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BWRX-300 UK Generic Design Assessment (GDA) Chapter 10 – Steam and Power Conversion Systems

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EXECUTIVE SUMMARY

Chapter 10 of the Preliminary Safety Report (PSR) provides information on the design of plant steam and power conversion systems. The steam and power conversion system for the BWRX-300 consists of the following systems:

- Turbine Generator
- Main Steam subsystem of the Nuclear Boiler System
- Main Condenser and Auxiliaries
- Moisture Separator Reheater System
- Turbine Gland Seal System
- Turbine Bypass System
- Circulating Water System
- Condensate Filters and Demineralizers (CFD)
- Condensate and Feedwater Heating System (CFS).

This chapter includes the Main Turbine Equipment (MTE) along with the systems listed below. The MTE is comprised of the following:

- High Pressure and Low Pressure Turbines.
- Main Steam stop and control valves, non-return valves, reheat steam stop (intermediate stop) and intercept valves, and turning gear.
- Turbine Gland Seal Subsystem
- Turbine Lube Oil System
- Extraction Steam System
- Electro-Hydraulic Controls Subsystem.

This chapter of the safety analysis report describes those aspects of the design and operation of the steam and power conversion systems that affect the reactor and its safety features or contribute towards the control of radioactive material. The information provided should show the capability of the system to function without compromising (directly or indirectly) the safety of the plant, under both steady state and transient situations.

Claims, arguments, and evidence relevant to GDA step 2 objectives and scope are summarised in Appendix A, along with an ALARP position.

Appendix B has been included to capture any Forward Action Plan (FAP) items. However, none were identified for PSR Chapter 10.

ACRONYMS AND ABBREVIATIONS

Acronym	Explanation
AC	Alternating Current
ALARP	As Low As Reasonably Practicable
AOV	Air Operated Valve
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
BWR	Boiling Water Reactor
BPVC	Boiler and Pressure Vessel Code
BWROG	Boiling Water Reactor Owner's Group
CAE	Claims, Argument, Evidence
CFD	Condensate Filters and Demineralizers
CFS	Condensate and Feedwater Heating System
CIV	Containment Isolation Valves
CRD	Control Rod Drive
CST	Condensate Storage Tank
CUW	Reactor Water Cleanup System
CWS	Circulating Water System
D-in-D	Defence-in-Depth
DC	Direct Current
DCIS	Distributed Control and Information System
DL2	Defense Line 2
DL4b	Defense Line 4b
EFS	Equipment and Floor Drain System
EHC	Electro-Hydraulic Control
EMIT	Examination, Maintenance, Inspection and Testing
FC	Fail Close
FO	Fail Open
FAC	Flow Accelerated Corrosion
FAI	Fail-As-Is
FAP	Forward Action Plan
FW	Feedwater
FWH	Feedwater Heater
GDA	Generic Design Assessment
GEH	GE-Hitachi Nuclear Energy
GSC	Gland Steam Condenser
HDVS	Heater Drain and Vent System
HP	High Pressure

Acronym	Explanation
HPU	Hydraulic Power Unit
HVS	Heating, Ventilation and Cooling System
IAEA	International Atomic Energy Agency
I&C	Instrumentation and Controls
ISI	In Service Inspection
LFCV	Low Flow Control Valve
LfE	Learning from Experience
LP	Low Pressure
LOPP	Loss-of-Preferred Power
LWM	Liquid Waste Management System
MCA	Main Condenser and Auxiliaries
MCR	Main Control Room
MS	Main Steam
MSCIV	Main Steam Containment Isolation Valve
MSL	Main Steam Line
MSR	Moisture Separator Reheater System
MSRIV	Main Steam Reactor Isolation Valve
MTE	Main Turbine Equipment
NBS	Nuclear Boiler System
NDTT	Nil-Ductility Transition Temperature
NHS	Normal Heat Sink
ONR	Office of Nuclear Regulation
OPEX	Operational Experience
PCW	Plant Cooling Water
PREMS	Process Radiation and Environmental Monitoring System
PSR	Preliminary Safety Report
RCS	Reactor Coolant System
RGP	Relevant Good Practice
RLC	Reactor Level Control System
RP	Requesting Party
RPC	Reactor Pressure Control
RPV	Reactor Pressure Vessel
RTP	Rated Thermal Power
SC1	Safety Class 1
SC2	Safety Class 2
SC3	Safety Class 3
SCDS	Safety Case Development Strategy

Acronym	Explanation
SCN	Non-Safety Class
SDC	Shutdown Cooling System
SIR	Seismic Interface Restraint
SJAE	Steam Jet Air Ejectors
SMR	Small Modular Reactor
SWM	Solid Waste Management System
SSC	Structures, Systems and Components
TASS	Turbine Auxiliary Steam Subsystem
TB	Turbine Building
TBS	Turbine Bypass System
TBV	Turbine Bypass Valves
TCV	Turbine Control Valves
TG	Turbine Generator
TGCS	Turbine Generator Control System
TGSS	Turbine Gland Seal System
TLOS	Turbine Lube Oil System
TMA	Trip Manifold Assembly
TSV	Turbine Stop Valves
UK	United Kingdom
USNRC	U.S. Nuclear Regulatory Commission
U.S.	United States

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REVISION SUMMARY

Revision #	Section Modified	Revision Summary
A	All	Initial Issuance
B	All	Update for end of GDA Step 2 consolidation

10 STEAM AND POWER CONVERSION SYSTEM

Introduction

The purpose of this Preliminary Safety Report (PSR) Chapter is to describe the BWRX-300 Steam and Power Conversion System, and how it will comply with its design and safety requirements. Steam and Power Conversion systems include a description of how the human factor requirements and standards described in NEDO-34190, "BWRX-300 UK GDA Chapter 18: Human Factors Engineering," (Reference 10-1) are applied to the design.

The steam and power conversion system for the BWRX-300 consists of the following systems: Turbine Generator (TG), Main Steam (MS) subsystem of the Nuclear Boiler System (NBS), Main Condenser and Auxiliaries (MCA), Moisture Separator Reheater System (MSR), Turbine Gland Seal System (TGSS), Turbine Bypass System (TBS), Circulating Water System (CWS), CFD, and the CFS. The components of the steam and power conversion system are designed to produce electrical power utilising the steam generated by the reactor.

A simplified system flow diagram and representative heat balance of the steam and power conversion system is provided in Figure 10-1, note that this figure was prepared specifically for TVA based on their heatsink temperatures and are provided as representative only. A summary of the important design and performance characteristics is provided in Table 10-1.

This chapter includes the 006N7717, "Main Turbine Equipment (MTE)," (Reference 10-2) along with the systems listed below. The MTE is comprised of the following:

- One High Pressure (HP) and two Low Pressure (LP) turbines, Turbine Stop Valves (TSVs), Turbine Control Valves (TCVs), non-return valves, intermediate stop valves and intercept valves (or combined intercept valves, depending on vendor-specific design), and turning gear
- TGSS
- Turbine Lube Oil System (TLOS)
- Extraction Steam System
- Electro-Hydraulic Control (EHC) Subsystem

The MS subsystem of the BWRX-300, from the non-safety ASME B31.1 piping interface with the ASME Boiler and Pressure Vessel Code (BPVC), Section III, Class 2 piping downstream of the Safety Class 1 (SC1) Seismic Interface Restraint (SIR), to the TSVs, is presented in Section 10.1.

