping speed of operating feedwater pump.	Mechanical Electrical/ I&C	Increased speed for one of the two feedwater pumps results in the other operating pump being ramped down to the appropriate speed to return flow to steady state values.	Uneven flow rate can be determined from measurements from instruments FE-0054 A/B/C	As the one pump begins to ramp up in speed, the flow rate to the SGs increases temporarily. The MCS reduces the speed of the other operating feedwater pump to an acceptable level returning the feedwater flow rate to the steady state value.
		E) VFD failure of both operating VFDs resulting in decreased pump speed operations.		Decreased feedwater flow rate to the SGs. As the feedwater flow begins to decrease the supply pressure to the feedwater pumps begins to increase. If the flow rate falls below some low flow set point, the third feedwater pump is started automatically by the MCS. Inability to restore normal feedwater flow rate to the SGs results in reduced power operations or reactor module trip based on decision from operations.	Low feedwater flow rate measured by FE-0054 A/B/C Decreased feedwater flow rate measured by FE-1005 and FE-2005. Increase in primary side temperature	Decreased feedwater flow rate causes the primary side temperature and pressure to increase as the amount of heat removed from the primary side decreases. If a third feedwater pump is started and flow can be returned to normal operating conditions the system remains online. If flow cannot be returned to normal, operation can be continued at a reduced power or module can be removed from operation due to a loss of feedwater flow. If the loss of feedwater flow is substantial, the reactor could trip due to a high primary side pressure set point. Loss of feedwater is an AOO for a NuScale module.
		F) VFD failure decreasing the pumping speed of one operating feedwater pump.		When the VFD fails, decreasing the speed of one of the two pumps, the control system attempts to increase the speed of the other online pump. There is a limit to how much the second pump can be ramped up, while there is no limit to the reduced speed of the affected pump. If the feedwater flow rate drops enough, the standby pump starts in order to make up the difference in flows.	Uneven flow rate can be determined from measurements from instruments FE-0054 A/B/C	The primary side temperature and pressure is temporarily affected as the MCS changes the feedwater pump speeds to accommodate the decreased speed of one of the two pumps. If the feedwater flow drops too rapidly it could result in a reactor trip due to high primary side pressure trip point.

Table 10.4-18: Condensate and Feedwater System Failure Modes and Effects Analysis (Continued)

Component Identification	Function	Failure Mode	Failure Mechanism	Effect on the Condensate and Feedwater System	Method of Failure Detection	Remarks
Feedwater Pump Minimum Flow Protection Flow Control Valve xx*-FW-FCV-0057 A/B/C (normally closed, fail closed) *reserved for module number (01 - 12)	1) Modulates open based on measurements from FE-0054 A/B/C to provide minimum flow protection to the feedwater pumps.	A) Failure to Open	Mechanical Electrical/ I&C	Failure of the feedwater pump minimum flow protection valve to open causes feedwater pump damage and results in a feedwater pump trip. A pump trip of both of the running feedwater pumps would cause a reactor trip due to insufficient feedwater flow and pressure.	FE-0054 A/B/C is used to determine a failure of this valve. Valve position can be identified using ZT-0057 A/B/C	No safety-related feedwater equipment is affected by a feedwater pump trip based on the failure of the minimum flow protection valves. Both SGs are still available for decay heat removal. Loss of feedwater is an AOO for a NuScale module.
		B) Partial Opening		A partial opening of the feedwater pump minimum flow control valve, instead of full opening could cause the affected feedwater pump to overheat leading to a single feedwater pump trip		
		C) Spurious Closure	Mechanical Electrical/ I&C Operator Error	Spurious closure of the minimum flow protection valves could cause the feedwater pumps to trip. If the two operational feedwater pumps trip, the reactor trips.		
		D) Spurious Opening		Spurious opening of the minimum flow protection valve/valves results in a reduced feedwater flow rate to the SGs. Reduced feedwater flow rates result in an increased RCS temperature and pressure.		

Table 10.4-18: Condensate and Feedwater System Failure Modes and Effects Analysis (Continued)

Component Identification	Function	Failure Mode	Failure Mechanism	Effect on the Condensate and Feedwater System	Method of Failure Detection	Remarks
High-Pressure Feedwater Heater xx*-FW-HX-0060 *reserved for module number (01 - 12)	1) Heats condensate to increase reactor module thermal efficiency.	A) Shell Side Failure High	Mechanical Electrical/ I&C Operator Error	Failure of the HP FWH shell side in the high causes high level notifications. If the normal level control valve is not capable of reducing the water level in the heater, the emergency level control valve attempts to reduce level. At some high-high liquid level turbine water induction interlocks are initiated protecting the turbine from damage. Turbine water induction protection includes isolating the heater from its steam supply source. If this is done the temperature delivered to the SG is decreased. If level control of the heater cannot be established operators make the decision to bypass the HP FWH on the condensate side. This reduces the temperature of the feedwater entering the SGs.	Level indication on the shell side of the feedwater heater is the primary means of detecting level fluctuations on the shell sided of the HP FWH.	Decreasing feedwater temperature being supplied to the SGs results in the SG going through a power transient. The higher level of heat removal from the SGs causes a decrease in primary side temperature. As the colder temperatures pass over the core the reactivity increases as does the reactor power level. If the temperature drops low enough the reactor trips based on a high reactor power set point. Decrease in feedwater supply temperature is an AOO for a NuScale module.
		B) Shell Side Failure Low		Failure of the HP FWH shell side in the low causes low level notifications. The emergency level control valve and the normal level control valve modulate closed in an effort to increase the liquid level in the feedwater heater. Without an established water level in the heater, the feedwater supply temperature decreases. If the problem persists operators are responsible for determining the problem and deciding the best course of action.		

