December 15, 2022 Docket No. 99902078

U.S. Nuclear Regulatory Commission
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SUBJECT: NuScale Power, LLC Submittal of the NuScale Standard Design Approval Application Part 2 – Final Safety Analysis Report, Chapter 10, "Steam and Power Conversion System," Revision 0

REFERENCES:
1. NuScale letter to NRC, "NuScale Power, LLC Submittal of Planned Standard Design Approval Application Content," dated February 24, 2020 (ML20055E565)
2. NuScale letter to NRC, "NuScale Power, LLC Requests the NRC staff to conduct a pre-application readiness assessment of the draft, 'NuScale Standard Design Approval Application (SDAA),'" dated May 25, 2022 (ML22145A460)
3. NRC letter to NuScale, "Preapplication Readiness Assessment Report of the NuScale Power, LLC Standard Design Approval Draft Application," Office of Nuclear Reactor Regulation dated November 15, 2022 (ML22305A518)
4. NuScale letter to NRC, "NuScale Power, LLC Staged Submittal of Planned Standard Design Approval Application," dated November 21, 2022 (ML22325A349)

NuScale Power, LLC (NuScale) is pleased to submit Chapter 10 of the Standard Design Approval Application, "Steam and Power Conversion System," Revision 0. This chapter supports Part 2, "Final Safety Analysis Report," of the NuScale Standard Design Approval Application (SDAA) (Reference 1). NuScale submits the chapter in accordance with requirements of 10 CFR 52 Subpart E, Standard Design Approvals. As described in Reference 4, the enclosure is part of a staged SDAA submittal. NuScale requests NRC review, approval, and granting of standard design approval for the US460 standard plant design.

From July 25, 2022 to October 26, 2022, the NRC performed a pre-application readiness assessment of available portions of the draft NuScale Final Safety Analysis Report (FSAR) to determine the FSAR's readiness for submittal and for subsequent review by NRC staff (References 2 and 3). The NRC staff reviewed draft Chapter 10. NuScale is enclosing information in this submittal that: 1) closes gaps identified between the draft SDAA Chapter 10 and technical content generally expected by the NRC; and 2) resolves identified technical issues that may have adversely impacted acceptance, docketing, or technical review of the application. Enclosure 2 provides NuScale's responses to Reference 3 for Chapter 10 observations.

Enclosure 1 contains Part 2 Chapter 10 of the SDAA, “Steam and Power Conversion System,” Revision 0. Enclosure 2 contains the Readiness Assessment Report responses for this chapter.

This letter makes no regulatory commitments and no revisions to any existing regulatory commitments.

If you have any questions, please contact Mark Shaver at 541-360-0630 or at mshaver@nuscalepower.com.

I declare under penalty of perjury that the foregoing is true and correct. Executed on December 15, 2022.

Sincerely,

Carrie Fosaaen
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Distribution: Brian Smith, NRC
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Enclosure 1: SDAA Part 2 Chapter 10, “Steam and Power Conversion System,” Revision 0
Enclosure 2: Readiness Assessment Report responses for Chapter 10

Enclosure 1:

SDAA Part 2 Chapter 10, “Steam and Power Conversion System,” Revision 0

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NuScale US460 Plant
Standard Design Approval Application

Chapter Ten

Steam and Power Conversion System

Final Safety Analysis Report

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. Heat energy from the NuScale Power Module (NPM) is transferred from the primary coolant by helical-coil steam generators to convert secondary coolant to steam. Turbine generators convert this steam energy to electrical power. The steam and power conversion system has no safety-related or risk-significant function.

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

- turbine generator system (TGS) (Section 10.2)
- main steam system (MSS) (Section 10.3)
- air cooled condenser system (ACCS) (Section 10.4.1)
- condenser air removal system (CARS) (Section 10.4.2)
- turbine gland sealing system (TGSS) (Section 10.4.3)
- turbine bypass system (TBS) (Section 10.4.4)
- condensate polisher skid and resin regeneration system (CPS) (Section 10.4.5)
- condensate and feedwater system (FWS) (Section 10.4.6)
- auxiliary boiler system (ABS) (Section 10.4.7)
- feedwater treatment system (FWTS) (Section 10.4.8)

Table 10.3-1 shows major system operating parameters at rated thermal power. Table 10.2-1 provides turbine generator design parameters.

Figure 10.1-1 provides a power conversion system simplified diagram of an NPM.

10.1.1 Protective Features

Section 10.3 and Section 10.4 describe load rejection capabilities of the steam and power conversion system.

Main steam safety valves provide overpressure protection of the steam and power conversion system as described in Section 10.3.

Plant accidents and transient events that result in a loss of feedwater are addressed in Section 10.4.6 and Section 15.2.7.

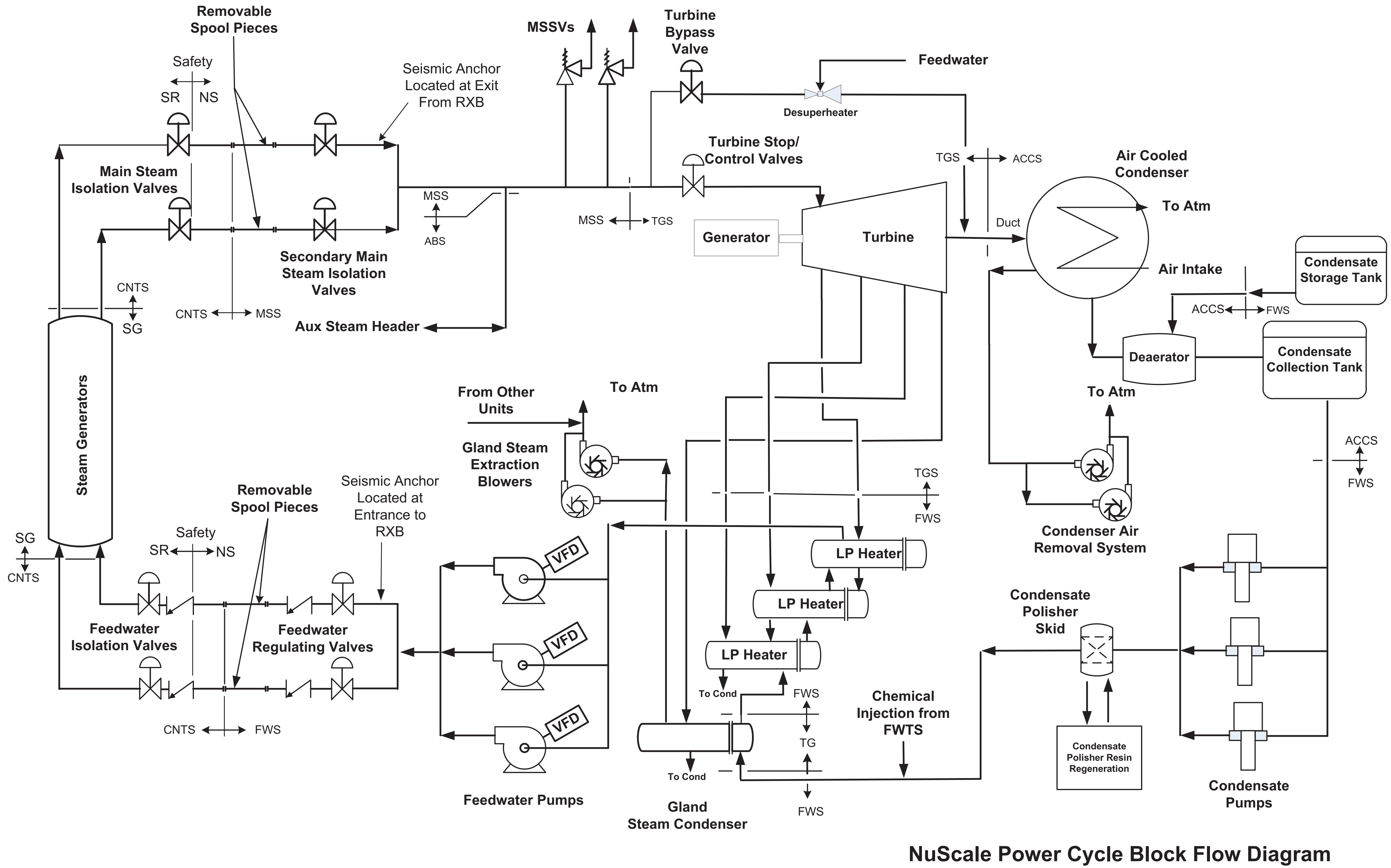
The turbine overspeed protection provides protection from exceeding overspeed limits as discussed in Section 10.2.

Turbine missiles are discussed in Section 3.5.

Under normal operating conditions, radioactive contaminants are not expected in the steam and power conversion system. However, it is possible for the system to become contaminated. Implications of detecting radioactivity in the secondary side are addressed in Section 11.5.

The design of nonsafety-related portions of steam and power conversion systems that could adversely impact safety-related systems incorporate considerations to prevent erosion, corrosion, and flow-accelerated corrosion. Design implementations are further addressed in Section 10.3.5 and Section 10.3.6.

Figure 10.1-1: Power Conversion System Block Flow Diagram



10.2 Turbine Generator

The turbine generator system (TGS) converts steam into electricity. Each turbine generator system services one NuScale Power Module (NPM).

10.2.1 Design Bases

The TGS serves no safety-related functions, is not risk-significant, is not credited for mitigation of a design basis accident, and has no safe shutdown functions. General Design Criterion (GDC) 4 is considered in the design of the TGS.

10.2.2 System Description

The subsystems for the TGS include turbine, turbine gland seal, turbine lube oil, turbine control oil, generator, and generator air coolers. Figure 10.2-1 is a TGS simplified piping and instrumentation diagram. The TGS and associated piping, valves, and controls are located completely within the Turbine Generator Building. No safety-related systems or components are located within the Turbine Generator Building. The TGS is not required to operate during or after an accident.

The TGS is Seismic Category III and TGS piping is designed to the ASME B31.1 code (Reference 10.2-1).

Table 10.2-1 shows TGS component design parameter details.

10.2.2.1 Turbine Subsystem

The main steam system provides the turbine with steam from the steam generators. Steam passes through the turbine, converting 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
- provides bypass of steam to the condenser (discussed in Section 10.4.4)
- provides gland sealing steam (discussed in Section 10.4.3)

Major components of the turbine subsystem include the

- steam turbine
- turbine stop valve
- turbine control valve
- turbine bypass valve and desuperheater (discussed in Section 10.4.4)
- gland seal steam condenser and blower (discussed in Section 10.4.3)

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 from extraction line connection points. Figure 10.2-1 and Section 10.3 provide additional information.

Turbine generators use a commercially available condensing steam turbine with a proven design and reliable operation based on operating experience in steam systems. The turbine is a single inlet design with stop and control valves.

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

10.2.2.2 Generator Subsystem

The generator converts rotational mechanical energy from the turbine to electricity by rotating a magnetic field mounted on the generator shaft (rotor windings) surrounded by stationary current-carrying conductors (stator windings). The brushless exciter provides electrical current to produce the magnetic field in the rotor windings. The frequency is synchronized with the off-site transmission system and power is transferred to the grid. The generator is directly coupled to the turbine, and is air cooled. Components of the generator subsystem include the generator stator, generator air coolers, generator rotor, and exciter.

10.2.2.3 Lube Oil Subsystem

The lube oil system supports the turbine subsystem and generator subsystem by providing lubrication and cooling to journal and thrust bearings during normal operation.

Components of the lube oil subsystem include the lube oil reservoir, primary oil pumps, and the emergency oil pump.

The lube oil subsystem is skid-mounted and provides oil by two main lube oil pumps. An emergency lube oil pump protects bearings from damage following a loss of the main pumps. Once oil is returned to the reservoir, the oil is cooled, filtered, and conditioned.

10.2.3 Component Description

Steam flow to the turbine is controlled by a stop valve located adjacent to the turbine. The stop valve isolates steam flow to the turbine upon receiving a trip signal.