MS piping is not part of the MTE System, refer to Section 10.4 for additional information. Section 10.4 also details the turbine overspeed protection and turbine integrity that minimise the probability of turbine missile generation.

Load rejection capabilities are discussed in Section 10.4.3.

Other steam and power conversion systems described in the sections below include:

- Feedwater (FW) Systems in Section 10.2
- Condensate Filters and Demineralizers in Section 10.2.1
- Condensate and Feedwater Heating System in Section 10.2.2
- Turbine Gland Seal System in Section 10.3.3
- MCA in Section 10.4.1

    - MSR in Section 10.4.2
    - Turbine Bypass System in Section 10.4.3
- Circulating Water System in Section 10.4.5

The BWRX-300 approach to classifying of Structures, Systems and Components (SSC) is discussed in NEDO-34165, “BWRX-300 UK GDA Chapter 3: Safety Objectives and Design Rules for SSCs,” (Reference 10-3), Section 3.2. Radiation shielding for personnel protection is provided for all required components as discussed in NEDO-34175, “BWRX-300 UK GDA Chapter 12: Radiation Protection,” (Reference 10-4), Section 12.3.2. Additional structural integrity requirements to the American Society of Mechanical Engineers (ASME) BPVC requirements for Class 2 and Class 3 metallic components are described in NEDO-34194, “BWRX-300 UK GDA Chapter 22: Structural Integrity,” (Reference 10-5).

This chapter describes the relevant systems within the Steam and Power Conversion System, their required safety and non-safety functions, design bases and provide arguments as to how the functions will be met by the systems. System interfaces /dependencies are identified, and suitable cross references used to direct the reader to the relevant interfacing chapters of the safety justification.

Interfaces with other Chapters

- PSR Chapter 3: Safety Objectives and Design Rules for SSCs (Reference 10-3)
- PSR Chapter 5: Reactor Coolant System and Associated Systems (Reference 10-8)
- PSR Chapter 6: Engineered Safety Features (Reference 10-11)
- PSR Chapter 7: Instrumentation and Control (Reference 10-13)
- PSR Chapter 9A: Auxiliary Systems (Reference 10-18)
- PSR Chapter 11: Management of Radioactive Waste (Reference 10-19)
- PSR Chapter 12: Radiation Protection (Reference 10-4)
- PSR Chapter 15.5: Deterministic Safety Analysis (Reference 10-14)
- PSR Chapter 18: Human Factor Engineering (Reference 10-1)
- PSR Chapter 21: Decommissioning and End of Life (Reference 10-54)
- PSR Chapter 22: Structural Integrity (Reference 10-5)

Claims and arguments relevant to Generic Design Assessment (GDA) step 2 objectives and scope are summarised in Appendix A, along with an As Low As Reasonably Practicable (ALARP) position.

Appendix B has been included to capture any Forward Action Plan (FAP) items. However, none were identified for PSR Chapter 10.

10.1 Main Steam System

The following MS information is consistent with 006N7828 “Nuclear Boiler System,” SDD (Reference 10-6). The MS is a subsystem of the NBS. This section describes the MS subsystem from the non-safety ASME B31.1 piping interface with the ASME BPVC, Section III, Class 2 piping downstream of the Safety Class 1 (SC1) SIR, to the TSVs (Section 10.3.2 – Turbine gland seal subsystem), the Turbine Bypass Valves (TBVs), the Main Steam Line (MSL) drains, and other load isolation/maintenance valves. The lines to these loads, all connecting branch lines up to and including their respective isolation valves, and all associated piping supports are also part of the MS subsystem. The design of the MS subsystem complies with the following codes and standards:

- MS piping in Containment and the RB, from the discharge of the outboard Main Steam Reactor Isolation Valves (MSRIV) to the outboard Main Steam Containment Isolation Valve (MSCIV) and up to the SIR, is designed to ASME BPVC Section III, Class 2, and Seismic Category I requirements
- The SIR is designed to ASME BPVC Section III Class NF requirements
- The MS piping in the Turbine Building (TB) is designed ASME B31.1, Non-Seismic Category requirements.
- The portion of the MS subsystem located in the TB meets the requirements of ASME B31T “Standard Toughness Requirements for Piping,” Paragraphs 3, 4 and Appendix A, (Reference 10-7)

Information pertaining to the MS subsystem from the outboard side of the outboard MS Reactor Isolation Valves up to and including the SIR is addressed in NEDO-34167, “BWRX-300 UK GDA Chapter 5: Reactor Coolant System and Associated Systems,” (Reference 10-8).

10.1.1 System and Equipment Functions

The system and equipment functions associated with the MS subsystem are identified below.

Normal Functions (Non-Safety Category)

The MS subsystem described in this section does not perform any Non-Safety Category functions during normal conditions.

Normal Functions (Safety Category)

The MS subsystem described in this section performs a Safety Category 3 function to convey steam from the reactor to the main turbine to support the fundamental safety function of removal of heat from the fuel.

Off-Normal Functions (Non-Safety Category)

The MS subsystem described in this section does not perform any Non-Safety Category functions during off-normal conditions.

Off-Normal Functions (Safety Category)

The MS subsystem described in this section does not perform any Safety Category functions during off-normal conditions but does support the safety function of detecting a line break.

10.1.2 Safety Design Bases

The MS subsystem described in this section performs a Safety Category 3 function to convey steam from the reactor to the main turbine at nominal conditions to support the fundamental safety function of removal of heat from the fuel.

The MS subsystem also supports (but does not perform) leak detection in MSL piping outside of containment (safety category 1 and safety category 2 functions in Defense Line 2 (DL2) and Defense Line 4b (DL4b) respectively).

The design of the MS System meets International Atomic Energy Agency (IAEA) requirements specified in SSR-2/1 "Safety of Nuclear Power Plants: Design" as it relates to the steam lines, Requirement 47 (Reference 10-9) as it relates to design for Defence-in-Depth (D-in-D) and IAEA SSG-30 "Safety Classification of Structures, Systems and Components in Nuclear Power Plants," (Reference 10-10) as it relates to classification of SSC.

As noted in BWRX-300 Fire Hazard Assessment Requirements Document (006N6567), major internal and external fire hazards associated with the Turbine Building are due to the lube oil system for the steam turbine/generator bearings and control oil system.

10.1.3 Description

The MS subsystem consists of two MSLs from the discharge flange of the outboard MSRIVs to the TSVs, the TBVs, the MSL drains, and other load isolation/maintenance valves. The steam supply lines to these loads, all connecting branch lines up to and including their respective isolation/maintenance valves, and all associated piping supports are also part of the MS subsystem.

This section describes the portion of the MS subsystem located downstream of the ASME BPVC, Section III, Class 2 piping interface with the ASME B31.1 piping, the portion of the MS subsystem upstream on the SIR (including the SIR) is described in PSR Chapter 5. Two MSLs are routed to the TSVs, the equalizing header, and the MSL drains. Figure 10-2 depicts the MS subsystem.