Table 10.4-18: Condensate and Feedwater System Failure Modes and Effects Analysis (Continued)

Component Identification	Function	Failure Mode	Failure Mechanism	Effect on the Condensate and Feedwater System	Method of Failure Detection	Remarks
Long-Cycle Recirculation Flow Control Valve xx*-FW-FCV-0064 (normally closed, fail closed) *reserved for module number (01 - 12)	1) Opens for flow path during system flushing during startup. During normal operation the valve is normally closed	A) Failure to Close	Mechanical Electrical/ I&C	There are two valves in series on the long cycle recirculation path. One for isolation purposes, one for flow control. If FCV-0064 fails to close, AOV-0165 closes preventing condensate from returning to the condenser instead of going to the steam generator.	Position of valve as measured by ZT-0064.	When the reactor is critical during normal operation, the long cycle recirculation path is not in use. Therefore, a failure to open event or a partial opening of one of the two valves is not analyzed. Because there are two valves operating in series, a failure of one of the two valves does not result in a CFWS transient.
		B) Spurious Opening	Mechanical Electrical/ I&C Operator Error	There are two valves in series on the long cycle recirculation path. One for isolation purposes, one for flow control. If FCV-0064 spuriously opens, AOV-0165 remains closed preventing condensate from returning to the condenser instead of going to the steam generator.		
Long-Cycle Cleanup Air Operated Valve xx*-FW-AOV-0165 (normally closed, fail closed) *reserved for module number (01 - 12)	1) Opens for flow path during system flushing during startup. During normal operation the valve is normally closed	A) Failure to Close	Mechanical Electrical/ I&C	There are two valves in series on the long cycle recirculation path. One for isolation purposes, one for flow control. If AOV-0165 fails to close, FCV-0064 closes preventing condensate from returning to the condenser instead of going to the steam generator.	Position of valve as measured by ZSO-0165 and ZSC-0165.	
		B) Spurious Opening	Mechanical Electrical/ I&C Operator Error	There are two valves in series on the long cycle recirculation path. One for isolation purposes, one for flow control. If AOV-0165 spuriously opens, FCV-0064 remains closed preventing condensate from returning to the condenser instead of going to the steam generator.		

Table 10.4-18: Condensate and Feedwater System Failure Modes and Effects Analysis (Continued)

Component Identification	Function	Failure Mode	Failure Mechanism	Effect on the Condensate and Feedwater System	Method of Failure Detection	Remarks
Feedwater Regulating Valve xx*-FW-FCV-1006 xx*-FW-FCV-2006 (normally open, fail closed) *reserved for module number (01 - 12)	1) Controls feedwater flow to the SGs during low flow operations below the feedwater pump VFDs abilities.	A) Spurious Opening	Mechanical Electrical/ I&C Operator Error	Uneven feedwater flow rate to one of the two SG headers.	Feedwater flow rate as measured by FE-1005 and FE-2005. Position indication by ZT-1006 and ZT-2006. Primary side temperature and pressure.	During startup, and during other low feedwater flow rate operations, the spurious opening of the FWRV results in an increase in flow through the spuriously opened path. If the increase in flow to the SG results in over cooling of the primary side the reactor trips due to high reactor power. With the inability to control the feedwater flow rate to one of the two steam generators, the DHRS is actuated and the reactor module is isolated for decay heat removal. No safety related portions of the NSSS are affected, as SGs can be isolated by the FWIVs. Decay heat is removed by the DHRS exchanger.
		B) Spurious Closing	Mechanical Electrical/ I&C Operator Error	No feedwater flow to one of the two SG headers.	Feedwater flow rate as measured by FE-1005 and FE-2005. Position indication by ZT-1006 and ZT-2006. Primary side temperature and pressure.	During startup, and during other low feedwater flow rate operations, the spurious closing of the FWRV results in the termination of flow through one of the two SGs. There is no plan to maintain operation if one of the two SGs is unavailable. If the decrease in feedwater flow does not cause a reactor trip due to high pressure on the primary side, the decision is made by operators to trip the reactor due to regulating valve failure. No safety related portions of the NSSS are affected, as SGs can be isolated by the FWIVs. Decay heat is removed by the DHRS exchanger.

Table 10.4-18: Condensate and Feedwater System Failure Modes and Effects Analysis (Continued)

Component Identification	Function	Failure Mode	Failure Mechanism	Effect on the Condensate and Feedwater System	Method of Failure Detection	Remarks
Feedwater Regulating Valve xx*-FW-FCV-1006 xx*-FW-FCV-2006 (normally open, fail closed) *reserved for module number (01 - 12) (cont)	2) Provides redundant isolation for FWIV actuation events.	A) Failure to Close B) Slow Closing	Mechanical Electrical/ I&C	Not available for containment isolation, not providing redundant containment isolation.	Position indication by ZT-1006 and ZT-2006. Position indication from ZSO-1006 A/B, ZSC-1006 A/B, ZSO-2006 A/B, ZSC-2006 A/B	The FWIVs are the primary method for providing steam generator isolation. There is no effect on reactor safety if the FWRVs fail with the FWIVs operating correctly. Additional protection is provided by the feedwater safety and non-safety check valves.
		C) Spurious Opening	Mechanical Electrical/ I&C Operator Error			
Feedwater Check Valve xx*-FW-CKV-1007/ 2007	1) Provides redundant isolation for safety-related check valve.	A) Failure to Close	Mechanical	Not available for containment isolation, not providing redundant containment isolation or maintaining level in the steam generators.	N/A	The safety related check valve is the primary method for maintaining steam generator inventory during a feedwater line break. There is no effect on reactor safety if the feedwater check valve were to fail with the safety related check valve operating correctly.