The turbine control valve is used to throttle steam flow to the turbine during startup, shutdown, and normal operation. This valve closes upon actuation of the trip signal.

10.2.4 Control Functions

The TGS is monitored and controlled by the main turbine control system (MTCS). The MTCS interfaces with the module control system (MCS). The MCS provides

instrumentation and control of the TGS inside the main control room. Chapter 7 provides additional information on the MCS.

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.

10.2.5 Inspection and Testing

Major system components are accessible for inspection and are available for testing during normal plant operations. The governor and overspeed protection are tested and inspected as recommended by the manufacturer. The stop valve and control valve are exercised at a frequency recommended by the turbine vendor or valve manufacturer.

10.2.6 Safety Evaluation

General Design Criterion 4 is considered in design of the TGS. Appendix A of Regulatory Guide 1.115, "Protection Against Turbine Missiles," identifies structures, systems, and components (SSC) requiring protection from turbine missiles and defines those SSC as "essential." The design protects essential SSC from high-trajectory and low-trajectory turbine rotor and blade fragments by using barriers. Section 3.5.1 describes how protection of essential SSC from the effects of turbine missiles is accomplished. There are no safety-related systems or components located within the Turbine Generator Building.

Section 11.5 describes instrumentation provided at the condenser air removal system discharge. The implications of detecting radioactivity in the secondary side are addressed by the requirements identified in Section 11.5. Section 12.3 provides further discussion of facility design features to protect against radioactive contamination.

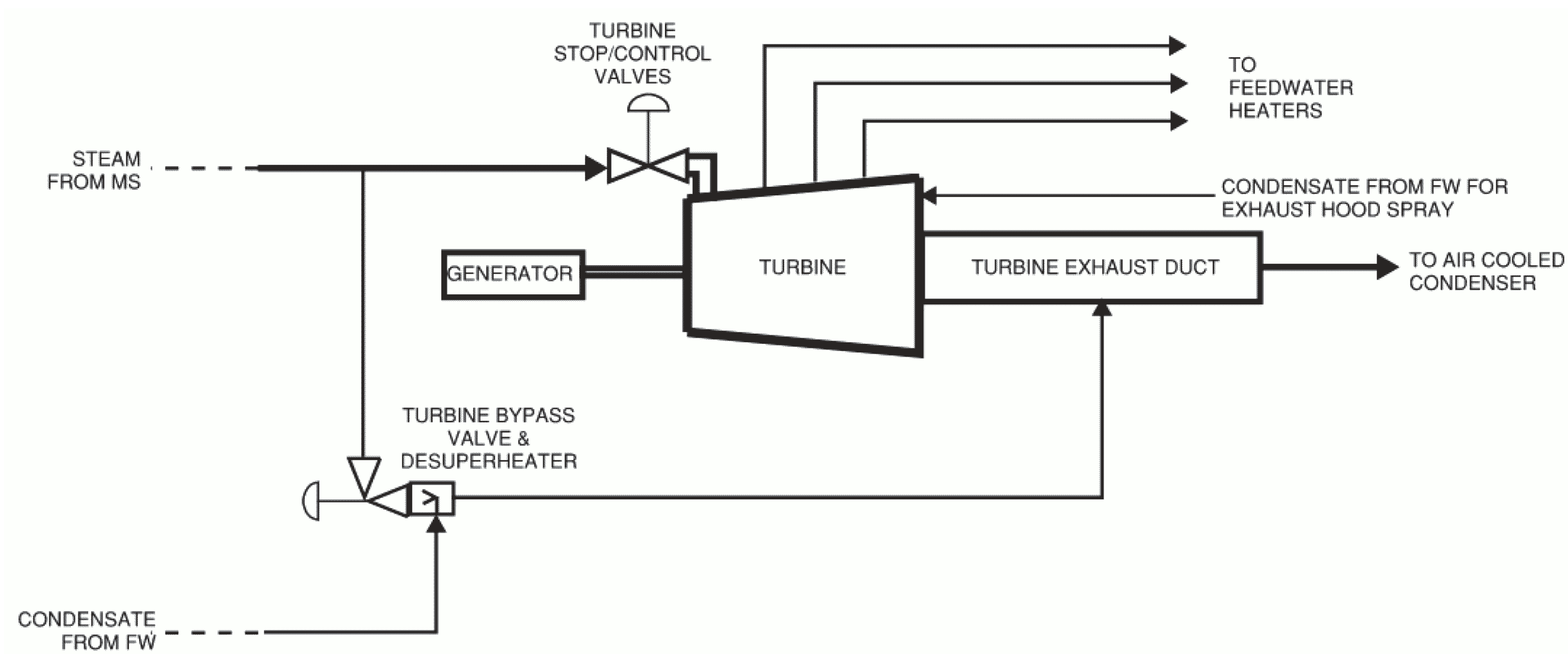
10.2.7 References

10.2-1 American Society of Mechanical Engineers, *Power Piping*, ASME Code for Pressure Piping, B31, ASME B31.1, New York, NY.

Table 10.2-1: Turbine Generator Design Details

Component or Parameter	Description
Turbine rotor	• Single Turbine • Condensing • ASTM A470 CL4 or equal (Section 3.5.1)
Turbine blades	ASTM A276 - A403 or equal (Section 3.5.1)
Turbine RPM	3600 rpm
Generator power output	77 MWe

Figure 10.2-1: Turbine Generator System Schematic



10.3 Main Steam System

The main steam system (MSS) transports steam from the steam generators (SGs) 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.

10.3.1 Design Bases

The MSS is nonsafety-related and has no risk-significant structures, systems, and components (SSC). A nonsafety-related secondary MSIV and associated secondary main steam isolation bypass valves (MSIBV) are located downstream of the containment system MSIV as backup for the containment system MSIV design bases functions described in Section 6.2.4.

The MSS design considers General Design Criterion (GDC) 2, GDC 4, GDC 5, 10 CFR 50.63, and Principal Design Criterion (PDC) 34.

10.3.2 System Description

The MSS performs nonsafety-related and non-risk-significant functions, including delivering steam from the SGs to the turbine and collecting drainage condensed in MSS piping and delivering it to the main condenser.

Each NPM has SGs 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 system boundaries. A common section of MSS piping is provided to mix the output of the SG lines before the steam is directed to the turbine generator.

Figure 10.3-1 is a simplified diagram for the MSS. Table 10.3-1 provides MSS design parameters.

Upstream of the secondary MSIVs, connections are provided for the removable pipe spool and the secondary MSIBV. Branch piping inside the RXB downstream of the secondary MSIVs is limited to the connections for dry layup and an additional valve in the secondary MSIV bypass line to protect bypass piping during startup operations.

The MSS piping is protected from overpressure by MSSVs.

Failure modes and effects analyses for the MSS are summarized in Section 5.4 (specific to providing backup to decay heat removal system (DHRS) operation) and

Table 10.3-2 (specific to providing backup of containment and secondary system isolation (SSI) functions of the MSS).

Leak detection capabilities for the MSS are provided by the DHRS, as discussed in Section 5.4.3. These capabilities cause an isolation signal to limit blowdown of the system.

10.3.2.1 Component Description

The secondary MSIVs and secondary MSIBVs are Seismic Category I. The MSSVs, condensate lift tank, and condensate lift pump are Seismic Category III. The MSS is nonsafety related and Quality Group D. Consistent with RG 1.26, "Quality Group Classifications and Standards for Water-, Steam-, and Radioactive-Waste-Containing Components of Nuclear Power Plants," these portions are designed in accordance with the provisions of ASME Power Piping Code B31.1.

10.3.2.1.1 Main Steam Piping

Figure 10.1-1 and Figure 10.3-1 depict MSS boundaries, including interconnections with other systems.

Flanges immediately downstream of the MSIVs enable disconnection of MSS piping from the NPM in preparation for moving the module for refueling or maintenance. The MSS piping boundary starts immediately downstream of the flanges.

Steam lines are then routed inside the RXB toward the Turbine Generator Building (TGB). The lines are supported between the RXB and the TGB.

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

10.3.2.1.2 Secondary Main Steam Isolation Valves

One nonsafety-related secondary MSIV is located downstream of each containment system MSIV. The secondary MSIV has an augmented quality requirement to serve as backup for performance of the containment system MSIV design bases functions as described in Section 6.2. In response to a DHRS actuation signal and secondary system isolation (SSI) signal, the secondary MSIVs automatically close. The secondary MSIVs are capable of closing in steam conditions.

The nonsafety-related secondary MSIVs are used for event mitigation as backup protection for the safety-related MSIVs as described in Section 15.0. The secondary MSIV is a commercially available valve that utilizes a proven design and demonstrates reliable operation based on operating experience in steam systems. A design with no previous operating experience may be proven through testing to demonstrate that the valve can reliably close at full power steam flow and pressure conditions.

Each secondary MSIV is periodically tested in the Inservice Testing (IST) Program described in Section 3.9.6. These valves are designed with the capability to periodically test operability of the valve and associated apparatus, and to determine if valve leakage is within acceptable limits.

10.3.2.1.3 Secondary Main Steam Isolation Bypass Valves

The secondary MSIVs have bypass valves for pressure equalization and warming during startup. The secondary MSIBVs are normally closed. The nonsafety-related secondary MSIBVs have augmented quality requirements to serve as backup protection for the safety-related MSIBVs as described in Section 15.0. The secondary MSIBV is a commercially available valve that utilizes a proven design and demonstrates reliable operation based on operating experience in steam systems. A less proven design can be utilized with qualification testing to demonstrate that the valve can reliably close at full power steam flow and pressure conditions.

Each secondary MSIBV is periodically tested in accordance with the IST Program described in Section 3.9.6.

10.3.2.1.4 Main Steam Safety Valve

The MSS piping is protected from overpressure by the use of MSSVs located in the main steam header exhausting to the atmosphere.

10.3.2.1.5 Condensate Drains

The main steam piping layout provides for collection and drainage of condensate to avoid water entrainment. Condensate from the MSS drains is routed to the main condenser.

10.3.2.2 System Operation

NuScale Power Module and Main Steam System Startup

The MSS startup coincides with startup of the associated NPM. Before reactor heat-up, the secondary MSIBVs are opened and the entire MSS is warmed at once. During plant startup, condensate is generated in the main steam piping and 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 SGs in the NPM reactor pressure vessel are in operation, discharging steam to the turbine. During power operation, the MSS for a module can supply steam to a startup module's auxiliary steam users.

NuScale Power Module and Main Steam System Shutdown

Main steam system shutdown coincides with shutdown of the associated NPM. The MSS and condensate and feedwater system (FWS) are used to provide cooldown from normal operating temperature. During the cooldown process, the FWS maintains SG water inventories.

Anticipated Operational Occurrences and Accidents

Analyses of anticipated operational occurrences and postulated accidents are provided in Chapter 15. Events analyzed in Chapter 15 may be categorized as those that involve automatic closure of the MSIVs 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

Remaining events analyzed in Chapter 15 involve automatic closure of the MSIVs upon receipt of a plant signal. Input signals that result in an MSIV closure signal and associated actuation setpoints and time delays are addressed in Section 15.2.4.

Analyses in Chapter 15 further describe operation of the MSS in response to postulated events, including a main steam line break and SG tube failure.

10.3.3 Safety Evaluation

The portions of the MSS downstream of the MSIVs to the secondary MSIVs are contained in the RXB. Chapter 3 describes the adequacy of the structural design of the RXB. 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 RG 1.29, "Seismic Design Classification for Nuclear Power Plants." The RXB is designed as an engineered barrier to withstand a postulated design basis missile. This design satisfies the criteria of GDC 2 by the proper design and use of missile barriers to protect essential SSC against potential missiles generated by tornado or hurricane winds.

The MSS is nonsafety-related and non-risk-significant. The MSS satisfies GDC 2 in that nonsafety-related with augmented requirement components (e.g., secondary MSIVs and secondary MSIBVs) are located in the RXB which protects them from the effects of natural phenomena. Flooding is evaluated in Section 3.4.