The MS equalizing header is designed to be located as close as practical to the TSVs and at least as large in diameter as a single main steam line. The MS equalizing header supplies HP steam via branch piping to the TBVs, the MSR, the FW Heater No. 6, the Process Radiation and Environmental Monitoring System (PREMS), and the Turbine Auxiliary Steam Subsystem (TASS).

The MSL drains drain condensate from the MSLs to the main condenser during startup, low power operation, normal power operation, and shutdown. A reduction in power below 40% Rated Thermal Power (RTP) results in the automatic opening of drain line valves, thereby establishing drain flow to the main condenser.

Sections 10.3.6 and 10.4.3 provide information related to Reactor Pressure Control (RPC) during startup and normal operation respectively. In addition, NEDO-34168, "BWRX-300 UK GDA Chapter 6: Engineered Safety Features," (Reference 10-11) provides information pertaining to overpressure protection.

Component Description

Main Steam Lines

MSLs are designed to mitigate acoustic loads generated as a result of NBS and interfacing system configuration such that their impact on system functional capabilities and material condition is acceptable.

The MS piping in the TB is designed to ASME B31.1 "Power Piping," (Reference 10-12), Non-Seismic Category requirements including all the connecting branch lines up to the various steam loads including their respective isolation valves.

The MS subsystem piping has a design pressure of 10.342 MPa (1,500 psig) and design temperature of 314.4°C (598°F). It is sized to limit steam velocities at full power steady-state operating conditions (to limit the effects of flashing, noise, vibration, water/steam hammer, and erosion) and are design to minimize the potential for water (steam) hammer through the implementation of specific design features and system layout(s).

The MS system is designed so that the pressure drop through the piping at 100% RTP condition does not exceed the minimum and maximum limits.

The NBS is designed so that the pressure downstream of the outboard MSCIV is equal to or greater than the pressure specified for standard plant operating conditions with 10% margin.

Main Steam Line Drains

The MS drain lines provide the ability to drain the condensate from the MSL to the condenser in a controlled manner during startup, lower power operation (approximately 40% RTP for the bypass drain valves), normal power operation, and shutdown.

Drains are at low points or catch-points to drain condensate back to the main condenser.

The drain line isolation valves on MSL drain lines fail open. The drain lines contain an orifice and an in-line strainer.

10.1.4 Materials

Material and process control requirements for the BWRX-300 components ensure the reliability of plant operations through its design life by minimizing irradiation of the plant components, corrodents and mitigating the degradation of materials specifically from corrosion through material chemistry, heat treatment, contamination, and material processes controls.

10.1.5 Interfaces with Other Equipment or Systems

Refer to Table 10-2 for system interfaces.

10.1.6 System and Equipment Operation

PSR Chapter 5 describes NBS operations. The sections below focus on operations of the MS subsystem in each of the facility modes.

Initial Configuration (Pre-Startup)

System configuration is established per plant procedures.

System Startup

PSR Chapter 5, Section 5.3.4 (System startup) describes RCS startup. The MSL drains remain open to approximately 40% RTP to remove excess moisture carryover during RCS startup operations.

Normal Operations

PSR Chapter 5, Section 5.3.4 (Normal operation) describes normal operations of the RCS system. During normal operations, the MS subsystem continues to transport steam generated in the Reactor Pressure Vessel (RPV) that passed through containment from the RPV nozzles through the MS Reactor Isolation Valves and MSCIVs provide the steam power needed to drive the main turbine. Steam is directed through the open maintenance block valves to the MSR, FW Heater No. 6, and TASS. MSL drain line valves open and close as a function of the level of condensed steam in the drain pot up to about 40% power where they are closed.

During power operation, the RCS also vents non-condensable gases generated in the RPV through the RPV head vent to the MS piping.

Off-Normal Operations

PSR Chapter 5, Section 5.3.4 (Off-normal operation) describes planned and unplanned transients for the NBS system. Transients that lead to reductions in power to 40% or less result in automatic opening of the drain line valves to the main condenser.

Unplanned transients are listed in the fault list described in PSR Chapter 3, Appendix 3A.

System Shutdown

PSR Chapter 5, Section 5.3.4 (System shutdown) describes NBS system shutdown consisting of hot shutdown, stable shutdown, and cold shutdown. Normally, the reactor design is to be cooled down from the hot shutdown condition by opening one or more TBVs to direct steam to the main condenser. Opening of a TBV reduces pressure in the reactor and the steam lines. The reactor coolant is flashed to steam, which flows through the MSLs and the TBVs and ultimately to the main condenser.

The MS drain lines provide the ability to drain the condensate from the MS lines to the condenser in a controlled manner during startup, lower power operation (approximately 40% nuclear boiler rated for the drain valves), normal power operation, and shutdown.

10.1.7 Instrumentation and Controls

The Instrumentation and Controls (I&Cs) for the MS subsystem, NEDO-34167 (Reference 10-8) within the NBS described in PSR Chapter 5 consists of the following:

1. NEDO-34169, "BWRX-300 UK GDA Chapter 7: Instrumentation and Control," (Reference 10-13). NEDO-34169, (Reference 10-13) section 7.3.3 describes the I&Cs for the RPC system.
2. The TB contains MSL leak detection instrumentation. This instrumentation is designed to fail-safe as the TB is a non-seismic structure
3. The MSL drain isolation valves have control logic interlocked to support automatic plant startup and shutdown operation
4. Pressure transmitters are provided and located on the MSLs near the equalizing header in the TB to monitor steam line parameters

10.1.8 Monitoring, Inspection, Testing, and Maintenance

Piping and components are inspected and tested in accordance with the requirements of ASME B31.1 (Reference 10-12). Areas requiring inspections are provided with access spaces/routes and with removable and reusable insulation coverings.

The MS equalizing header arrangement upstream of the TSVs allows for online testing.

10.1.9 Radiological Aspects

PSR Chapter 12 provides information pertaining to measures taken to ensure that occupational exposures arising from the operation or maintenance of the equipment or system are ALARP in operational states.

10.1.10 Performance and Safety Evaluation

Components and piping for the MS subsystem described in this section are designed in accordance with the ASME B31.1 code (Reference 10-12). MSLs are designed to minimise negative interactions between lines. This ensures that the MS subsystem can accommodate operational stresses resulting from static and dynamic loads, including water (steam) hammer and includes provisions to limit water entrainment. Operating and maintenance procedures include adequate precautions to minimise the potential for water (steam) hammer.

The break of a MSL is assessed in NEDO-34183, “BWRX-300 UK GDA Chapter 15.5: Deterministic Safety Analysis,” (Reference 10-14), Section 15.5.9 (Main steam line break outside containment).

10.2 Feedwater Systems

10.2.1 Condensate Filters and Demineralizer System

The following information is consistent with 006N7741, "Condensate Filters and Demineralizers System SDD," (Reference 10-15).