Table 10.4-18: Condensate and Feedwater System Failure Modes and Effects Analysis (Continued)

Component Identification	Function	Failure Mode	Failure Mechanism	Effect on the Condensate and Feedwater System	Method of Failure Detection	Remarks
Condensate Header Emergency Rejection Level Control Valve xx*-FW-LCV-0070 (normally closed, fail closed) *reserved for module number (01 - 12)	1) Provides emergency level control of condensate inventory.	A) Spurious Opening	Mechanical Electrical/ I&C Operator Error	Condensate flow is diverted to the condensate storage tank. Low condensate flow and pressure is delivered to the feedwater pumps and subsequently the steam generators. The feedwater pumps increase in speed in an attempt to make up the difference in flow rate. It is possible that the third condensate pump is started to ensure adequate flow is supplied to the feedwater pumps.	Condenser level reading by LIT-0004 A/B/C Valve position as measured by ZT-0070 Feedwater Pump Supply Pressure as measured by PIT-0050 A/B/C	Safety-related portions of the NSSS remain available for decay heat removal if reactor trips without the ability to remove decay heat with the CFWS. No impact on the primary isolation valves or the DHRS exchanger which remain available to remove decay heat.
		B) Fail to open	Mechanical Electrical/ I&C	If this valve fails to open, level in the condenser rises (i.e., major tube rupture in the condenser). If level rises above high-high set point, the CFWS is tripped, and the reactor must be isolated.	Condenser level reading by LIT-0004 A/B/C Valve position as measured by ZT-0070	
Condensate Header Normal Rejection Level Control Valve xx*-FW-LCV-0071 (normally closed, fail closed) *reserved for module number (01 - 12)	1) Provides normal level control of condensate inventory.	A) Spurious opening	Mechanical Electrical/ I&C Operator Error	Condensate flow is diverted to the condensate storage tank. Low condensate flow and pressure is delivered to the feedwater pumps and subsequently the steam generators. The feedwater pumps increase in speed in an attempt to make up the difference in flow rate. It is possible that the third condensate pump is started to ensure adequate flow is supplied to the feedwater pumps.	Condenser level reading by LIT-0004 A/B/C Valve position as measured by ZT-0071 Feedwater Pump Supply Pressure as measured by PIT-0050 A/B/C	Safety-related portions of the NSSS remain available for decay heat removal if reactor trips without the ability to remove decay heat with the CFWS. No impact on the primary isolation valves or the DHRS exchanger which remain available to remove decay heat.
		B) Fail to open	Mechanical Electrical/ I&C	Condensate level in the main condenser rises. High condenser level alarms go off in the control room. The condensate header emergency rejection level control valve (LCV-0070) opens, lowering the level in the condenser	Condenser level reading by LIT-0004 A/B/C Valve position as measured by ZT-0070	None

Table 10.4-18: Condensate and Feedwater System Failure Modes and Effects Analysis (Continued)

Component Identification	Function	Failure Mode	Failure Mechanism	Effect on the Condensate and Feedwater System	Method of Failure Detection	Remarks
Main Condenser Hotwell Emergency Make up Level Control Valve xx*-FW-LCV-0076 (normally closed, fail closed) *reserved for module number (01 - 12)	1) Provides emergency level control of condensate inventory.	A) Spurious Opening	Mechanical Electrical/ I&C Operator Error	Condensate is gravity feed to the main condenser hotwell. High level in the condenser causes the condensate header normal rejection level control valve (LCV-0071) to actuate open to reduce hotwell level	Condenser level reading by LIT-0004 A/B/C Valve position as measured by ZT-0076	Safety-related portions of the NSSS remain available for decay heat removal if reactor trips without the ability to remove decay heat with the CFWS. No impact on the primary isolation valves or the DHRS exchanger which remain available to remove decay heat.
		B) Fail to open	Mechanical Electrical/ I&C	Main condenser hotwell level continues to fall. Low condenser hotwell level causes MCS to close both the condensate header normal and emergency level control valves (LCV-0070 and LCV-0071). If level continues to drop, condensate pumps could be tripped based on low NPSH due to low condenser level.		
Main Condenser Hotwell Normal Make up Flow Control Valve xx*-FW-LCV-0077 (normally closed, fail closed) *reserved for module number (01 - 12)	1) Provides normal level control of condensate inventory.	A) Spurious Opening	Mechanical Electrical/ I&C Operator Error	Condensate is gravity feed to the main condenser hotwell. High level in the condenser causes the condensate header normal level control valve (LCV-0071) to actuate open to reduce hotwell level.	Condenser level reading by LIT-0004 A/B/C Valve position as measured by ZT-0070	None
		C) Fail to open	Mechanical Electrical/ I&C	Main condenser hotwell level continues to fall. Low condenser hotwell level measurements cause the main condenser hotwell emergency make up level control valve (LCV-0076) to open.		