General Design Criterion 4 is considered in the design and arrangement of main steam components located in the RXB. The MSS satisfies GDC 4 in that

nonsafety-related with augmented requirement components (e.g., secondary MSIVs and secondary MSIBVs) are protected from dynamic effects. The dynamic loads such as those caused by MSIV closure or turbine stop valve closure due to water hammer and steam hammer, and relief valve discharge loads are evaluated in the design and analysis of the MSS piping. Section 3.12 describes the design of piping systems and piping supports used in Seismic Category I, Seismic Category II, and non-seismic systems. Analysis of a postulated high-energy line break is provided in Section 3.6.1 and Section 3.6.2. The design and layout of the MSS include provisions to minimize potential for water hammer and other flow instabilities (Section 3.6.3).

General Design Criterion 5 is 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 impair the ability of other NPMs to perform their safety functions.

The decay and residual heat removal safety function per PDC 34 is performed by the DHRS flowpath, and the containment isolation function of the containment system is performed by the MSIVs and the feedwater isolation valves. Secondary system isolation is provided to protect the SG inventory without an unnecessary cooldown. 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 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) and 10 CFR 20.1406 are considered in the design of the MSS. Section 12.3 provides further discussion of the facility design features to protect against contamination.

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. Successful operation of the DHRS relies on the MSIVs, which form part of the DHRS flowpath and pressure boundary. Secondary MSIVs provide backup to the MSIVs and thus are required to fail closed during an SBO. This functionality is ensured with or without electrical power. Conformance with 10 CFR 50.63 is discussed in Section 8.4.

10.3.4 Inspections and Tests

Section 14.2 describes the Initial Test Program used to test and inspect MSS components. Nonsafety-related MSS piping and components are inspected and tested in accordance with the requirements of American Society of Mechanical Engineers (ASME) B31.1.

Inspections, Tests, Analyses, and Acceptance Criteria are discussed in Section 14.3.

10.3.5 Water Chemistry

The SG water and feedwater quality requirements are based on water chemistry technology reflected in Electric Power Research Institute (EPRI) chemistry guidelines (Reference 10.3-1 and Reference 10.3-2) and Nuclear Energy Institute 97-06, Steam Generator Program Guidelines (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 are 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: An applicant that references the NuScale Power Plant US460 standard design will provide a site-specific Secondary Water Chemistry Control Program based on the latest revision of the Electric Power Research Institute Pressurized Water Reactor Secondary Water Chemistry Guidelines and Nuclear Energy Institute 97-06 at the time of the application.

Objectives of the Secondary Water Chemistry Control Program are to protect the SGs, turbine, and FWS from general and localized corrosion caused by ingress of oxygen and other chemical contaminants; and to minimize the metal release rate from the steam-water cycle materials in order to reduce transport of corrosion products into the SGs.

The Secondary Water Chemistry Control 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 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 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 SGs in plants with copper alloys in their secondary system. Eliminating copper from the secondary system mitigates copper transport to SGs. The use of ferrous materials allows 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 SGs. Therefore, emphasis is placed on excluding copper and copper alloy pipe, valves, and components from the secondary chemistry environment.

10.3.5.1 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 10.3-3e.

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

10.3.5.2 Sampling

The secondary system for each NPM is designed to allow 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 secondary water chemistry and to permit corrective actions to be taken in the event of contaminant ingress or other chemistry excursion.

Section 9.3.2 discusses the secondary sampling system.

10.3.5.3 Contaminant Ingress

Several sources may introduce contaminants into the secondary system during operation:

- poor quality makeup water
- improperly regenerated condensate polishers
- atmospheric leaks at the condenser or pump seals
- contaminated water treatment chemicals

The contaminated water treatment chemicals as source of contaminants is controlled by the Secondary Water Chemistry Control Program.

Remaining sources of contaminants, described below, are detected by 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 process monitoring of the condensate collection tank for cation conductivity and sodium and the condensate pump discharge for straight conductivity, cation conductivity, and dissolved oxygen.
- Condensate polisher discharge is monitored for cation conductivity, dissolved oxygen, and sodium when in use.

- Demineralized water is monitored as it is produced and demineralized water storage is routinely sampled to verify makeup water quality.

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

Condensate polishers are used in the FWS during power operation. Their use is important in the event of an upset in chemistry conditions, for example when inadequate performance of the makeup water system would introduce impurities to the SGs. The polishers also assist in minimizing iron transport to the SGs. Additional information on the condensate polishers and condensate polisher resin regeneration system is provided in Section 10.4.5.

10.3.5.4 Primary-to-Secondary Leakage

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

Requirements in Section 11.5 address the implications of detecting radioactivity in the secondary side.

10.3.5.5 Chemical Addition System

Equipment is provided to inject controlled quantities of treatment chemicals to feedwater as part of the Secondary Water Chemistry Control Program. Section 10.4.8 discusses the feedwater treatment system.

10.3.6 Steam and Feedwater System Materials

The portion of the steam and power conversion system discussed under this section includes the turbine generator system (including the turbine bypass system and the turbine gland sealing system), the MSS (including extraction steam), the condensate and feedwater system (including the condensate polishing skid), and the auxiliary boiler system. This portion of the steam and power conversion system is outside containment, is nonsafety-related, and is not relied upon to perform a nuclear safety function.

10.3.6.1 Fracture Toughness

The portions of the steam and power conversion system addressed in this section are Quality Group D; the piping is nonsafety-related and meets ASME B31.1 requirements.

10.3.6.2 Materials Selection and Fabrication

The materials of the safety-related portions of the containment system, steam generator system (SGS), and DHRS, in conjunction with the Secondary Water Chemistry Control Program described in Section 10.3.5, provide protection from contamination originating in the nonsafety-related steam and power conversion systems from impacting safety-related portions of the containment system, SGS, or DHRS.

10.3.6.3 Flow-Accelerated Corrosion

The design of piping in the steam and power conversion systems incorporates considerations to prevent erosion and corrosion. These considerations include material selection, limits on flow velocity, inspection programs, and limits on water chemistry to reduce FAC. The design meets guidance in Generic Letter 89-08 and NSAC-202L-R4 (Reference 10.3-1) governing design considerations to minimize FAC, including FAC monitoring programs.

The steam and power conversion systems 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.

Power conversion system piping exposed to wet steam, flashing liquid flow, or turbulent single phase flow is within the scope of the FAC Monitoring Program.

In addition to design and layout provisions, FAC is minimized by implementing a Secondary Water Chemistry Control Program as described in Section 10.3.5.

COL Item 10.3-2: An applicant that references the NuScale Power Plant US460 standard design will provide a description of the Flow-Accelerated Corrosion Monitoring Program for the steam and power conversion systems based on Generic Letter 89-08 and the latest revision of the Electric Power Research Institute NSAC-202L at the time of the application.

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. Remote instrumentation readouts required for monitoring the system are in the main control room. The ability to manually initiate MSS control actions is available in the main control room.

A list of the instrumentation associated with SSI actuation and DHRS actuation and operation (including MSIV and secondary MSIV closure) is provided in Section 7.1.

10.3.8 References

10.3-1 Electric Power Research Institute, "Recommendation for Effective Flow-Accelerated Corrosion Program (NSAC-202L-R4)," EPRI #3002000563. Technical Report, EPRI, Palo Alto, CA, 2013.

10.3-2 Electric Power Research Institute, "Pressurized Water Reactor Secondary Water Chemistry Guidelines”, EPRI #1016555, EPRI, Palo Alto, CA, 2009.

10.3-3 Nuclear Energy Institute, "Steam Generator Program Guidelines," NEI 97-06, Revision 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	8.14E5 lb/hr
Design Conditions	
Design pressure upstream of the secondary MSIVs	2200 psia
Design pressure downstream of the secondary MSIVs	1000 psig
Design temperature	650 °F
Operating Conditions	
Pressure at rated power	475 psia
Temperature at rated power	542 °F
Secondary Main Steam Isolation Valves	
Number per main steam line	1
Total number of valves and valve type	2 gate valves
Valve size	12 in.
Design code	ASME B31.1
Seismic Category	I
Actuator System	Linear Piston
Closure speed	Within 10 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	Linear Piston
Closure speed	Within 10 seconds
Main Steam Safety Valves	
Total number of valves	2
Valve size	6 in. (inlet), 8 in. (outlet)
Valve type	Safety Relief

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

Component	Function	Failure Mode	Failure Mechanism	Effect on System or Facility	Method of Failure Detection	Remarks
Secondary Main Steam Isolation Valves (SMSIVs) Nonsafety-Related Normally Open, Fail Closed	Isolate SGs from each other by isolating MSS headers because of a module protection system (MPS) close signal.	Fail to Close on Demand	Mechanical Electrical instrumentation and controls (I&C)	SMSIV remains open and is unable to isolate.	Main control panel valve position indication.	Steam Line Break: For breaks upstream or downstream of SMSIV outside containment system (CNTS), closure of MSIV and MSIBV, which are part of the CNTS, isolate the SGs from the break. The SGs are available for heat removal via the DHRS. Steam Generator Tube Failure: For tube ruptures, closure of MSIV and MSIBV isolate the SGs from the failure and each other. The failed SG tube fills up the steam line to the closed MSIV of the affected SG. The non-affected SG is available for heat removal via the DHRS. Note that SMSIV failure to close upon MPS actuation signal does not impact the SSI and DHRS actuation credited for mitigating transient events (such as steam line break and SG tube failure) provided there is no failure of MSIV (i.e., only single failure is assumed).
		Fails Closed During Normal Operation	Mechanical Electrical I&C Operator Error	SMSIV closes.	Main control panel valve position indication. Steam flow at flow element.	When SMSIV fails closed during normal operation, there is a rapid decrease in steam flow and subsequent loss of reactor coolant heat removal capability. The SG pressure increases rapidly resulting in a reactor trip and actuation of DHRS and SSI.(a)
		Fails Partially Closed During Normal Operation	Mechanical Electrical I&C	SMSIV partially closes.	Main control panel valve position indication. Steam flow at flow element.	When SMSIV fails partially closed during normal operation, a reduction in steam flow (small or large) is realized. For a small reduction, the reactor follows steam demand and stabilizes at a lower reactor power. For a large reduction, the failure mode and system response are similar to that of complete closure of the valve discussed above.(a)

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

Component	Function	Failure Mode	Failure Mechanism	Effect on System or Facility	Method of Failure Detection	Remarks
Secondary Main Steam Isolation Bypass Valves (SMSIBVs) Nonsafety-Related Normally Closed, Fails Closed	Isolate SGs from each other by isolating MSS headers because of an MPS close signal.	Spuriously Opens During Normal Operation	Mechanical	There is no credible mechanism for this valve to mechanically fail open.	N/A	N/A
			Electrical I&C	SMSIBV opens.	Main control panel valve position indication.	Steam Line Break: For breaks upstream or downstream of SMSIBV (outside CNTS), closure of MSIV and MSIBV, which are part of the CNTS, isolate the SGs from the break. The SGs are available for heat removal via the DHRS. Steam Generator Tube Failure: For tube ruptures, closure of MSIV and MSIBV isolate the SGs from the failure and each other. The failed SG tube fills up the steam line to the closed MSIV of the affected SG. The non-affected SG is available for heat removal via the DHRS.
MSSVs Nonsafety-Related	Provide overpressure protection for steam lines downstream of SMSIV	Spuriously Opens During Normal Operation	Mechanical	MSSV opens because of spring failure.	Increase in steam flow indicated by flow element.	The MSSV does not serve backup means for required boundary conditions for DHRS operation or backup SSI. However, MSSV failure can result in a transient that subsequently actuates DHRS and SSI. Each MSSV is capable of discharging a flow rate greater than 50 percent of total MSS flow. A spurious opening of one MSSV yields a steam flow increase less than 100 percent of the flow at full power conditions. A spurious opening of the turbine bypass valve yields a similar system response as it is also located downstream of the SMSIVs. However, the increase in steam flow due to a spurious opening of the turbine bypass valve could result in a 100 percent increase in steam flow. Therefore, this failure mode is bounded by spurious opening of the turbine bypass valve. In increased steam flow events that result in a reactor trip, the subsequent MPS actuation of SSI and DHRS is credited for maintaining reactor cooling.