The “Condensate Filters and Demineralizer System SDD” (CFD) 006N7741 (Reference 10-15) purifies the condensate and the Reactor Water Cleanup System (CUW) water, as required, to maintain reactor FW purity. The CFD uses filtration to remove suspended solids, including corrosion products, and ion exchange resin to remove dissolved solids from various condensate sources of impurities including CUW, Condensate Storage Tank (CST), condenser tube leakage and other impurities. The CFD is a full flow system that consists of high efficiency backwash-type filters followed by mixed, deep bed demineralizers with replaceable ion exchange resin. The CFD system is designed to ensure the effluent meets the water quality requirements described in the BWRX-300 Water Quality Design Specification.

The CFD system is designed in accordance with the following codes and standards:

- Where available, the maximum values in the BWRX-300 Water Quality Specification are similar to, or the same as, EPRI BWRVIP-190 Revision 1: “BWR Vessel and Internals Project,” 2019 Interim Guidance (Reference 10-16).
- Piping and valves associated with resin and sludge systems are stainless steel designed to the requirements of ASME B31.1, ASME B16.5, ASME B16.34, and ASME 31.3 for filter backwash and spent resin.

10.2.1.1 System and Equipment Functions

Normal Functions (Non-Safety Category)

The CFD continuously operates during all modes of normal power plant operation, including startup and shutdown, receiving untreated condensate from, and supplying treated condensate to, the CFS. The CFD carries out the following functions:

1. Removes soluble and insoluble impurities from the condensate at 100% rated flow to meet or exceed the plant water quality requirements for feedwater. The series of filters and demineralizers through which FW is processed target the achievement of water chemistry requirements specified in Electric Power Research Institute, “BWRVIP-190 Revision 1: BWR Vessel and Internals Project,” Volume 1, 2014, (Reference 10-17), or most current version.
2. Removes impurities entering the power cycle due to condenser circulating water leaks as required to permit continued power operation within specified water quality limits as long as such condenser leaks are small. Continued operation with minor condenser circulating water leaks is controlled by site-specific chemistry threshold values.
3. The CFD limits the entry of dissolved solids into the FW system in the event of large condenser leaks, such as a tube break, to permit a reasonable amount of time for orderly plant shutdown.
4. The CFD flow controls and bypass are arranged such that the condensate system flow is uninterrupted even in the presence of a single failure.
5. The CFD filters and removes ionic impurities from the CUW, (see Section 9A.2.2) NEDO-34171, “BWRX-300 UK GDA Chapter 9A: Auxiliary Systems,” (Reference 10-18).

Normal Functions (Safety Category)

The CFD system performs the following Safety Category function during normal conditions:

- Provides a flow path to supply 100% rated flow of condensate to the CFS system

Off-Normal Functions (Non-Safety Category)

The CFD removes soluble and insoluble impurities from the condensate at 100% rated flow to meet or exceed the plant water quality requirements for feedwater.

The CFD bypass can be used during startup and normal operations, in the event of an Anticipated Operational Occurrence resulting in a disruption of CFS flow through the CFD. The CFD bypass will remain open until the CFD flow is returned to normal, or the plant is brought to an orderly shutdown.

The CFD is not required to operate during or after a design basis event.

Off-Normal Functions (Safety Category)

During off-normal events the CFD supports 100% rated FW flow which maintains DL2 Safety Category 3 functions.

10.2.1.2 Safety Design Bases

The CFD System components and piping associated with the fundamental safety function of maintaining reactor condensate/feedwater flow are classified as Safety Class 3.

The CFD is not required to operate during or after a design basis event. The design of the CFD meets IAEA requirements specified in SSR-2/1 Requirement 7 (Reference 10-9) as it relates to design for D-in-D and IAEA SSG-30 (Reference 10-10) as it relates to classification of SSC.

10.2.1.3 Description

Refer to Figure 10-3 which depicts the CFD.

CFD equipment, valves, and instrumentation are located within the Turbine Building.

The CFD includes three (3) filter vessels, each rated at 50% of total FW flow with high efficiency backwash type filter elements arranged in parallel, complete with valves, piping, instrumentation, and filter backwash equipment. The condensate demineralizers include three (3) demineralizer vessels, each rated at 50% of total FW flow arranged in parallel, complete with valves, piping, controls, and instrumentation.

The CFD has connections to auxiliary skids and tanks to assist in tasks required to clean the condensate filters and replace spent resin in the condensate demineralizers. A fresh resin hopper is used to feed the demineralizer. This hopper also provides a location to inject an anion resin underlay underneath the mixed resin bed by bypassing the storage tank.

The CST transfer pumps will provide adequate pressure and condensate flow to transport resin to and from the demineralizers. The capability exists to wash resin injected into the condensate demineralizer prior to placing the demineralizer into standby mode.

The CFD is capable of handling the normal condensate flow while maintaining the required water quality.

Demineralizer influent and effluent conductivities are monitored by the PREMS in Section 11.5, NEDO-34174, “BWRX-300 UK GDA Chapter 11: Management of Radioactive Waste,” (Reference 10-19), to determine condenser leakage and resin exhaustion, respectively.

Total throughput capacity for each demineralizer and filter vessel is monitored. Flow rates of demineralizers and filters in-service are monitored and controlled.

Initial resin rinse for the mixed resins is performed in the offline condensate demineralizer tank. Rinse water is supplied from the Liquid Waste Management System (LWM) (PSR Chapter 11, Section 11.2) CST and drained to the condenser hotwell (PSR Chapter 9A, Section 9A.9.3).

Individual bypass valves are provided for both the condensate filters and condensate demineralizers. Each bypass valve is capable of handling full condensate flow.

Each bypass system includes a single automatic bypass valve with two manual isolating valves. These manual valves are used to isolate the automatic valve from the CFS.

Provisions are included to permit cleaning and replacement of the ion exchange resin. To perform the addition of new resins to the condensate demineralizers, one fresh resin hopper is included in the CFD design.

Component Description

The following paragraphs provide information that pertains to the major CFD components. Table 10-3 contains a summary of CFD components.

Condensate Filters

The CFD includes backwash type high efficiency filters. The filters and vessels are designed to meet the requirements of ASME BPVC, Section VIII, Division 1 “Rules for Construction of Pressure Vessels,” (Reference 10-20). The condensate filters receive condensate from the CFS and assist in purifying by filtering out suspended solids that have entered the condensate stream.

Filter vessels are constructed of corrosion resistant stainless steel.

Condensate Demineralizers

Demineralizer vessels are constructed of corrosion resistant steel or lined with corrosion resistant material. The demineralizers are designed to meet the requirements of ASME BPVC, Section VIII, Division 1 (Reference 10-20). The mixed bed type condensate demineralizers receive condensate water from the CFS after being filtered by the condensate filters. The demineralizers assist in treating the condensate water by removing impurities and suspended solids.

Resin Traps

The CFD includes resin trap housings located downstream of the condensate demineralizers. A resin trap is installed downstream of each demineralizer vessel to preclude gross resin leakage into the power cycle in case of vessel resin screen failure and capture resin fines to maintain higher water quality.

The resin traps are constructed of corrosion resistant stainless steel resin baskets.

Condensate Filter Bypass Valve

A condensate filter bypass valve is provided for use during startup and in an off-normal condition until the condensate flow is returned to normal or the plant is brought to an orderly shutdown.

The condensate filter bypass valve is constructed of corrosion resistant stainless steel.