Table 10.4-18: Condensate and Feedwater System Failure Modes and Effects Analysis (Continued)

Component Identification	Function	Failure Mode	Failure Mechanism	Effect on the Condensate and Feedwater System	Method of Failure Detection	Remarks
Condensate Storage Tank Make up Level Control Valve xx*-FW-LCV-0078 (normally closed, fail closed) *reserved for module number (01 - 12)	1) Provides level control of the condensate storage tank inventory.	A) Spurious Opening	Mechanical Electrical/ I&C Operator Error	Cause high level alarms to trigger for the Condensate storage tank. It is possible that the tank overflows.	Level indication as measured by LIT-0073 A/B	None
		C) Fail to open	Mechanical Electrical/ I&C	Level in the condensate storage tank drops as no make up water is being supplied to the condensate and feedwater system. If the level in the condenser continues to fall operators are responsible for determining the cause and taking the appropriate actions.		
Feedwater Lines Outside of Containment (Including ball joints).	Supplies feedwater to the steam generators	A) Main feedwater header line break outside of containment	Mechanical Operator Error	A major feedwater header line break outside of containment causes a reactor trip.	Increased CFWS flow rate. Decreased CFWS header pressure Rapid increase in primary side temperature and pressure.	For feedwater line breaks, the decreased amount of heat removal results in a rapid increase in RCS temperature. This transient results in a reactor trip due to high pressurizer pressure signal. Flow reversal is prevented by the feedwater check valves and the DHRS is actuated to remove decay heat. Feedwater line break outside containment is an accident condition for a NuScale module.

Table 10.4-19: Condensate and Feedwater System Instrumentation

Equipment Name	Monitored Parameter (NPMs)	Local Display	Signal To MCS
Condensate pump inlet temperature indicating transmitter	Condensate pump suction temperature (F)	Yes	Yes
Condensate pump startup strainer pressure differential indicating transmitter	Equipment pressure drop (psid)	Yes	No
Condensate pump inlet pressure indicating transmitter A/B/C	Condensate pump suction pressure (psia)	Yes	Yes
Condensate pump outlet flow meter A/B/C	Condensate pump discharge flow rate (gpm)	No	No
Condensate outlet flow transmitter A/B/C (redundant)	Condensate pump discharge Flow Rate (gpm)	Yes	Yes
Condensate pump outlet pressure indicating transmitter A/B/C	Condensate pump discharge pressure (psia)	Yes	Yes
Condensate conductivity analyzer	Micro Siemens per centimeter @ 25°C (μS/cm)	Yes	Yes
Condensate flow meter	Condensate flow rate (gpm)	No	No
Condensate flow indicating transmitter	Condensate flow rate (gpm)	Yes	Yes
Condensate oxygen concentration analyzer	ppb	No	Yes
Gland steam condenser inlet pressure indicating transmitter	Piping system pressure (psia)	Yes	Yes
Gland steam condenser outlet temperature indicating transmitter	Condensate temperature (°F)	Yes	Yes
Gland steam condenser outlet pressure indicating transmitter	Piping system pressure (psia)	Yes	Yes
Condensate storage tank inlet flow meter	Condensate flow rate (gpm)	No	No
Condensate storage tank inlet flow transmitter	Condensate flow rate (gpm)	Yes	Yes
LP-FWH outlet temperature indicator transmitter	Condensate temperature (°F)	Yes	Yes
LP-FWH outlet pressure indicating transmitter	Piping system pressure (psia)	Yes	Yes
IP-FWH outlet temperature indicator/transmitter	Condensate temperature (°F)	Yes	Yes
IP FWHIP-FWH outlet pressure indicating transmitter	Piping system pressure (psia)	Yes	Yes
Short cycle cleanup flow control valve position indicator	Flow control valve position (%)	No	Yes
Feedwater pump inlet pressure indicating transmitter	piping system pressure (psia)	Yes	Yes
Feedwater pump inlet manual valve open position switch	valve not fully open	No	Yes
Feedwater pump outlet pressure indicating transmitter A/B/C	Piping system pressure (psia)	Yes	Yes
Feedwater pump outlet flow meter A/B/C	Feedwater flow rate (gpm)	No	Yes
Feedwater pump outlet flow indicator/ transmitter	Feedwater flow rate (gpm)	Yes	Yes
Feedwater pumps minimum flow protection flow control valve open position transmitter A/B/C	Flow control valve position (%)	No	Yes
HP-FWH outlet temperature indicating transmitter	Feedwater temperature	Yes	Yes
Long cycle cleanup flow control valve position transmitter	Flow control valve position (%)	No	Yes
Feedwater header pressure indicating transmitter	Piping system pressure (psia)	Yes	Yes
Feedwater header flow meter A/B/C	Feedwater flow rate (gpm)	No	No

Table 10.4-19: Condensate and Feedwater System Instrumentation (Continued)

Equipment Name	Monitored Parameter (NPMs)	Local Display	Signal To MCS
Feedwater header flow meter indicating transmitter (duplicate)	Feedwater flow rate (gpm)	Yes	Yes
Feedwater regulating valve A/B position indicating transmitter	Flow control valve position (%)	No	Yes
Feedwater regulating valve A/B position switch open indicators	Valve not fully open	No	Yes
Feedwater regulating valve A/B position switch closed indicators	Valve not fully closed	No	Yes
Condensate header emergency rejection level control valve position indicating transmitter	Level control valve position (%)	No	Yes
Condensate header normal rejection level control valve position indicating transmitter	Level control valve position (%)	No	Yes
Condensate storage tank level indicating transmitter	Vessel level (inches of H_2O)	Yes	Yes
Condensate makeup conductivity analyzer	Condensate conductivity [microsiemens per centimeter @ 25°C (µS/cm)]	Yes	Yes
Condensate storage tank makeup level control valve position indicating transmitter	Level control valve position (%)	No	Yes
Condensate pump inlet manual valve position switch open	Valve not fully open	No	Yes
Long cycle cleanup air operated valve position switch open	Valve not fully open	No	Yes
Long cycle cleanup air operated valve position switch closed	Valve not fully closed	No	Yes
Condensate pump redundant minimum flow protection valve position switch open	Valve not fully open	No	Yes
Condensate pump redundant minimum flow protection valve position switch closed	Valve not fully closed	No	Yes
Long cycle recirculation flow element	Flow rate (lb/hr)	No	Yes
Long cycle recirculation flow indicating transmitter	Flow rate (lb/hr)	Yes	Yes