Notes:

a) Section 15.2.4 discusses large and small losses of steam flow due to MSIV closure.

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

Parameter	Normal Value	Value Necessary before Heatup Above >200°F
pH @ 25°C	≥9.8	-
Hydrazine[(a)], ppm	≥75	>3 x Oxygen (ppm)
Sodium, ppb	<1000	≤100
Chloride, ppb	<1000	≤100
Sulfate, ppb	<1000	≤100
Diagnostic Parameters		**Analysis Basis**
Hideout return Analysis (Na, Cl, SO_4, SiO_2, K, Mg, Ca, Al)		Assessment of SG impurity deposition

Notes:

a) Alternative oxygen scavenger to hydrazine (if used) must be qualified by the utility before use. Revised limits applicable to the hydrazine alternative are used. As the SG water cannot be sampled nor concentration adjustments made once the layup is established, the hydrazine concentration of ≥ 75 ppm includes a margin to allow for decay of hydrazine during the outage period and still meet the minimum required concentration of ≥ 25 ppm.

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 percent Reactor power	≤ 5
Hydrazine, ppb	> 8 x condensate pump discharge (O_2), ≥ 20
Silica, ppb (Reactor Critical)	≤10
Diagnostic Parameters	Target Range
Suspended solids, ppb	
Mode 3[(d)], Mode 4[(e)]	≤100
Mode 1[(b)], Mode 2[(c)]	≤10
Diagnostic Parameters	**Analysis Basis**
pH at 25°C	Minimize system corrosion
Sodium, ppb	Minimize contaminant transport to the SGs
Sulfate, ppb	Minimize contaminant transport to the SGs
Chloride, ppb	Minimize contaminant transport to the SGs
Cation conductivity, μS/cm at 25°C	Minimize contaminant transport to the SGs

Notes:

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

b) Mode 1 "Operations"

c) Mode 2 "Hot Shutdown"

d) Mode 3 "Safe Shutdown"

e) Mode 4 "Transition"

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

Control Parameters	Allowable Normal Value[(b)]
pH Agent	(a)
Hydrazine, ppb	≥ 8 x condensate pump discharge O2 ≥ 20 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	Monitor to maintain amine concentration.
Cation conductivity, μS/cm at 25°C	Indication of impurity ingress.
Fluoride, ppb	High cation conductivity may be caused by fluoride.
Copper, ppb	Initial monitoring should be monthly until a copper baseline is established.
Lead, ppb	Monitor to assess potential for lead assisted corrosion of SG tubes.
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.

b) Allowable normal values are values below Action Level 1 (defined by EPRI guidelines (Reference 10.3-2)).

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

Diagnostic Parameters	Allowable Normal Value[b]
Dissolved O_2, ppb	≤ 10[a]

Notes:

a) Measured at the condensate polisher effluent

b) Allowable normal values are values below Action Level 1 (defined by EPRI guidelines (Reference 10.3-2)).

Table 10.3-3e: Steam Generator Fill Water (initial fill subsequent to a shutdown)

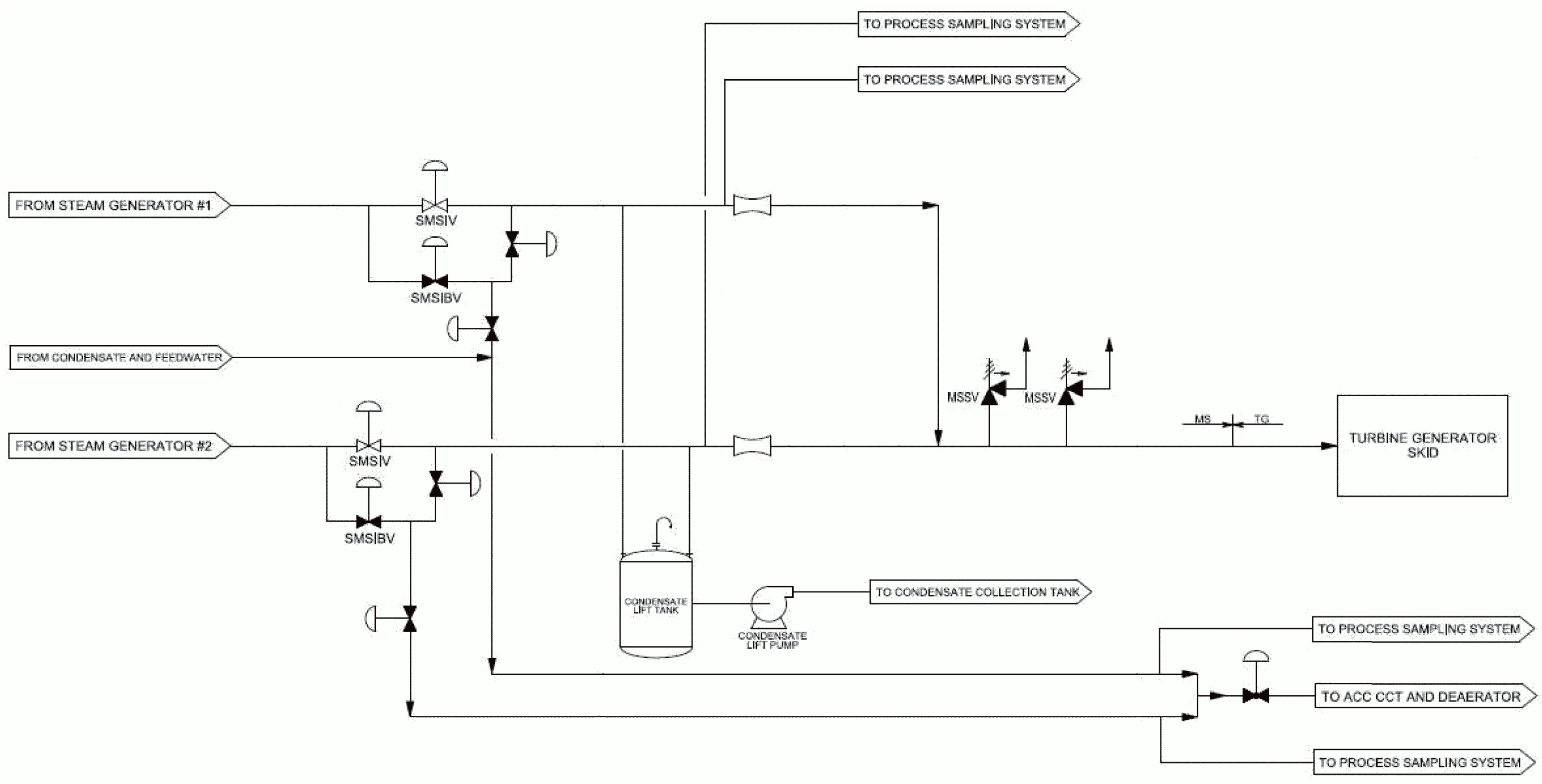
Control Parameter	Normal Value	Frequency
Hydrazine (ppm)[(a)]	>3 times fill water oxygen (ppm)[(b)]	Before fill

Notes:

a) Deoxygenated condensate is typically used to fill the SGs following shutdown, feed and bleed operations, or refill operations occurring while the FWS is connected to the module. An alternate source of fill water that is oxygenated may be used to fill the SGs if actions are taken to minimize oxygen exposure to the SG tubes. These actions may include nitrogen sparging or the treatment of the fill water with an approved oxygen scavenger (e.g., hydrazine). The oxygen scavenger may be added to the fill water or directly to the SG using batch additions before recirculation.

b) This value may be determined by calculation or measurement.

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



10.4 Other Features of Steam and Power Conversion System

10.4.1 Air Cooled Condensers

The air cooled condenser system (ACCS, also referred to as the main condenser) is made up of the air cooled condensers and its subsystem, the condenser air removal system (CARS). Each NuScale Power Module (NPM) has a condenser that provides adequate capacity for the condensate and feedwater system (FWS) described in Section 10.4.6. Each ACCS functions to condense and deaerate exhaust from the main turbine and the turbine bypass system (TBS).

10.4.1.1 Design Basis

The ACCS serves no safety-related functions, is not risk-significant, is not credited for mitigation of a design-basis accident (DBA), and has no safe shutdown functions.

Consistent with General Design Criterion (GDC) 60, the ACCS controls releases of radioactive materials to the environment.

10.4.1.2 System Description

10.4.1.2.1 General Description

The ACCS collects and condenses steam from the turbine generator system and provides feedwater to the FWS, described in Section 10.4.6. The CARS deaerates condensate before discharging it to the FWS. The CARS removes dissolved oxygen and other non-condensable gases as described in Section 10.4.2. Figure 10.1-1 shows condenser connections and interfaces with other systems.

10.4.1.2.2 System Operation

During normal operation exhaust steam from the turbine is directed into the ACCS through the turbine exhaust ducts (TED). Steam is condensed inside the finned tubes of the ACCS modules by rejecting heat to the ambient air flowing outside of the tubes. Airflow is delivered to the ACCS by induced draft fans driven by electric motors. Steam condensate from ACCS modules is collected in the return condensate header, and gravity-drains to the deaerator where the dissolved oxygen level is reduced to an acceptable level and flows to the condensate collection tank (CCT). The CCT also accepts drains from the main steam system and recycle streams from various locations in the FWS, including feedwater heater (FWH) normal drains and FWH emergency drains. The CCT level is regulated automatically using makeup from the condensate storage tank (CST) or demineralized water system. Condensate pumps (in FWS scope) move condensate in the CCT to the FWS where it is polished and treated before feeding the steam generators (SG).

The ACCS operates under a vacuum maintained by the CARS. The CARS continuously removes air and non-condensable gases from the condenser as

described in Section 10.4.2. Section 9.3.2 describes sampling lines that monitor for radioactivity and water chemistry.

During anticipated operational occurrences (AOOs) the ACCS is capable of accepting full-load steam from the turbine generator system (TGS) diverted through the turbine bypass line while maintaining a vacuum. Section 10.4.4 describes the turbine bypass system (TBS). In the turbine bypass line, bypass steam is pressure let-down by the turbine bypass valve and enthalpy is reduced by injecting condensate into the steam at the desuperheater before arriving at the ACCS. The turbine bypass line ties into the TED. The condenser may receive bypass steam without damaging condenser tubes or internal components.

Oxygen levels and ACCS pressure are monitored to detect, control, and correct ACCS air leaks.

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

The ACCS tubes and fins are constructed of materials to prevent corrosion and erosion. Section 10.3.5 describes control of secondary side water chemistry to reduce corrosion and erosion of ACCS components.

10.4.1.3 Safety Evaluation

The design and layout of the ACCS ensure failure of the system does not adversely affect functional performance of safety-related systems or components. Equipment, valves, instrumentation, and system piping are nonsafety-related and not risk-significant, Quality Group D, and Seismic Category III. Portions of the ACCS are located outside the Turbine Generator Building (TGB). Requirements of GDC 2 are satisfied and in accordance with GDC 4, a failure of the ACCS would not affect safety-related equipment.

Flooding resulting from a failure of the CCT does not prevent operation of a safety-related system because no such systems are located in the TGB. Section 3.4 addresses the flooding evaluation.

Design of the ACCS satisfies GDC 60 with regard to control of radioactive material releases to the environment. Section 10.4.2 describes how gases in the condenser are removed by the CARS to control release of radioactive contaminants.