Condensate Demineralizer Bypass Valve

A condensate demineralizer bypass valve is provided for use during startup and in an off-normal condition until the condensate flow is returned to normal or the plant is brought to an orderly shutdown.

The condensate demineralizer bypass valve is constructed of corrosion resistant stainless steel.

Air Surge Tank

An air surge tank is provided in the CFD as a means of transporting spent resin from the condensate demineralizer drain to the Solid Waste Management System (SWM) (PSR Chapter 11, Section 11.4) spent resin tanks. The air surge tank can also provide air for backwashing the filters when needed. The air surge tank receives air from the Plant Pneumatics System (PSR Chapter 9A, Section 9A.4.1). The air surge tank is designed to meet the requirements of ASME BPVC, Section VIII, Division 1 (Reference 10-20). SWM tanks also provides vent and drain locations for filter and demineralizer vessels.

Fresh Resin Addition Hopper

The fresh resin addition hopper provides a location for storage of fresh resin before injection into a condensate demineralizer vessel.

The resin addition hopper is constructed of corrosion resistant stainless steel.

Piping and Valves

The piping and valves associated with resin and sludge systems are designed to meet the requirements of ASME B31.1 for power piping (Reference 10-12), ASME B16.5 “Pipe Flanges and Flanged Fittings: NPS ½ through NPS 24, Metric/Inch Standard,” (Reference 10-21, and ASME B16.34 , “Valves-Flanged, Threaded, and Welding End,” (Reference 10-22).

Isolation valves are provided on the inlet and outlet of each condensate filter vessel and each demineralizer vessel to allow the vessel to be out of service for backwashing, resin transfer or vessel maintenance.

10.2.1.4 Materials

Material and process control requirements for the BWRX-300 components ensure the reliability of plant operations through its design life by minimising irradiation of the plant components, corrodents and mitigating the degradation of materials specifically through material chemistry, heat treatment, contamination, and material processes controls. CFD components are constructed of stainless steel or lined with corrosion resistant materials as applicable.

10.2.1.5 Interfaces with Other Equipment or Systems

Refer to Table 10-4 for system interfaces.

10.2.1.6 System and Equipment Operation

The CFD is capable of performing its system functions as described in Section 10.2.1.1 during the modes of operation described below.

Normal Operational Concept

Plant Startup Mode

The CFD is used during plant startup to clean up the condensate, and to minimize the time required to achieve low power operation of the unit. The CFD provides high purity water to the CFS. The CFS provides recirculation flow paths to assist in cleaning the condenser hotwell and facilitate achieving the desired condensate water chemistry prior to sending FW to the reactor.

Plant Normal Operation Mode

The CFD operates continuously and provides the required reactor FW quality.

The CFD is designed to operate with two online demineralizers and two online filters. Demineralizers are sequenced as necessary to prevent resin channeling. The filters are sized to allow full-load operation with one filter out of service. Each filter is capable of handling approximately 50% of normal condensate flow.

During normal operation, the condensate pump discharge is routed through the CFD. The condensate enters the filters, which removes filterable solids. The effluent from the filters passes through mixed bed ion exchange demineralizers, which are also piped in parallel (one on standby) and where removal of dissolved impurities is accomplished. Effluent from the CFD is returned to the CFS.

During normal operation the CFD is capable of completing typical resin and filter maintenance activities, including backwashing, receiving fresh resin, resin transfer, discharging exhausted resin, placing a standby filter or demineralizer into service, and removing an operating filter or demineralizer from service.

CFD System Bypass

The design includes bypass facilities capable of bypassing condensate flow around the CFD to provide continuous short-term condensate flow in the event of a condition within CFD which prevents treatment of the entire condensate flow. The CFD bypass can also be used during CFS startup of the condensate pumps.

Independent bypass valves are supplied for both the condensate filters and condensate demineralizers. The filter bypass valve automatically opens based upon differential pressure across the filters. The filter bypass valve is capable of passing full condensate flow. The demineralizer bypass valve opens automatically based upon the differential pressure across the demineralizers. The demineralizer bypass valve is capable of passing full condensate flow. The demineralizer bypass valve will open upon high temperature upstream of the CFD system to prevent damage to the resin media.

Plant Shutdown

The CFD is not required to be in-service during unit shutdown.

Off-Normal Operational Concept

Turbine Trip

During and following a turbine trip, the CFD operates continuously and provides treated condensate to the CFS.

Reactor Low Load

The CFD operates continuously and provides treated condensate to the CFS under low load conditions.

Condenser Tube Leak

The CFD limits the entry of dissolved solids into the CFS and, in the event of a tube break, allows a reasonable amount of time for orderly plant shutdown. In the event of a small condenser tube leak or ingress of impurities into the condensate system, the CFD will allow for continued operation of the unit until the leak is repaired.

10.2.1.7 Instrumentation and Control

The following defines some Instrumentation and Controls (I&Cs) required for system operation and control, NEDO-34169 (Reference 10-13). Most operations are through the Main Control Room (MCR) and the following indications, alarms and controls are provided but are not limited to the items below.

The following defines the basic controls required for system operation and control.

The MCR is equipped with the appropriate instruments and controls to allow an operator the ability to perform the following operations as directed by procedure:

- Monitor filters and demineralizers in normal operation
- Control the filters and demineralizers in their various operating modes
- Remove a saturated filter from service
- Clean up the isolated filter by backwashing and place it back in operation
- Remove an exhausted demineralizer from service and replace it with a standby unit
- Transfer the resin inventory of the isolated demineralizer vessel into the spent resin tank for disposal
- Wash resin within an isolated demineralizer via slow water washing
- Transfer the fresh resin to any isolated demineralizer vessel

Interlocks are provided for the following:

- To prevent feed into a demineralizer with a high differential pressure across the demineralizer inlet isolation valve
- To prevent high temperature feed to demineralizers
- To open the bypass in case of high differential pressure across the condensate filters or demineralizers
- To prevent sending waste backwash water from the filter to the SWM if the SWM is unavailable

The following signals for the condensate filters are monitored in the MCR:

- Condensate filter status
- Condensate filters common inlet conductivity (monitored by PREMS). Includes alarm
- Individual condensate filter flow and totalisation
- Differential pressure across condensate filters individually and the system. Includes alarms
- Condensate filter combined effluent flow

The following signals for the demineralizers are monitored in the MCR:

- Condensate demineralizer status
- Condensate demineralizer flow and totalisation
- Condensate demineralizer individual vessel and system differential pressure. Includes alarm
- Differential pressure across resin trap. Includes alarm

- CFD inlet header temperature. Includes alarm
- Condensate demineralizer effluent conductivity individually and at combined outlet (monitored by PREMS). Includes alarms

10.2.1.8 Monitoring, Inspection, Testing, and Maintenance

Section 10.2.1.7 (Instrumentation and control) identifies some conductivity measurements that are monitored by PREMS.

Pre-operational tests are performed on the CFD to ensure operability, reliability, and integrity of the system. Each filter and demineralizer vessel can be isolated during normal plant operation to permit testing and maintenance. Filters can be backwashed remotely.