Table 10.4-20: Auxiliary Boiler System Component Design Parameters

	High-Pressure Auxiliary Boiler	Low-Pressure Auxiliary Boiler
Fuel	Site-specific	Site-specific
Number of boilers	2	1
Steam supply pressure	1100 psig	500 psig
Steam rate and temperature	18,000 lb/hr at 575°F	4,600 lb/hr at 575°F
Feedwater pump rate	80 gpm	10 gpm
Pipe code / material	ASME B31.1 / SA-335 P11 or equivalent	ASME B31.1 / SA-335 P11 or equivalent
Estimated blowdown (demineralized feed, 10 cycles)	17.3 gpm	9.2 gpm

Table 10.4-21: Auxiliary Boiler System Instrumentation

System	Type	Location	Indication	
			Local	MCR
HP	Radiation ind trans	Exit of MHS heat exchangers	Yes	Yes
HP	Valve open	Exit of MHS heat exchangers	No	Yes
HP	Valve closed	Exit of MHS heat exchangers	No	Yes
HP	Valve pos trans	Demineralized water supply	No	Yes
HP	Radiation ind trans	Vent of high-pressure condensate tank pressure regulating valve	Yes	Yes
HP	Valve pos trans	High-pressure condensate tank pressure regulating valve	No	Yes
HP	Level indicator trans	High-pressure condensate tank	Yes	Yes
HP	Pressure ind trans	High-pressure condensate tank	Yes	Yes
HP	Valve open	Steam supply from high-pressure boiler A	No	Yes
HP	Valve closed	Steam supply from high-pressure boiler A	No	Yes
HP	Valve open	Steam supply from high-pressure boiler B	No	Yes
HP	Valve closed	Steam supply from high-pressure boiler B	No	Yes
HP	Pressure ind trans	High-pressure steam supply header	Yes	Yes
HP	Temp ind trans	High-pressure steam supply header	Yes	Yes
HP	Valve open	Supply to MHS heat exchangers	No	Yes
HP	Valve closed	Supply to MHS heat exchangers	No	Yes
HP	Flow ind trans	Blowdown from boiler B	Yes	Yes
HP	Valve pos trans	Blowdown from boiler B	No	Yes
HP	Valve open	Blowdown from boiler B to PSS	No	Yes
HP	Valve closed	Blowdown from boiler B to PSS	No	Yes
HP	Flow ind trans	Blowdown from boiler A	Yes	Yes
HP	Valve pos trans	Blowdown from boiler A	No	Yes
HP	Valve open	Blowdown from boiler A to PSS	No	Yes
HP	Valve closed	Blowdown from boiler A to PSS	No	Yes
LP	Flow ind trans	Main Steam/ABS supply to TGS gland steam	Yes	Yes
LP	Pressure ind trans	Main Steam/ABS supply to TGS gland steam	Yes	Yes
LP	Temp ind trans	Main Steam/ABS supply to TGS gland steam	Yes	Yes
LP	Valve pos trans	Cross over from HP to LP system	No	Yes
LP	Pressure ind trans	Cross over from HP to LP system	Yes	Yes
LP	Temp ind trans	Cross over from HP to LP system	Yes	Yes
LP	Valve pos trans	Demineralized water supply	No	Yes
LP	Radiation ind trans	Vent of low-pressure condensate tank pressure regulating valve	Yes	Yes
LP	Valve pos trans	Low-pressure condensate tank pressure regulating valve	No	Yes
LP	Level indicator trans	Low-pressure condensate tank	Yes	Yes
LP	Pressure ind trans	Low-pressure condensate tank	Yes	Yes
LP	Valve open	Steam supply from low-pressure boiler	No	Yes
LP	Valve closed	Steam supply from low-pressure boiler	No	Yes
LP	Flow ind trans	Blowdown from LP boiler	Yes	Yes
LP	Valve pos trans	Blowdown from LP boiler	No	Yes
LP	Valve open	Blowdown from LP boiler to PSS	No	Yes
LP	Valve closed	Blowdown from LP boiler to PSS	No	Yes
LP	Valve open	Cross feed with MS to TGS gland seals	No	Yes
LP	Valve closed	Cross feed with MS to TGS gland seals	No	Yes
LP	Valve open	Feed to TGS gland seals	No	Yes
LP	Valve closed	Feed to TGS gland seals	No	Yes

Table 10.4-22: Feedwater Treatment System Operating Parameters

Item	Limit
pH	Determined by site-specific requirements, expected to be 9.3 to 9.7 pH (25°C) using ammonia
Hydrazine	≥20 ppb
Dissolved oxygen	≤5 ppb (to minimize equipment degradation from erosion-corrosion