Instrumentation monitors flow and pressure within the ACCS, and effluent release from the CARS is monitored for radiation (Section 10.4.2). The combination of these functions allows for monitoring the presence and potential release of radioactive material from the piping outside the TGB in compliance with GDC 64. The CARS effluent monitoring and grab sampling capabilities also ensure compliance with the requirements in 10 CFR 20.1406.

Section 9.3.3 describes how leakage from the CCT flows into the BPDS through the turbine building floor drains. Monitors in the BPDS drain tanks determine if contamination is present.

The ACCS is designed to facilitate maintenance, inspection, and testing in accordance with guidance in RG 8.8, "Information Relevant to Ensuring that Occupational Radiation Exposures at Nuclear Power Stations Will Be as Low as Is Reasonably Achievable." Section 12.3 provides further discussion of facility design features that protect against contamination.

10.4.1.4 Inspection and Testing

Section 14.2 describes the Initial Test Program (ITP) used to test and inspect ACCS components.

10.4.1.5 Instrumentation

Temperature, pressure, level, and conductivity sensors monitor ACCS performance.

10.4.2 Condenser Air Removal System

The CARS is a subsystem of the ACCS and maintains ACCS operating pressure under vacuum by removing air and non-condensable gases from condensers. The CARS design uses a hybrid option that consists of two common liquid ring vacuum pumps (LRVP) shared among six ACCS units and six steam jet air ejector skids (SJAEs), one for each of the six ACCS units.

10.4.2.1 Design Bases

The design basis for the CARS is provided in Section 10.4.2.3.

10.4.2.2 System Description

10.4.2.2.1 General Description

The CARS primary functions are to reduce dissolved oxygen in the feedwater and to maintain ACCS vacuum condition during plant startup, cooldown, and normal operating conditions by removing air and non-condensable gases from the main condensers.

Components of the CARS include

- LRVPs (shared by NPMs for startup).
- SJAEs (for normal operation).
- gaseous effluent discharge radiation monitors.

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

The CARS materials are based on compatibility with temperature, pressure, and secondary loop water chemistry. System piping complies with ASME B31.1 (Reference 10.4-3) requirements.

The CARS is Quality Group D and Seismic Category III. Quality group and seismic category designations are in accordance with guidance in RG 1.26 "Quality Group Classifications and Standards for Water-, Steam-, and Radioactive-Waste-Containing Components of Nuclear Power Plants," and RG 1.29, "Seismic Design Classification for Nuclear Power Plants." In accordance with RG 1.26, piping, components, and instruments that are Quality Group D correspond to nonsafety-related piping that is not relied upon to perform a nuclear safety function.

The CARS subsystem has a nonsafety-related with augmented requirements (NSAR) function to provide post-accident instrumentation to monitor variables such as radioactivity, status of safety-related equipment, and status of fission product barriers.

Radiation Monitors

An integrated sampling skid with a gamma radiation monitor is located at each of the LRVP and SJAE gaseous effluents. A radiation monitor is also located at the common exhaust header. Section 11.5 discusses radiation monitors and interaction with the MCS and the plant control system (PCS).

Flow-measuring instrumentation is available at the gaseous effluent output of the SJAE skid to determine the non-condensable flow vented to atmosphere. Condensate from the inter/after-condenser is routed to the deaerator. The CARS is supplied with drains to the BPDS, which provide capability during or after a contamination event to route liquid to the radioactive waste drain system. Radioactivity of exhausted air is monitored before it is released to the atmosphere. Section 11.5 describes instrumentation provided for monitoring radiation levels at the CARS discharge.

10.4.2.3 Safety Evaluation

The CARS serves no safety-related or risk-significant functions, is not credited for mitigation of a DBA, and has no safe shutdown functions. The CARS is nonsafety-related and has a NSAR function to provide post-accident instrumentation to monitor variables.

The CARS meets RG 1.29 because 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.

The design of the CARS follows GDC 3. Design of the CARS protects structures, systems, and components (SSC) from effects of fire and explosion, and minimizes probability of fire and explosion. The condenser exhaust gas consists mainly of air and ammonia. Ammonia concentrations may be considered minimal because the source is from pH control of the FWS and from hydrazine reactions with oxygen in

the FWS. 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 similar to atmospheric levels. Therefore, potential for explosive mixtures within the CARS does not exist. Section 9.5.1 describes the Fire Protection Program.

The design of the CARS meets GDC 5 because each NPM has a dedicated ACCS and SJAE skid. This dedication eliminates potential adverse effects that sharing of ACCS among power modules could have on the ability to perform required safety functions, including in the event of an accident in one module and an orderly shutdown and cooldown of the remaining modules. The NPMs share a common LRVP skid for startup of one ACC at a time. However, there is no adverse impact to SSC performing safety functions.

The design of the CARS follows GDC 60 for controlling releases of gaseous effluent during anticipated modes of operation. Radiation monitors and representative sampling are provided at the common gaseous effluent discharge header for each CARS. Radioactivity indication setpoints are set in accordance with 10 CFR 50, Appendix I, and can alert operations to take appropriate actions. Liquid effluent from the CARS is routed to the FWS or the BPDS where radiation monitors for these systems measure the release of radioactive materials.

The design of the CARS follows GDC 64 for monitoring releases of gaseous effluent during anticipated modes of operation. Radiation monitors and representative sampling capabilities, by use of an integrated sampling skid, are provided at the common gaseous effluent discharge header of each CARS.

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

Detected radioactive material at or above limits in 10 CFR 50, Appendix I is isolated in the CARS. The CARS normally drains to the condenser, but includes manually operated valves that allow contaminated fluids to be routed to the BPDS. These fluids may then be routed to the radioactive waste drain system for processing during or after a contamination event.

A failure of the CARS does not impact safe operation of the NPM nor does it affect safety-related equipment. A failure of the CARS results in a slow increase in ACCS pressure. The loss of ACCS vacuum trip setpoint is designed so that a turbine trip is initiated before a reactor trip. Section 15.2.3 describes a loss of ACCS vacuum condition.

10.4.2.4 Inspection and Testing

Section 14.2 describes the ITP used to test and inspect the CARS and its components. Plant startup testing and inspection is performed before plant

operation. The CARS design provides for online testing to determine the amount of exhaust flow and monitor ACCS performance and leakage rates. Flow-measuring instrumentation determines the exhaust flow from the NPM.

10.4.2.5 Instrumentation

The following instrumentation and controls monitor and control the system and components of the CARS.

- Temperature monitors are provided for ambient air temperature, exhaust steam temperature, and main condenser return condensate temperature.
- Pressure monitors are provided for exhaust steam back pressure, non-condensable pressure, and air from the ACCS.
- The seal water separator tank is provided with level monitoring and level control for tank makeup and letdown. This configuration controls the water for the seal in the LRVP as well.
- Flow gauges are provided for manual measurement of the LRVP and SJAE gaseous vent flow. The gauges are used to quantify inleakage and gas, including noncondensable gas removed from the ACCS.
- Radiation monitors are provided at LRVP and SJAE gaseous vents.

10.4.3 Turbine Gland Sealing System

The turbine gland sealing system (TGSS) is part of the TGS described in Section 10.2 and is shown in Figure 10.1-1.

10.4.3.1 Design Bases

The TGSS serves no safety-related function, is not risk-significant, is not credited for mitigation of a design-basis accident, and has no safe shutdown functions.

Consistent with GDC 60, the TGSS controls releases of radioactive materials to the environment. Section 11.5 provides further detail.

10.4.3.2 System 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 gland seal steam prevents escape of steam from the turbine shaft and casing penetrations and the glands of turbine valves. Sealing steam is distributed to the turbine shaft seals from either the auxiliary boiler system (ABS) or from the main steam system.

Controls regulate gland steam pressure and temperature.

The TGSS effluents are monitored by a radiation monitor and grab sample point located on the exhaust line to the gland seal steam vent. Section 11.5 discusses process effluent radiation monitoring and sampling.

10.4.3.3 Safety Evaluation

The TGSS has no safety-related functions, is not risk-significant, is not credited for mitigation of a DBA, and has no safe shutdown functions. The TGSS is anticipated to contain quantities of radioactive contaminants below regulatory limits. Section 11.5 identifies requirements addressing the implications of detecting radioactivity in the secondary side.

10.4.3.4 Inspection and Testing

Section 14.2 describes the ITP used to test and inspect the TGSS and its components.

10.4.4 Turbine Bypass System

The TBS provides main steam directly from the steam generators to the air cooled condenser in a controlled manner to remove heat from the NPM.

10.4.4.1 Design Bases

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

10.4.4.2 System Description

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

Turbine bypass components include the turbine bypass valve and the turbine bypass desuperheater.

The TBS consists of a line connected to the main steam combined header with a regulating valve and an inline desuperheater discharging to the ACCS.

The turbine bypass valve dumps steam from the main steam header through the desuperheater to the condenser. The valve is capable of throttling the full bypass flow from the turbine to the condenser without requiring actuation of the main steam safety valve.

The desuperheater is downstream of the turbine bypass valve to reduce steam temperature.

The TBS is not used during normal operation.

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

10.4.4.3 Safety Evaluation

The design of the TBS follows GDC 4. The TGB does not contain safety-related equipment, thereby eliminating the possibility of damage as a result of TBS pipe break or malfunction. Section 10.2 and Section 3.6 provide more information.

Section 15.1.3 discusses effects of TBS equipment malfunctions on the reactor coolant system (RCS).

Section 5.4 and Section 1.9 discuss conformance to Principal Design Criterion (PDC) 34.

10.4.4.4 Inspection and Testing

Section 14.2 describes the ITP used to test and inspect the turbine bypass valve.

10.4.5 Condensate Polisher Skid and Resin Regeneration System

The condensate polisher skid is part of the FWS and is located in the TGB. The condensate polisher skid treats and cleans feedwater to remove corrosion products and ionic impurities. The condensate polisher resin regeneration system (CPS) is a shared system between all NPMs and receives cation resin from the condensate polisher skids, regenerates the cation resin, and returns it to the condensate polisher skids within the FWS.

10.4.5.1 Design Basis

The condensate polisher skid and CPS serve no safety-related functions, are not risk-significant, are not credited for mitigation of a DBA, and have no safe shutdown functions.

Section 10.3.5 discusses how, consistent with GDC 14, the design of the condensate polisher skid and CPS maintains acceptable secondary water chemistry as discussed in the EPRI report series "PWR Secondary Water Chemistry Guidelines" (Reference 10.4-1).

10.4.5.2 System Description

The condensate polisher skid removes corrosion products and ionic impurities from the FWS and provides adequate capacity to treat feedwater at plant startup and maintain water quality of the FWS during operation. The condensate polisher skid is supported by the CPS, which restores resin quality to polisher requirements for reuse.

The condensate polisher skid includes the following major equipment:

- condensate inlet filters
- condensate polisher trains
- resin filters

The CPS includes the following major components:

- condensate polisher resin regeneration skid
- CPS chemical skids
- CPS chemical storage
- CPS neutralization tank and pumps

The condensate polisher resin regeneration skid contains vessels for the storage of new and spent resin. The size and number of new and spent resin vessels are listed in Table 10.4-1.

A full flow bypass path is provided around the condensate polisher skid.

Section 10.3.5 discusses how the condensate polisher skid maintains water quality to avoid corrosion-induced failure of the reactor coolant pressure boundary. The system controls flow through the condensate polishers to avoid hydraulic surges and additional hydraulic loads due to flow.

Corrosion, erosion, and flow-accelerated corrosion (FAC) resistant materials, as discussed in Section 10.3.5, are used for components where loss of material could occur.

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.

10.4.5.3 System Operation

The condensate polisher skid cleans the FWS water during startup to meet secondary water chemistry specifications. Secondary water is recirculated until water quality is within the specifications. The feedwater treatment system (FWTS) (Section 10.4.8) manages chemical addition for pH control and oxygen scavenging. Section 10.4.6 describes the remainder of the FWS.