Isolation valves are provided on the inlet and outlet of each condensate demineralizer vessel to allow the vessel to be out of service for backwashing, resin transfer, or vessel maintenance. CFD capacity is designed to allow full power operation with one condensate filter or demineralizer out of service for maintenance.

The equipment and components of the CFD are designed for ease of inspection and maintenance during plant operation. Routine testing of the CFD is conducted in accordance with normal power plant requirements for demonstrating system and component operability and integrity.

The CFD design provides equipment removal paths and personnel access for maintenance. Shielding is provided to protect personnel from the concentration of radioactive material (activated corrosion products and fission products that are carried over from the reactor) in filters, demineralizers and other CFD equipment.

10.2.1.9 Radiological Aspects

PSR Chapter 12 provides information pertaining to occupational exposures arising from the operation or maintenance of the equipment or system are ALARP in operational states.

Shielding is provided to protect personnel from the concentration of radioactive material (activated corrosion products and fission products that are carried over from the reactor) in filters, demineralizers and other CFD equipment.

10.2.1.10 Performance and Safety Evaluation

The CFD is capable of performing its system functions during the modes described in Section 10.2.1.6 (System & equipment operation). The CFD perform Safety Category 3 functions during normal and off-normal conditions.

10.2.2 Condensate and Feedwater System

The following information is consistent with 006N7737 “Condensate and Feedwater Heating System SDD,” (Reference 10-24). This section describes the CFS from the outboard side of the FW Containment Isolation Valves (CIVs), through the Reactor Building, and In the Turbine Building. The remainder of the CFS is described in PSR Chapter 5.

The condensate portion of the CFS is designed to pump condensate from the main condenser hotwell through the CFD and three stages of LP FW heating to the suction side of the reactor feed pumps. The FW portion of CFS is designed to pump FW through three stages of HP FW heating and deliver the FW to the reactor inlet nozzles.

10.2.2.1 System and Equipment Functions

Normal Functions (Non-Safety Category)

The CFS provides the following Non-Safety Category functions during normal conditions:

1. Provide monitoring of parameters necessary for measuring core flow and reactor heat balance

Normal Functions (Safety Category)

The CFS provides the following Safety Category functions during normal conditions:

1. Supply feedwater to NBS RPV at the nominal conditions
2. Modulate the flow of feedwater to the reactor for the purpose of reactor water level control
3. Prevent reverse flow in the feedwater lines
4. Have the condensate and feedwater pumps trip when signalled to do so
5. Provide the capability to monitor the operational status of the Feedwater and Condensate pumps
6. Feedwater pump in standby start when signalled to do so
7. Provide instrument signals for final feedwater temperature

Off-Normal Functions (Non-Safety Category)

The CFS does not provide any Non-Safety Category functions during off-normal conditions.

Off-Normal Functions (Safety Category)

The CFS provides the following Safety Category functions during off-normal conditions:

1. CFS provide the capability to detect a line break in Feedwater piping outside containment
2. CFS remote-actuated Feedwater system isolation valves shall close when signaled to do so
3. CFS provide Feedwater system isolation valves on piping upstream of the outboard containment isolation valve
4. CFS remote-actuated Shutdown Cooling system isolation valves shall close when signaled to do so
5. CFS provide Shutdown Cooling system isolation valves on piping upstream of the outboard CIVs
6. CFS provides the capability to modulate the flow of FW to the reactor for the purpose of reactor level control, based on signals from I&C systems
7. Continues to supply condensate water following a single condensate pump trip
8. Continues to supply FW following a single FW pump trip
9. CFS provides the capability to monitor the operational status of the condensate and FW pumps
10. CFS FW pump in standby will start when signaled to do so by I&C systems
11. CFS provides the sensors to measure final FW temperature
12. CFS provides the sensors to detect a FW line break outside containment
13. CFS provides containment and system isolation of CFS piping penetrating the primary containment and will close when demanded from the SC1 I&C System or SC2 and SC3 I&C System

14. CFS provides the capability to measure FW flowrate

10.2.2.2 Safety Design Bases

The CFS system is primarily SC3. The CFS provides for closure of the CIVs and system isolation valves when signaled to do so as discussed in Section 10.3.2 (System & equipment operation). The containment isolation components, system isolation components, leak detection components, and flow measuring devices are SC1. Containment isolation is provided in accordance with IAEA SSR-2/1 requirement 56 (Reference 10-9).

Codes and standards related to pressure boundary and seismic classification are identified in the component descriptions in Section 10.2.2.3 (Component description) as applicable.

10.2.2.3 Description

The CFS supplies FW to the RPV at the required pressure, temperature, and flowrate to maintain RPV level in the required band. In addition, the CFS supplies water to various interface systems and responds to signals from the I&C systems. The CFS also provides the necessary indication, isolation functions, and design redundancy to support the required Safety Category functions.

Figure 10-4, Figure 10-5, Figure 10-6 and Figure 10-7 depict the CFS flow diagrams and the CFS heaters and vents associated with the CFS.

The CFS consists of the following components:

- Two (2) 100% capacity condensate pumps
- Three (3) LP Feedwater Heaters (FWHs) arranged with two (2) 50% capacity duplex FWHs (stages one and two) in parallel and one (1) 100% capacity stage three FWH in series
- One (1) Low Flow Control Valve (LFCV)
- Two (2) 100% capacity reactor FW pumps
- Three (3) HP FWHs arranged in series (stages four, five, and six)
- Bypass valves around each FWH
- Piping, valves, and instrumentation

The CFS is located in the TB, Reactor Building and Containment. During normal operation, the CFS provides a continuous supply of purified condensate water to the RCS (PSR Chapter 5) at the required temperature, pressure, and flowrate.

The CFS is designed to avoid Flow Accelerated Corrosion (FAC) damage. The design and layout of the piping system considers the effects on the piping material of fluid velocity, bend location and the location of flash points. The effects of FAC are considered when selecting the piping material. Material and equipment selection for the CFS is based on the range of normal environmental conditions that may exist at the location of the system's equipment and components.

A condensate pump discharge header connects the CFS to the CFD (Section 10.2.1). The CFS provides cooling to the CUW (PSR Chapter 9A, Section 9A.2.2) heat exchanger, Steam Jet Air Ejectors (SJAE) intercondensers, TGSS condenser, and off-gas condenser. The CFS provides condensate water to the condenser hood spray, Control Rod Drive (CRD) pumps, and the CST for high level control in the condenser. A recirculation line to the main condenser is equipped with a control valve that connects to the auxiliary condensate loop downstream of the TGSS condenser is provided to ensure condensate minimum flow and auxiliary condenser cooling.

Downstream of the auxiliary condensate loop, FW heaters are provided for condensate and FW temperature control. Condensate pumps and FW pumps are provided to meet rated pressure and flowrate entering the RCS. The condensate pump minimum flow/short cycle cleanup line provides water inventory control during multiple operating modes, in addition to the minimum flow and cleanup functions.

The shell side of the FW heaters drain in a cascading order from FW Heater No. 6 to FW Heater No. 1.

The final stage HP FW heater (No. 6) accommodates final FW temperature control during power operation and power maneuvering. It comes in-service gradually from 70-90% power. The final stage HP FW heater is fully in-service to raise FW temperature when power is above 90% to increase stability margins.