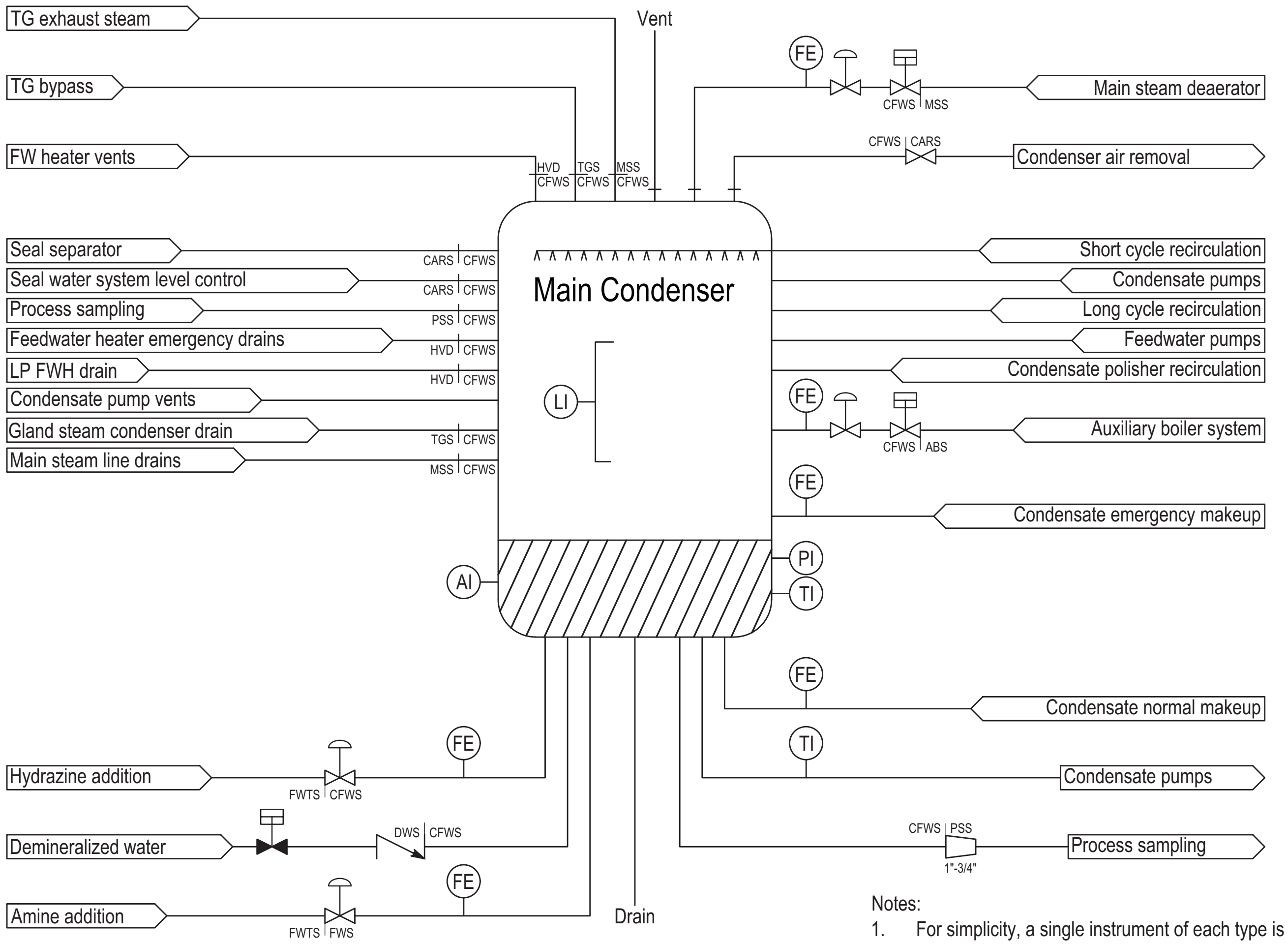
Table 10.4-23: Feedwater Treatment System Component Design Data

Hydrazine tank (oxygen scavenging)	
Volume	Site-specific
Material	Type 304 stainless steel
Amine tank (pH control)	
Volume	Site-specific
Material	Type 304 stainless steel
Pumps	
Material	Type 316 stainless steel
Type	Diaphragm simplex-type
Flow rate	Variable

Table 10.4-24: Feedwater Treatment System Instrumentation

Equipment Name	Monitored Parameter (Units)	Local Display	Signal to MCS
Feedwater header oxygen analyzer	ppb	Yes	Yes
Mass hydrazine addition flow control valve	Valve position	No	Yes
Mass amine addition flow control valve	Valve position	No	Yes
Shutdown hydrazine addition flow element	Flow rate (lb/hr)	No	Yes
Shutdown hydrazine addition flow indicating transmitter	Flow rate (lb/hr)	Yes	Yes
Shutdown amine addition flow element	Flow rate (lb/hr)	No	Yes
Shutdown amine addition flow indicating transmitter	Flow rate (lb/hr)	Yes	Yes