During normal operation, the condensate pumps move condensate flow from the CCT through the SJAE inter-/after-condenser then the condensate polishers, gland seal condenser (Section 10.4.3), and the FWHs to the feedwater pumps. Sampling points provide input to the process sampling system (PSS) (Section 9.3.2) to monitor condensate polisher performance.

The CPS regenerates spent resin in the lead cation vessel in the condensate polisher skid and is used to replace the mixed bed resin in the condensate

polisher skid. Operations staff start the neutralization water pump once level in the neutralization water tank is sufficient or above the low level setpoint. The sulfuric acid transfer pump, the sodium hydroxide transfer pump, the sulfuric acid dilution skid, and sodium hydroxide injection skid operate according to the process control system logic.

The water drained from the exhausted resin vessel is discharged to the BPDS where it is monitored for contamination. Section 11.4 discusses management of spent resins and their removal from the site, the effect of the condensate polisher skids on fission and corrosion product concentrations, and the effect of the quantity of spent resin and regenerant solution on radioactive waste system requirements.

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

Consistent with GDC 14, the design of the polisher skids and CPS provide the means to maintain acceptable secondary water chemistry as described in the EPRI report series "PWR Secondary Water Chemistry Guidelines." (Reference 10.4-1) as discussed in Section 10.3.5.

10.4.5.4 Inspection and Testing

Section 14.2 describes the ITP used to test and inspect the condensate polisher skids and CPS.

10.4.5.5 Instrumentation

Instrumentation is provided to measure the pressure drop, flow, and outlet conductivity from each polisher to monitor performance. The CPS is configured with flow, level, pressure, and temperature instrumentation to monitor process conditions.

10.4.6 Condensate and Feedwater System

The FWS supplies feedwater with the necessary flow rate, temperature, and pressure to the SG.

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

10.4.6.1 Design Bases

The feedwater regulating valve (FWRV) located upstream of each containment system feedwater isolation valve (FWIV) serves as backup isolation to the safety-related containment system FWIV as outlined in Section 6.2.4. The backup feedwater check valve is used as a backup to the safety-related FWIV integral check valve for isolation of the decay heat removal system (DHRS) when reverse flow is experienced during a break in the FWS piping. Section 15.0 discusses use of these valves as backup to plant safety features.

The FWS design meets GDC 2, 4, 5, 60, and 64 as discussed in Section 10.4.6.3.

10.4.6.2 System Description

The containment penetrating systems are divided into three portions: internal to containment, the containment and safety-related isolation valve(s) (Section 6.2.4), and the nonsafety-related portion external to the NPM. Figure 10.1-1 shows the FWS in addition to the rest of the steam and power conversion system.

The FWS includes the following equipment and components:

- condensate storage tank (CST) (Section 9.2.6)
- condensate pumps
- feedwater pumps
- feedwater heaters
- feedwater regulating valves and backup check valves
- condensate polisher skid and subcomponents (Section 10.4.5)

The FWS boundary extends from the ACCS to the downstream flange on the removable spool pieces between the FWRVs and FWIVs. Section 6.2 discusses components downstream of the removable spool pieces, including the FWIVs. The FWS is nonsafety-related and is located within the TGB and Reactor Building (RXB).

10.4.6.2.1 Feedwater Pumps

Feedwater pumps are located upstream of the feedwater regulating valves. Feedwater pump flow is monitored for each pump with minimum flow protection provided through a recirculation line.

10.4.6.2.2 Feedwater Regulating Valves

The FWRVs control and equalize feedwater flow to the steam generators. The FWRVs are located 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 may force closure. Each FWRV is designed to close on loss of power or control signal of DHRS actuation and secondary system isolation regardless of the operating mode, and performs a feedwater isolation function as a backup to the FWIV. As such, the FWRVs meet the same flow requirements as the FWIVs.

Section 15.0.0 describes how the nonsafety-related FWRVs are used for event mitigation as backup protection for the safety-related FWIVs. The FWRV is a commercially available valve that uses a proven design and demonstrates reliable operation based on operating experience in feedwater systems. A design with no previous operating experience may be proven

through testing to demonstrate the valve actuates as expected at operating conditions.

Section 3.9.6 describes inservice testing requirements for the FWRV. The valve position is classified as a Type D accident monitoring variable in accordance with IEEE 497-2002, as endorsed by RG 1.97, "Criteria for Accident Monitoring Instrumentation for Nuclear Power Plants" (Reference 10.4-4).

10.4.6.2.3 Backup Feedwater Check Valves

Figure 10.1-1 shows nonsafety-related backup feedwater check valves are installed in each feedwater line downstream of the FWRV. These backup feedwater check valves serve as backup isolation devices to the safety-related feedwater integral check valve for isolation of the DHRS when reverse flow is experienced during a break in the FWS piping and are designed to withstand the forces of closing after a FWS line rupture.

Section 6.2 discusses the safety-related check valve upstream of the FWIV. The nonsafety-related backup check valve is downstream of the FWRV for backup backflow prevention.

Section 15.0.0 describes the nonsafety-related backup feedwater check valves used for event mitigation as backup protection for the safety-related FWIV integral check valves. The nonsafety-related backup FW check valve is a commercially available valve that uses a proven design and demonstrates reliable operation based on operating experience in water systems. A design with no previous operating experience may be proven through testing to demonstrate the valve actuates as expected at operating conditions.

Section 3.9.6 describes the inservice testing requirements for the nonsafety-related backup feedwater check valve.

10.4.6.2.4 Condensate and Feedwater Piping

The FWS piping layout among components is shown in Figure 10.1-1. The FWS and SG design include features that minimize potential for water hammer and subsequent effects. Section 3.6.3 provides additional detail.

The FWS piping meets ASME B31.1 (Reference 10.4-3) requirements. Section 10.3.6 describes FWS piping materials and Section 3.6 provides descriptions of piping and support design.

The FWS incorporates considerations to prevent 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. Section 10.3.6 discusses FAC.

10.4.6.2.5 System Operation

The turbine provides extraction steam to the shell side of the FWHs, raising feedwater temperature as feedwater flow through the tube side of the heater increases.

There are three feedwater pumps and three condensate pumps. During normal operations, all feedwater pumps and condensate pumps are operational. The FWS is able to accommodate the step load changes from programmed SG water level or a major effect on the feedwater system. The FWS has the capability to accommodate changes in feedwater flow to the SG with the steam pressure increase resulting from a 100 percent load rejection.

The PSS, described in Section 9.3.2, provides the capability to collect and analyze FWS samples.

Condensate pumps are configured to provide redundancy to minimize adverse impact to plant operation in the event of a pump failure or trip.

Loss of a single feedwater pump does not result in a turbine generator or reactor trip.

Loss of normal alternating current power results in a loss of feedwater to the SG. Section 15.2.7 discusses 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. Section 15.1.2 discusses an increase in feedwater flow.

Loss of feedwater heating malfunction causes a decrease in feedwater temperature that increases heat removal from the RCS and lowers the RCS temperature. Section 15.1.1 discusses 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. Section 15.2.8 discusses feedwater line breaks.

Inadvertent DHRS actuation and secondary system isolation causes closure of the main steam isolation valve and main feedwater isolation valve on the affected side of the secondary system. Section 15.6.1 discusses inadvertent opening of a reactor safety valve.

FWRVs are credited to mitigate steam line break and steam generator tube failure (SGTF) events. Section 15.1.5 discusses a steam line break.

The SGTF is defined as a double-ended rupture of a single SG tube. Section 15.6.3 discusses an SGTF.

Sudden loss of FWS flow at power causes SG heat removal rates to decrease, which causes reactor coolant temperature to increase. Section 15.2.7 discusses a loss of feedwater flow.

10.4.6.3 Safety Evaluation

Section 6.2 describes the portion of the feedwater piping from the SG feedwater nozzles to the outermost FWIV flange, designed to ensure feedwater system isolation in accident situations and containment isolation in cases in which the feedwater system could potentially become a containment bypass pathway.

The design of the FWS follows GDC 2. The FWS SSC that are nonsafety-related with augmented requirements (i.e., FWRVs, backup feedwater check valves, and piping inside the RXB) are Seismic Category I and are located in the Seismic Category I portions of the RXB, which protects them from the effects of natural phenomena. Adequacy of the structural design of the RXB is 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. These backup portions of FWS are designed to remain functional during and after a safe shutdown earthquake and meet the guidelines of RG 1.29.

The design of FWS SSC and piping inside the RXB ensures protection against environmental and dynamic effects associated with normal operation, maintenance, testing, and postulated accidents in accordance with GDC 4. The FWS SSC that are nonsafety-related with augmented requirements (i.e., FWRVs, backup feedwater check valves) are located in the Seismic Category I portions of the RXB, which protects them from the effects of natural phenomena. The design of FWS piping and SSC inside the RXB ensures protection against dynamic effects such as water hammer. Section 3.12 describes the design of piping systems and piping supports used in Seismic Category I, Seismic Category II, and non-seismic systems. Section 3.6 provides the analysis of a postulated high-energy line failure.

Isolation backup portions of the FWS located within the RXB are protected from effects of missiles generated by plant equipment failures outside the RXB.

Section 3.6 describes SG design features implemented to prevent fluid flow water hammer. The potential for water hammer in the FWS is minimized by design features such as pipe slope, the use of available drains before startup, and adjustment of valve closure timing.

The design of the FWS follows GDC 5 because the components in the FWS are not shared among NPMs; therefore, failure of the FWS does not impair the ability of other NPMs to perform their safety functions.

The FWS 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 10.4-2).
- Feedwater chemistry is regularly monitored and controlled.

The FWS and supporting systems monitor and control secondary water chemistry to maintain water quality specifications during normal operation and AOOs. Section 10.3.6 discusses flow-accelerated corrosion.

Consistent with PDC 34, the FWRVs provide a nonsafety-related backup to the FWIVs and provide additional assurance that blowdown of a second SG is limited if a feedwater line were to break upstream of the FWIV. Section 5.4 discusses conformance with PDC 34.

The design of the FWS follows GDC 60 by allowing for controlling release of radioactive materials in gaseous and liquid effluents and to handle radioactive solid waste. Instrumentation monitors liquid and gaseous effluents, and solid wastes are handled according to Section 11.4. The design of the FWS follows GDC 64 because it 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. The FWS is designed to facilitate maintenance, inspection, and testing in accordance with guidance in RG 8.8, "Information Relevant to Ensuring that Occupational Radiation Exposures at Nuclear Power Stations Will Be as Low as Is Reasonably Achievable." Section 11.5 identifies requirements addressing implications of detecting radioactivity in the secondary side, along with process effluent radiation monitoring and sampling. Section 12.3 discusses design features to protect against contamination and those addressing RG 4.21, "Minimization of Contamination and Radioactive Waste Generation: Life-Cycle Planning," and 10 CFR 20.1406.

Table 10.4-2 presents the results of the FWS failure modes and effects analysis. Section 6.2 provides failure modes and effects analysis for FWIV valves.

10.4.6.4 Inspection and Testing Requirements

Section 14.2 describes the ITP used to test and inspect the FWS.

10.4.7 Auxiliary Boiler System

The ABS is designed to supply steam to auxiliary steam users when main steam is not available.

10.4.7.1 Design Bases

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

10.4.7.2 System Description

The ABS serves six NPMs. It has two subsystems, the auxiliary boiler and the chemical skids, that are both located in the TGB. The ABS provides steam at the required chemistry quality during plant operation including AOOs, for turbine gland sealing and sparging steam for ACCS deaeration at lower loads.

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. Additives are used to maintain the chemistry requirements of the system. Section 10.3.5 describes the secondary side chemistry requirements.

The ABS is Quality Group D and Seismic Category III. Piping is designed in accordance with ASME B31.1 and the auxiliary boiler skid is constructed in accordance with ASME BPVC (Reference 10.4-5). Section 10.3.6 describes what piping in the steam and power conversion system, including the ABS, is within the scope of the Flow-Accelerated Corrosion Monitoring Program.