The main FW line also connects to the long cycle cleanup recirculation path line back to the main condenser.

A final FW strainer is installed to minimise debris entry into the RCS. The strainer is placed downstream of FW Heater No. 6 and upstream of the FW measurement devices. Downstream of the HP FW heaters, the FW line divides into two (2) FW lines that pass through the containment via a system and CIV. Inside containment, each of these lines splits again into a total of four (4) lines that connect to the reactor via the RCS FW reactor isolation valves.

The Shutdown Cooling System (SDC) (PSR Chapter 9A, Section 9A.2.3) return lines connect to the FW lines upstream of the outboard CIVs. SDC uses the CFS containment penetrations to reduce the total number of containment penetrations.

The CFS design follows recommended practices for prevention of water damage to steam turbines and prevention of excessive corrosion/erosion damage due to flashing liquid flow (Section 10.2.3 – Extraction steam subsystem). The system capacity allows for continuous long-term power plant operation with either an HP FW heater or LP FW heater out of service.

Component Description

The following paragraphs provides descriptive information specific to the major equipment in the CFS. Table 10-5 summarises major components in the CFS.

Condensate Pumps

The CFS consists of two (2) 100% capacity condensate pumps.

One pump in operation and one in standby. The condensate pumps are located below the normal water level of the main condenser hotwell to ensure the pump suction remains flooded. Each condensate pump has an individual suction line and is equipped with an anti-vortex device. A permanent suction strainer is provided on the suction of the condensate pumps to remove larger debris from the condensate to protect the pumps.

A condensate pump discharge header connects the CFS to the CFD (Section 10.2.1).

Low Pressure Feedwater Heaters

The stage 1 and 2 duplex LP FW heaters are located within each condenser neck.

LP FW Heaters No. 1, No. 2, and No. 3 are closed FW heater types, designed in accordance with ASME BPVC, Section VIII, Division 1 (Reference 10-20), and the Heat Exchange Institute Standards.

The FW heater tubes and tubesheets are corrosion resistant stainless steel. Tube to tubesheet joints are welded. The FW heater internal vent piping is also constructed of corrosion resistant stainless steel. The FW heater shell material considers the effects of corrosion product metals to minimise deposits on fuel.

FW Heater No. 3 is designed for 100% of the plant condensate flow and duty. FW Heater No. 1 and No. 2 are designed for 50% of the plant condensate flow and duty.

High Pressure Feedwater Heaters

Three (3) HP FW heaters are provided. The HP FW heaters are horizontal U-tube type heat exchangers with integral drain cooler. Each HP FW heater is designed for 100% of the plant FW flow.

The FW heater tubes and tubesheets are corrosion resistant stainless steel. Tube to tubesheet joints are welded. The FW heater internal vent piping is also constructed of corrosion resistant stainless steel. The FW heater shell material considers the effects of corrosion product metals to minimise deposits on fuel.

The FW heaters are designed in accordance with ASME BPVC, Section VIII, Division 1 (Reference 10-20), and Heat Exchange Institute Standards.

Downstream of the HP FW heaters, the FW line divides into two (2) FW lines that pass through the containment via a system and CIV. Inside containment, each of these lines splits again into a total of four (4) lines that connect to the reactor via the RCS FW reactor isolation valves. The main FW line also connects to the long cycle cleanup recirculation path line back to the main condenser.

Feedwater Pumps

Two (2) FW pumps, driven by an electrical motor and powered by an Adjustable Speed Drive, are sized for 100% of the total rated FW flow, plus margin for control. One (1) pump is in operation while the other is on standby.

The FW pumps are located on grade elevation of the TB.

A bypass is provided around the FW pumps to permit FW supply to the reactor during early startup using only the condensate pumps as well as during preparation for outage leakage tests. During startup, a Low Flow Control Valve is used to control the RPV level.

Piping and Valves

The CFS CIVs and piping are SC1 and are designed to ASME BPVC, Section III, subsection NCD, Class 2 components “Rules for Construction of Nuclear Facility Components, Class 2 and Class 3 Components,” (Reference 10-25).

To ensure containment integrity at the primary vessel containment penetrations, the containment piping and isolation valves, and the CFS piping upstream of the CIVs to the system isolation valves are designed as Seismic Category 1A with the system isolation valves designed as Seismic Category 1B.

The CFS piping upstream of the system isolation valves is designed SC1, ASME Section III, Class 2 up to and including the seismic restraint upstream from the system isolation valve. The CFS piping upstream from the seismic restraint, located upstream of the system isolation valve, is classified as SC3, Quality Group D, Non-Seismic Category, and designed to meet the requirements of ASME Code for Pressure Piping B31.1 (Reference 10-12).

The low flow level control valve is capable of controlling condensate flow smoothly at low power levels.

The layout of the CFS and the characteristics of the valves is such that water hammer loads are below the reactor design limits. The design of the CFS complies with NUREG-0927 "Evaluation of Water Hammer Occurrence in Nuclear Power Plants," (Reference 10-26).

The normal and alternate drain control valves on the shell side of the FW heaters are located to minimise flashing upstream of the control valve under any load or drain flow condition and materials are selected to be compatible with any flashing conditions.

Refer to PSR Chapter 3, Section 3.9 for information pertaining to equipment qualification of BWRX-300 SSC.

10.2.2.4 Materials

The CFS is designed to avoid FAC damage. The design and layout of the piping system considers the effects on the piping material of fluid velocity, bend location and the location of flash points. The selection of piping layout, velocity and material is based on successful operating experience.

10.2.2.5 Interfaces with Other Equipment or Systems

Refer to Table 10-6 for system interfaces.

10.2.2.6 System and Equipment Operation

Normal Operational Concept

Startup Mode

The CFS is started by first placing the condensate portion of the system in service.

The condenser hotwell should be above the minimum operating level to start the condensate pumps, and the condensate pump minimum flow control valve is opened. The condensate pump suction valves are opened, and the pump discharge valves are initially closed and then opened simultaneously with pump startup. Condensate from the condenser hotwell is recirculated through the CFD system and returned to the hotwell through the short cycle cleanup line until the required water quality is achieved. The auxiliary heat exchangers will be placed in service as needed during startup of the plant.

During startup while at low power, the feedwater flowrate is too low for the feedwater pump ASDs to adequately control the flow. A LFCV is used in conjunction with a running condensate pump and a fixed speed FW pump discharge as needed to control the demanded flow to the reactor. When the low flow control valve nears its fully open position, the FW flow control is switched from low flow valve control to FW pump motor speed control.

Feedwater pumps may be started when the required condensate purity levels are reached. Flow through the LP heaters is then established, and adequate pressure is provided to the feedwater pump suction. Feedwater flows through the HP FWH and back to the condenser through the feedwater pump recirculation valve in long path cleanup mode.

The feedwater long cycle cleanup flow path is used to recycle the condensate and feedwater through the CFD before admission to the reactor core.

Recirculation/Cleanup Mode

The CFS is designed to enable the entire condensate and feedwater water volume (including the LP & HP FWHs) to be recirculated while cleaning the condensate through the CFD before plant startup, ensuring proper water quality before admission to the reactor. The long and short cycle recirculation line is sized to carry a flow equal to one-third rated feedwater flow.