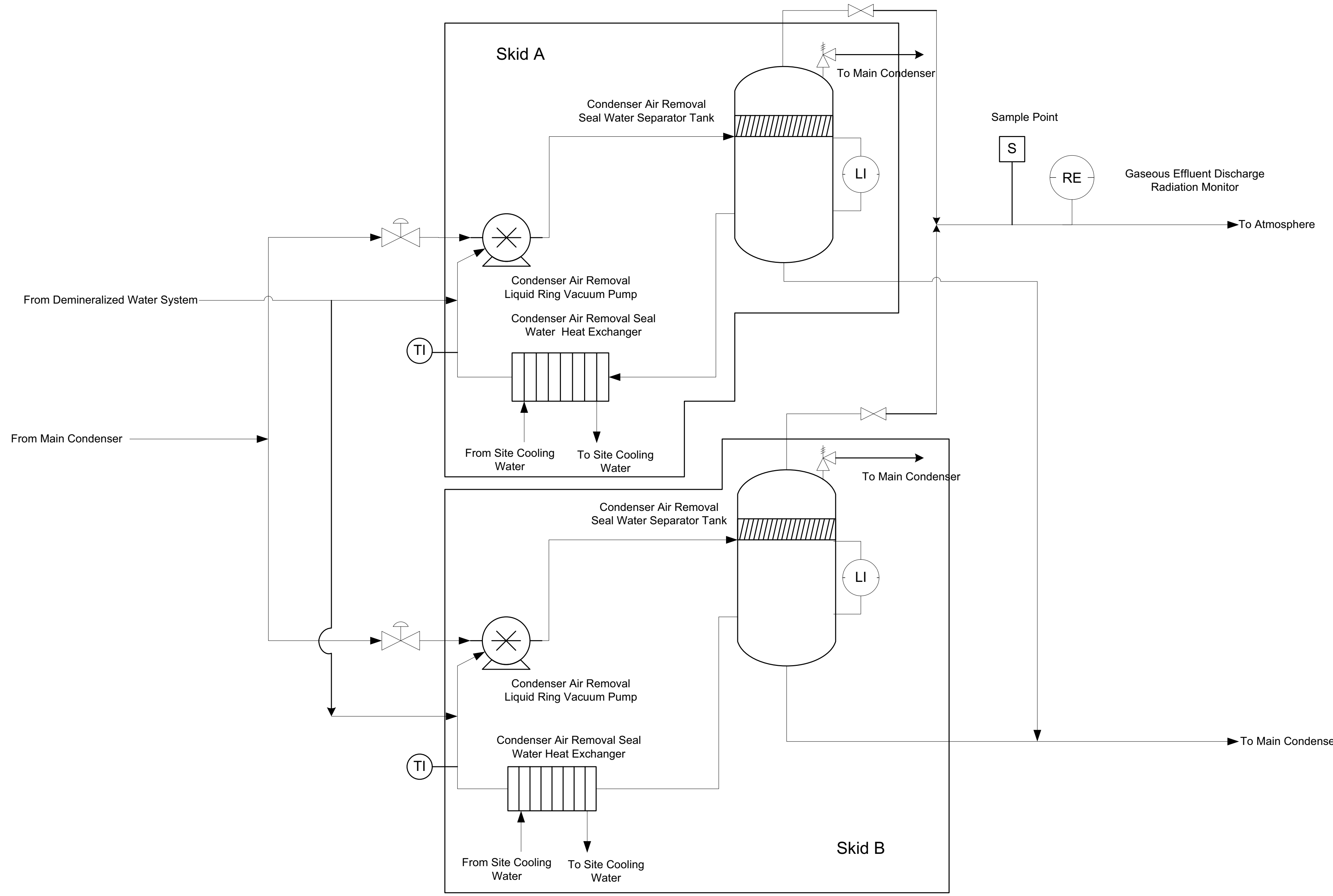
Figure 10.4-1: Main Condenser Piping and Instrumentation Diagram



Notes:

1. For simplicity, a single instrument of each type is shown in each location.

Figure 10.4-2: Condenser Air Removal System Piping and Instrumentation Diagram



Notes:
1. System vents and drains not shown. Drains go to balance of plant drain.
2. Orifices not shown.
3. Additional instrumentation not shown.
4.Tank isolation valves are manually controlled from Control Room during emergency operations.

Figure 10.4-3: Circulating Water System Piping and Instrumentation Diagram (Typical of 2)