The major ABS components include boiler skids, a boiler superheater skid, and chemical addition skids.

10.4.7.3 Safety Evaluation

The portions of ABS that are housed in the TGB are nonsafety-related, 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.

The design of the ABS follows GDC 5. There are no safety-related components in the ABS that are shared among NPMs; therefore, failure of the ABS does not impair the ability of other NPMs to perform their safety functions.

The design of the ABS satisfies GDC 60 and 64 as described in Section 11.5, which provides further discussion of the facility design features.

NuScale considered 10 CFR 20.1406, RG 8.8, and RG 4.21 in the design of the ABS. Section 12.3 provides further discussion of facility design features to protect against contamination.

10.4.7.4 Inspection and Testing

Section 14.2 describes the ITP used to inspect and test ABS components.

The ABS is designed to be tested and inspected in accordance with the equipment manufacturer inservice inspection and testing plan.

10.4.7.5 Instrumentation

Instrumentation to monitor pressure, temperature, flow, water level, and valve position are provided on ABS components. Section 11.5 discusses radiation monitoring in the ABS.

10.4.8 Feedwater Treatment System

The FWTS maintains feedwater quality in conjunction with the condensate polisher skid (Section 10.4.5). The FWTS controls feedwater chemistry in each of the FWS by providing capability for chemical injection.

10.4.8.1 Design Bases

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

The FWTS system has an SSC classification of B2, is Quality Group D, and is Seismic Category III.

GDC 14 is considered in design of the FWTS. Sections 10.3.5 and 10.4.5 describe how maintaining acceptable secondary water chemistry demonstrates compliance with GDC 14.

10.4.8.2 System Description

The FWTS is designed to control erosion and corrosion of FWS components by providing chemical injection capability for maintaining feedwater pH and dissolved oxygen levels.

Chemical injection points are provided downstream of the FWS condensate pumps. The FWTS includes separate equipment for pH control and oxygen scavenger injection.

COL Item 10.4-1: An applicant that references the NuScale Power Plant US460 standard design will provide a secondary water chemistry analysis. This analysis must 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 Control Program described in Section 10.3.5, and it is compatible with the chemicals used.

10.4.8.3 System Operation

During startup, the FWS is run in short cycle cleanup and long cycle cleanup mode. During either mode, the FWTS provides chemical addition capability to bring feedwater within chemistry limits.

During normal operation the PSS regularly monitors the feedwater and the FWTS makes chemical additions to keep feedwater chemistry within limits. The FWTS

chemical addition pumps are controlled by the PCS and MCS based on the PSS readings.

The design of the FWTS considers GDC 5. 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.

10.4.9 References

10.4-1 Electric Power Research Institute, “Pressurized Water Reactor Secondary Water Chemistry Guidelines – Revision 7," TR-1008224, EPRI, Palo Alto, CA, 2009.

10.4-2 Electric Power Research Institute, "Recommendation for Effective Flow-Accelerated Corrosion Program (NSAC-202L-R4)," EPRI #3002000563. Technical Report, EPRI, Palo Alto, CA, 2013.

10.4-3 American Society of Mechanical Engineers, *Power Piping*, ASME Code for Pressure Piping, B31, ASME B31.1, New York, NY.

10.4-4 Institute of Electrical and Electronics Engineers, "Standard Criteria for Accident Monitoring Instrumentation for Nuclear Power Generating Stations," IEEE Standard 497-2002, Piscataway, NJ.

10.4-5 American Society of Mechanical Engineers, BPVC.VIII.1-2017, ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, 2017, New York, NY.

Table 10.4-1: Condensate Polisher Resin Regeneration System Resin Tanks

Component	Number	Size
Cation Regeneration Vessels	2	5950 gal
Fresh Resin Vessel	1	1430 gal
Exhausted Resin Vessel	1	1430 gal
Weak Base Anion Resin Vessel	2	785 gal
Weak Base Anion Spent Resin Vessel	1	785 gal
Sulfuric Acid Storage Tank	1	16920 gal
Sodium Hydroxide Storage Tank	1	31726 gal
Weak Base Anion Rinse Tank	1	3067 gal
Regeneration Sump	1	3890 gal
Neutralization Water Tank	1	95178 gal

Table 10.4-2: Condensate and Feedwater System Failure Modes and Effects Analysis

Component	Function	Potential Failure Mode	Potential Causes	Potential Failure Effects	Current Control for Failure Detection or Mitigation	Remarks
Air Cooled Condenser System	Condensing low pressure exhaust steam from the turbine.	air in-leakage	mechanical failure	vacuum degradation water chemistry degradation	TED pressure transmitters x3 (vendor supplied)	Air in-leakage allows oxygen back into the system, degrading the vacuum and increasing dissolved oxygen levels.
		fan blade failure/high vibration	mechanical failure	reduced cooling capacity increase in turbine backpressure	Fan monitoring instrumentation (vendor supplied)	Outside of summer months, the ACCS maintains required capacity and prevents backpressure from increasing enough to necessitate a turbine trip.
		fan motor failure	mechanical failure	reduced cooling capacity increase in turbine backpressure	Fan monitoring instrumentation (vendor supplied)	Outside of summer months, the ACCS maintains required capacity and prevents backpressure from increasing enough to necessitate a turbine trip.
		gearbox failure	mechanical failure	reduced cooling capacity increase in turbine backpressure	Gearbox monitoring instrumentation (vendor supplied)	Outside of summer months, the ACCS maintains required capacity and prevents backpressure from increasing enough to necessitate a turbine trip.
		freezing	operator error control failure	reduced cooling capacity increase in turbine backpressure	temperature instrumentation (vendor supplied) Fan motor VFDs (vendor supplied) Sectionalization valves (vendor supplied)	Freezing condensate inside the main condenser tubes may cause damage, as well as blocking off sections of the condenser reducing cooling capacity.

Table 10.4-2: Condensate and Feedwater System Failure Modes and Effects Analysis (Continued)

Component	Function	Potential Failure Mode	Potential Causes	Potential Failure Effects	Current Control for Failure Detection or Mitigation	Remarks
Condensate Pump	Draws suction from the main condenser and delivers condensate to the feedwater pumps with adequate pressure	fail to start (1 pump only)	loss of power mechanical failure control failure	reduced feedwater to SG reduction of power produced	pump discharge pressure and flow instrumentation	There are redundant components in the system such that power reduction is expected, but there is no impact to safety or regulatory compliance
		fail to start (3 pumps)	loss of power	reduced feedwater to SG reduction of power produced	pump discharge pressure and flow instrumentation	The system design accommodates a loss of feedwater flow, there is no impact to safety or regulatory compliance.
		pump trip (1 pump only)	mechanical failure control failure operator error	reduced feedwater to SG	pump discharge pressure and flow instrumentation	There is a decrease in feedwater flow to the SG. The remaining online pumps run out on their pump curve, but will not be capable of supplying the full load flow rate.
Polisher bypass valve	Bypass condensate polisher skids upon high condensate temperature	fail to open	mechanical failure control failure	damage to polisher resin reduced feedwater to SG	solenoid valve position indicators	Failure of the condensate polisher 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 may make the choice to shutdown the module, preserving the integrity of the polishers.
		spurious opening	mechanical failure control failure	water chemistry degradation	solenoid valve position indicators	Spurious bypass valve opening is unlikely and degradation of the FW chemistry would not occur before valve maintenance
Resin verification control valve	Regulates flow from condensate polisher skid to CCT.	spurious opening	mechanical failure control failure operator error	reduced feedwater to SG	condensate polisher skid outlet flow and pressure instrumentation	The system design accommodates a loss of feedwater flow, there is no impact to safety or regulatory compliance.
		fail to operate	mechanical failure control failure operator error	water chemistry degradation	condensate polisher skid outlet flow and pressure instrumentation	Degradation of the FW chemistry would not occur before valve maintenance.

Table 10.4-2: Condensate and Feedwater System Failure Modes and Effects Analysis (Continued)

Component	Function	Potential Failure Mode	Potential Causes	Potential Failure Effects	Current Control for Failure Detection or Mitigation	Remarks
Gland steam condenser	Condense the low-pressure steam supplied to the turbine seals.	tube failure (rupture)	mechanical failure	loss of vacuum leading to turbine trip	gland condenser level transmitter (vendor supplied)	A substantial tube failure results in the inability to supply steam to the turbine and the turbine trips.
		tube failure (minor leak)	mechanical failure	none	gland condenser level transmitter (vendor supplied)	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.
Feedwater Heater	Heats condensate to increase thermal efficiency	tube failure (rupture)	mechanical failure	turbine trip	temperature and pressure instrumentation in the FWS and TGS feedwater heater level indicator non return valve (vendor supplied)	Major tube failure causes condensate to rapidly enter the shell side of the feedwater heater. If liquid accumulates to the point of entering the turbine, the turbine must trip.
		tube failure (minor leak)	mechanical failure	none	temperature and pressure instrumentation in the FWS and TGS feedwater heater level indicator	Minor tube leaks result in higher than normal condensate flows entering the shell side of the feedwater heaters. Condensate must be removed with normal controls.
		shell side liquid level high	mechanical failure control failure operator error	turbine trip	temperature and pressure instrumentation in the FWS and TGS feedwater heater level indicator non return valve (vendor supplied)	If liquid accumulates to the point of entering the turbine, the turbine must trip.
		shell side liquid level high	mechanical failure control failure operator error	low feedwater temperature	feedwater heater level indicator emergency drain to CCT	Decrease in 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 decreases the primary side temperatures. As the colder temperatures pass over the core, reactivity and the reactor power level rise. If the temperature drops low enough the reactor trips based on high reactor power set point.

Table 10.4-2: Condensate and Feedwater System Failure Modes and Effects Analysis (Continued)

Component	Function	Potential Failure Mode	Potential Causes	Potential Failure Effects	Current Control for Failure Detection or Mitigation	Remarks
Short cycle cleanup control valve	Provides condensate pump minimum flow protection	spurious opening	mechanical failure control failure operator error	reduced feedwater to SG	FWH outlet pressure feedwater pump discharge flow and suction pressure	The system design accommodates reduced feedwater flow, there is no impact to safety or regulatory compliance.
		fail to operate (minimum flow control)	mechanical failure control failure operator error	damage to condensate pump	condensate polisher skid outlet flow condensate pump discharge pressure	This valve receives the signal to open when a plant transient occurs that forces the condensate pump to approach minimum flow. A failure would cause a loss of feedwater flow with the reactor at full power.

Table 10.4-2: Condensate and Feedwater System Failure Modes and Effects Analysis (Continued)

Component	Function	Potential Failure Mode	Potential Causes	Potential Failure Effects	Current Control for Failure Detection or Mitigation	Remarks
Feedwater Pump	Delivers feedwater to the SGs with adequate pressure to maintain steam generation	failure to start (1 pump)	loss of power mechanical failure control failure	reduced feedwater to SG	feedwater pump discharge flow and pressure feedwater heater flow SG feedwater header flow	There are redundant components in the system such that power reduction is expected, but there is no impact to safety or regulatory compliance.
		failure to start (3 pump)	loss of power control failure	reduced feedwater to SG	feedwater pump discharge flow and pressure feedwater heater flow SG Feedwater header flow	The system design accommodates a loss of feedwater, there is no impact to safety or regulatory compliance.
		pump trip (1 pump only)	loss of power mechanical failure control failure Operator error	loss of feedwater to SG	feedwater pump discharge flow and pressure feedwater heater flow SG Feedwater header flow	There is a decrease in feedwater flow to the SG. The remaining online pumps run out on their pump curve, but will not be capable of supplying the full load flow rate.
		variable frequency drive failure high (single pump)	mechanical failure control failure	minor flow imbalance	feedwater pump discharge flow and pressure feedwater heater flow SG Feedwater header flow	As 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 pumps to an acceptable level, returning feedwater flow rate to the steady state value.
		variable frequency drive failure low (single pump)	mechanical failure control failure	reduced feedwater to SG	feedwater pump discharge flow and pressure feedwater heater flow SG feedwater header flow	The primary side temperature and pressure are temporarily affected as the MCS changes the feedwater pump speeds to accommodate the decreased speed of one of the pumps. If the feedwater flow drops too rapidly it could result in a reactor trip due to high primary side pressure trip point.

Table 10.4-2: Condensate and Feedwater System Failure Modes and Effects Analysis (Continued)

Component	Function	Potential Failure Mode	Potential Causes	Potential Failure Effects	Current Control for Failure Detection or Mitigation	Remarks
Feedwater Pump Minimum flow control valve	Modulates open based on measurements from the feedwater pump discharge flow instrument to provide minimum flow protection to the feedwater pumps.	failure to open	mechanical failure control failure	pump trip resulting in loss of feedwater to SG	feedwater pump discharge flow	No safety-related feedwater equipment is compromised by a feedwater pump trip based on the failure of the minimum flow protection valves. Both SGs are available for decay heat removal.
		spurious opening	control failure	reduced feedwater to SG	feedwater pump discharge flow and pressure feedwater heater flow feedwater header flow	No safety-related feedwater equipment is compromised by a feedwater pump trip based on the failure of the minimum flow protection valves. Both SGs are available for decay heat removal.
Long cycle cleanup control valves	Opens for flow path during system flushing during startup	spurious opening	mechanical failure control failure operator error	reduced feedwater to SG	solenoid valve position indicators	The system design accommodates reduced feedwater flow, there is no impact to safety or regulatory compliance.

Table 10.4-2: Condensate and Feedwater System Failure Modes and Effects Analysis (Continued)

Component	Function	Potential Failure Mode	Potential Causes	Potential Failure Effects	Current Control for Failure Detection or Mitigation	Remarks
Feedwater regulating valves	Controls feedwater flow to the SGs during low flow operations below the feedwater pump VFDs abilities	spurious opening	mechanical failure control failure	uneven flow to SG headers followed by reactor trip	SG feedwater header flow feedwater regulating 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 actuates and the reactor module is isolated for decay heat removal.
		spurious closing	mechanical failure control failure	loss of feedwater to SG followed by reactor trip	SG feedwater header flow feedwater regulating pressure	During startup, and during other low feedwater flow rate operations, the spurious closing of the FWRV must result 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.
	Provides redundant isolation for FWIV actuation events	fail to close	mechanical failure control failure	loss of redundant containment isolation	feedwater regulating pressure	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.

Table 10.4-2: Condensate and Feedwater System Failure Modes and Effects Analysis (Continued)

Component	Function	Potential Failure Mode	Potential Causes	Potential Failure Effects	Current Control for Failure Detection or Mitigation	Remarks
Backup Feedwater Check Valve	Provides redundant isolation for safety-related check valve	fail to close	mechanical failure	loss of redundant containment back flow prevention	feedwater regulating pressure SG differential pressure	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.
		fail to open	mechanical failure	loss of feedwater to SG followed by reactor trip	SG feedwater header flow	During startup, if the feedwater check valve fails to open it results in no flow through one of the two SGs. There is no plan to maintain operation if one of the two SGs is unavailable. If the loss of 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 check valve failure.
Condensate rejection valve	Provides emergency level control of condensate inventory	spurious opening	mechanical failure control failure operator error	reduced feedwater to SG overfill of CST	condensate supply to CST inlet flow condensate supply to CST valve CST level	The system design accommodates a loss of feedwater flow, there is no impact to safety or regulatory compliance.
		fail to open	mechanical failure control failure operator error	overfill of CCT and deaerator leading to turbine trip	CCT level (vendor supplied) condensate supply to CST inlet flow CST to CCT normal makeup valve	If this valve fails to open, level in the condenser rises. If level rises above the high-high set point, the turbine trips and the reactor is isolated.

Table 10.4-2: Condensate and Feedwater System Failure Modes and Effects Analysis (Continued)

Component	Function	Potential Failure Mode	Potential Causes	Potential Failure Effects	Current Control for Failure Detection or Mitigation	Remarks
CCT makeup valve	Provides level control of condensate inventory	spurious opening	mechanical failure control failure operator error	overfill of CCT and deaerator leading to turbine trip	CCT level (vendor supplied) condensate supply to CST inlet flow CCT makeup normal line flow	If this valve spuriously opens, level in the condenser rises. If level rises above the high-high set point, the turbine trips and the reactor is isolated.
		fail to open	mechanical failure control failure operator error	loss of level in CCT condensate pump trip loss of water to SG	CCT level (vendor supplied) condensate supply to CST inlet flow CCT makeup normal line flow	The system design accommodates a loss of feedwater flow, there is no impact to safety or regulatory compliance.
CST makeup valve	Provides level control of the condensate storage tank inventory	spurious opening	mechanical failure control failure operator error	overfill of CST	demineralized water supply to CST valve CST level	Overfill of the CST does not impact normal operation of the FWS.
		fail to open	mechanical failure control failure operator error	loss of level in CST leading to loss of water to SG	demineralized water supply to CST valve CST level	Loss of CST level prevents makeup water flow to the CCT, eventually leading to loss of feedwater flow to the SG. The system design accommodates a loss of feedwater flow, there is no impact to safety or regulatory compliance.

Table 10.4-3: Auxiliary Boiler System Component Design Parameters

Auxiliary Boiler Skid	
Parameter	**Value**
ABS Steam Flow Rate	5000 lb/hr
ABS Steam Operating Pressure	205 psig
Boiler Type	Electric
Auxiliary Boiler Superheater Skid	
Parameter	**Value**
Superheater Operating Pressure	191 psig
Superheater Operating Temperature	422 °F
Auxiliary Boiler Ammonia Addition Skid	
Parameter	**Value**
Ammonia Concentration	1-10wt percent
Storage Volume	5 gal
Injection Pump Rated Flowrate	0.005 gpm
Injection Pressure	10 psig
Auxiliary Boiler Hydrazine Addition Skid	
Parameter	**Value**
Hydrazine Concentration	1-10wt percent
Storage Volume	5 gal
Injection Pump Rated Flowrate	0.010 gpm
Injection Pressure	10 psig

Enclosure 2:

Readiness Assessment Report responses for Chapter 10

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The table below provides the NuScale responses to each of the Nuclear Regulatory Commission readiness assessment observations on draft Chapter 10, “Steam and Power Conversion System” of the Standard Design Approval Application.

Section	Observation	Response
10.1	Information in the DCA that provided an understanding in broad terms of the steam and power conversion system design and operation is not in the current SDAA. The information in Table 10.1-1 is available in Section 10.3, but heat balances diagrams (Figure 10.1-2 in DCA) should be included in Section 10.1 of the US460 SDAA.	Chapter 10, in text, tables, and figures, provides necessary information for the steam and power conversion system design and operation. NuScale removed the heat balance diagrams (Figures 10.1-2 and 10.1-3) from what was in the Design Certification Application (DCA) because those figures are beyond the level of detail required for the Standard Design Approval Application (SDAA) for non-safety systems. That level of detail is not required by Regulatory Guide (RG) 1.206 Revision 1, nor was it referenced in the DCA Final Safety Evaluation Report (FSER).
10.3-1	Table 10.3-1 removed design information (including secondary main steam isolation and main steam bypass valves closure times). Although not safety-related, the secondary main steam isolation valves are credited as backup protection for the safety-related MSIVs and were included in the Technical Specifications in the DCA.	NuScale validated the information that was credited in Chapter 15 and reinserted the information.
10.3.2.1	Is the information for the condensate drain still valid for the air-cooled condenser which will be located outside the turbine building?	The information is still valid because the condensate drains feed into the condensate collection tank (CCT) beneath the air cooled condensers (ACCs). The information is in 10.3.2.1.5 and 10.4.1.2.2.
10.3	It appears all discussion of extraction steam has been removed. Extraction steam is the heat source for the feedwater heaters. What is the reason for removal?	Extraction steam is now taken from the turbine (unfinished design) rather than from the main steam system. Discussion of extraction steam has been added to 10.4.6.2.5 and 10.2.2.1.
10.4	Section 10.4 gives the design basis for the air-cooled condensers which will be located outside the Turbine Building. The turbine exhaust will be transported to the condenser, and condensate returned from the condenser via piping external to the Turbine Building. GDC 4 is the only GDC identified. Failure of the system or its components could lead to the release of radiation directly to the atmosphere, GDCs 2, 4, and 64 may need to be considered, as well as 10 CFR 20.1406.	The air cooled condenser system (ACCS) complies with these requirements through other system functions. NuScale added text so that compliance is stated in Section 10.4.1.3.
10.4.6.5	There is no mention of temperature control in the section on instrumentation. As with the system components in general, this makes it hard to conclude the system is designed to protect the resin from high temperature.	The condensate polishing skids do not contain temperature control because they share that function with the feedwater system. The condensate polisher resin regeneration system does have instrumentation for monitoring temperature. NuScale added the requested information to Section 10.4.5.5.

Section	Observation	Response
10.4.7.3	It appears that GDC 60 and GDC 64, and 10 CFR 20.1406 were removed from the design basis. In general, 10 CFR 60 and 64 may not be applicable to a condensate and feedwater systems enclosed in the Turbine Building, however parts of the condensate and feedwater system might be external to the Turbine Building and GDC 60 and 64 should be considered, or an explanation on why they would not apply should be included. 10 CFR 20.1406 applies to the condensate and feedwater system and should also be addressed in the SDA. These items were previously addressed in the DCA.	Discussion of General Design Criteria (GDC) 60 and 64 was removed from what was in the DCA because they are not required by the design-specific review standard (DSRS) and were not referenced in the DCA FSER. DSRS 10.4.7 does not include GDC 60 and 64 because the condensate and feedwater system (FWS) does not have the same potential for contamination and releases of radioactive materials to the environment, regardless of location, as other secondary water systems subject to GDC 60 and 64. Discussion of 10 Code of Federal Regulations (CFR) 20.1406 was removed because the implications of detecting radioactivity on the secondary side are addressed in the Final Safety Analysis Report (FSAR) Section 11.5. NuScale reinserted the removed sections of text in 10.4.6.3 in response to this request.
10.4.9.3	Section 10.4.9.3 only addresses startup. Should it also address operations? If not, why not?	This information has been added to 10.4.8.3.
All	It was noted from discussions with NuScale that the SDAA will be a standalone application, and that much of the documentation made available was being further developed. During the Readiness Assessment review of Chapter 10 systems the NRC staff found the information regarding the design and operation of the systems was insufficient to permit understanding of the system design and the potential impact of the system operation or failure on plant safety or the potential for radiological release. Chapter 10 covers the steam and power conversion system, which differs appreciably from the NuScale DCA in that the system now must support a nuclear module that has significantly higher energy output (54 percent higher than currently approved design), and incorporates air-cooled condensers into the system design, which is the first such application of an air-cooled condenser to serve as the main condenser for a nuclear power plant. The information provided to NRC staff for the Readiness Assessment for the air-cooled condenser system (ACCS) in Section 10.4.1 does not sufficiently define the ACCS design that is to be used in plant's power conversion system. Design information (system design requirements, drawings, design data and performance requirements) for the ACCS was not included in Section 10.4.1. While detailed information on the condenser design is not needed, general information such as a simplified ACCS diagram, design information on the major components, and design performance requirements should be included. Additionally, the information provided for Turbine Bypass System, Condensate and Feedwater System, and ABS does not sufficiently define the systems and it is noted that design information for these systems was included in the DCA, but information was removed in the current SDAA.	Chapter 10 contains more information than was than was available for the Readiness Assessment. However the SDAA has less detail on nonsafety-related and non-risk-significant systems than the DCA to better focus attention on issues commensurate with the issues' importance to public health and safety. System descriptions have been evaluated against the requirements of the standard review plan (SRP) the Final Safety Analysis Report (FSAR), DSRS, and other regulatory requirements.