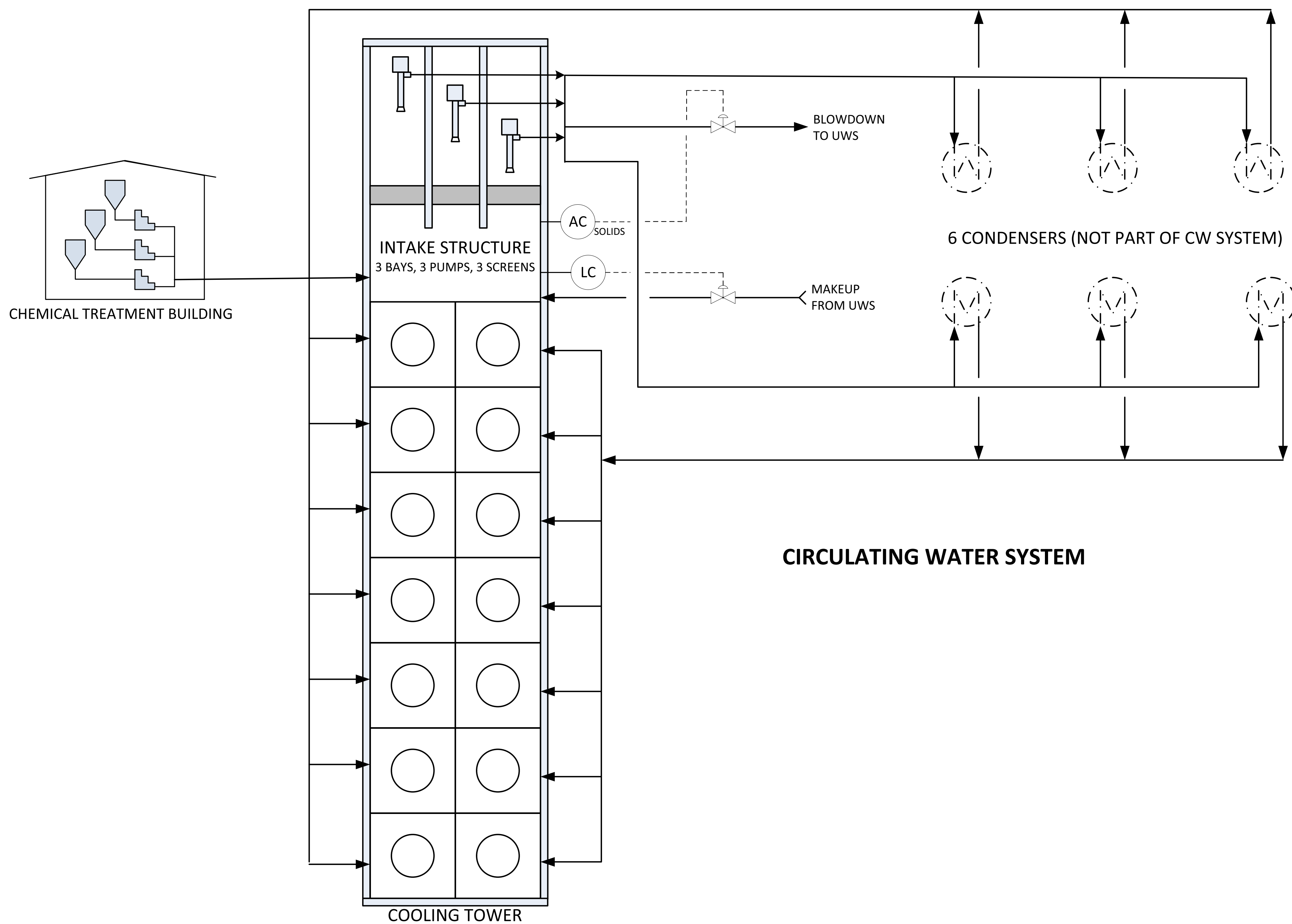


Figure 10.4-4a: Auxiliary Boiler System Piping and Instrumentation Diagram

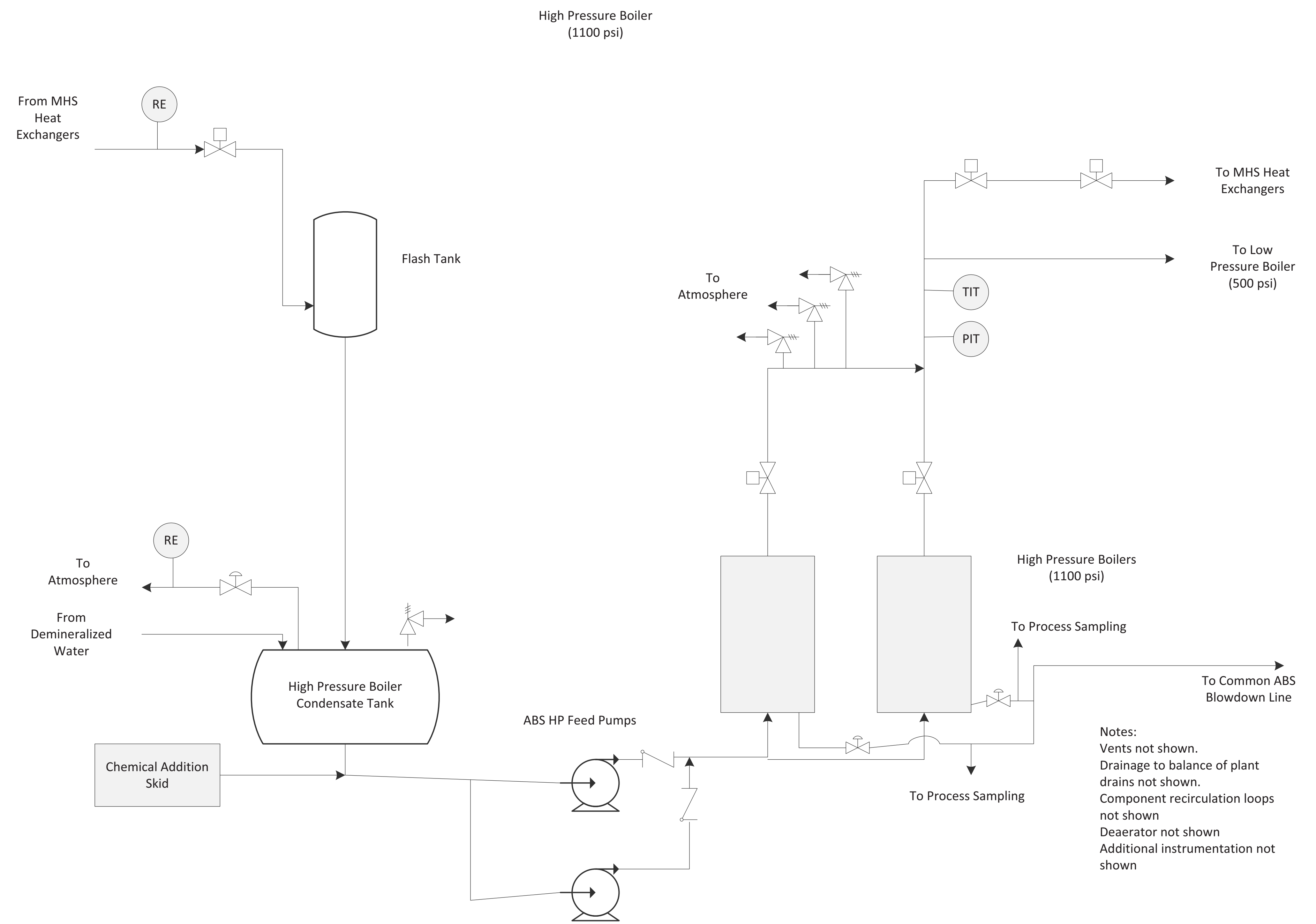


Figure 10.4-4b: Auxiliary Boiler System Piping and Instrumentation Diagram