The CFS cleanup process is carried out using the condensate pumps to clean the condensate subsystem and using the feedwater pumps operating at lower speed to clean the feedwater subsystem.

The setpoint of the cleanup feedwater recirculation loop flow control valve is manually adjusted from the Control Room to achieve the desired flow rate.

Water in the CST may be cleaned by opening the CST discharge line to the main condenser. When the water level in the main condenser rises, the condensate reject valve opens providing a flow path back to the CST. This circulates the water in the CST.

Normal Plant Operation

The CFS is normally operated with one (1) condensate pump operating and one (1) on stand-by and one (1) feedwater pump operating and one (1) on standby. The design of CFS allows for operation of two (2) feedwater pumps and/or 2 condensate pumps simultaneously if chosen to do so. The operating condensate pump and feedwater pump are attached to different electrical buses of the non-safety electrical distribution system. The condensate pumps and feedwater pumps are operated on separate buses to spread the load change in case of an electrical bus trip. All LP and HP FWH isolation valves are normally open. The LP FWHs bypass valves and the HP FWHs bypass valves are normally closed.

During power operation, reactor vessel water level is controlled by the Reactor Level Control System (RLC) (PSR Chapter 7, Section 7.3.3 – Reactor control system, reactor level control system, system design bases & associated safety functions). RLC controls feedwater flow and thus reactor water level by adjusting feedwater pump speed. The demanded feedwater flow is determined by a simplified heat balance using inputs from: reactor level, reactor steam flow, reactor pressure and feedwater temperature. At higher powers, typically above 25%, the control algorithm uses the triplicated instrumentation signals listed above to calculate the required ASD speed demand. At lower powers and using the low flow control valve the control signals are based on level only.

The CFS modulates a control valve to receive main steam from the NBS to control final feedwater temperature entering the RPV. The CFS continuously drains the condensed HP and LP extraction steam in a cascading setup from the number 6 FW heater to the number 1 A/B FW heater. Normal and alternate drain line control valves will maintain water level in each HP and LP FWH based on the signal from the corresponding level transmitters.

The CFS continuously vents vapor and non-condensables from the closed FWHs to the main condenser.

Off-Normal Operational Concept

Condensate Pump Trip

The CFS is normally operated with one condensate pump operating and one on stand-by. In the event of a condensate pump trip, the stand-by pump starts to continue supplying condensate to the feedwater pump suction and RPV. The CFS has built in logic to immediately start the standby pump to minimize the system transients to the system and RPV.

The Safety Class 3 Instrument and Control system provides for a condensate pump trip at high reactor level (level 8).

Feedwater Pump Trip

The CFS is normally operated with one feedwater pump operating and one on stand-by. In the event of a feedwater pump trip the stand-by pump starts to continue supplying feedwater to the RPV. The CFS has built in logic to immediately start the stand-by pump to minimize the system transients to the system and RPV.

The feedwater pumps receive a signal from the Safety Class 1 Instrument and Control system to trip on high water level (Level 8) in the RPV.

One LP or HP Feedwater Heater Out of Service or Isolated

The CFS can be operated with one LP FWH or one HP FWH out of service by closing the FWH inlet and outlet isolation Air Operated Valves (AOVs) and opening the air -operated FWH bypass valve. The FWH bypass valve is fully opened prior to isolation of one of the LP FWHS or HP FWHS.

The Extraction Steam System (Section 10.3.3 – Lube oil pump) HP or LP extraction isolation valves for the effected heater close, the non-return valves for the effected heater (release to close), and the extraction steam drain isolation valves upstream of the extraction steam isolation valves for the effected heater open, providing a path to the main condenser.

A signal is provided to the Safety Class 3 Distributed Control and Information System (DCIS) to provide automatic reactor power reduction upon isolation of one of the LP FWHS or HP FWHs.

10.2.2.7 Instrumentation and Control

This section describes some I&Cs required for system operation and control, NEDO-34169 (Reference 10-13).

Instrumentation is provided to verify condensate and FW pumps, as well as FW heater performance. Provisions include instrumentation to provide input to the plant heat balance.

Differential pressure transmitters are provided to monitor the following parameters:

1. LP and HP FW heater differential pressure
2. Condensate pump strainer differential pressure
3. Differential pressure across the feedwater low flow control valve
4. Differential pressure across the auxiliary condensate loop
5. Differential pressure across the FW LFCV

Flow transmitters are provided to monitor the following parameters:

1. The discharge flow in the condensate pump header. The measurement is used to modulate the valve on the minimum flow/short cycle cleanup line. It is also used to trip the pump when flow through the pump is below a preset value.
2. Flow is measured at each main FW pump discharge and each main FW pump minimum flow recirculation line. This allows for measurement of the total FW flow from each pump.
3. Flow through the LFCV
4. The FW supply line to the reactor water flow. The measurement is used to determine the FW supply to the reactor. The signals from the flow transmitter are used by the FW Control System to control reactor level by adjusting the FW pump speed.

Pressure transmitters are provided to monitor the following parameters:

1. Suction and discharge pressure of each condensate pump
2. Pressure at the inlet of the auxiliary condensate loop
3. The suction pressure and discharge pressure of each FW pump
4. The discharge pressure of the feedwater pumps after the LFCV

Temperature is monitored in the following system locations:

1. Each condensate pump suction line contains a thermal well
2. Condensate pump discharge header
3. Each SJAE intercondenser A/B outlet line
4. Off-gas condenser outlet line
5. Gland seal steam condenser outlet line
6. CUW heat exchanger outlet line
7. Each FWH inlet and outlet line. These measurements are used to determine FWH temperature rise and heat up rates and performance.
8. Feedwater pump discharge common header
9. Feedwater temperature in each feedwater train into the Reactor Building
10. Normal drain outlets of the closed FWHs
11. Alternate drain inlets to the main condenser

Vibration transducers and monitoring equipment are provided for the condensate pumps and FW pumps. in accordance with API 670 "Machinery Protection Systems," (Reference 10-27). Vibration level control limits are in accordance with applicable standards (API 610 "Centrifugal Pumps for Petroleum, Petrochemical and Natural Gas Industries," (Reference 10-28)).

10.2.2.8 Monitoring, Inspection, Testing, and Maintenance

The equipment and components of the CFS are designed to support inspection and maintenance activities.

Routine testing of the CFS is conducted in accordance with normal power plant requirements for demonstrating system and component operability and integrity. Suitable access and/or remote functions to permit in-service testing and inspection of the FW piping are provided. In Service Inspection (ISI) accessibility is provided by appropriate arrangement of piping and major equipment.

For the portion of the system that is ASME III Class 2, accessible arrangement of vents and drains in the system comply with ASME Code Section XI "Rules for Inservice Inspection of Nuclear Power Plant Components, Rules for Inspection and Testing of Components of Light-Water-Cooled Plants," (Reference 10-29) requirements for the performance of ISI and testing for assessing operational readiness.

CFS piping and valves for the containment penetrations are tested in accordance with 10 CFR 50, Appendix J "Primary Reactor Containment Leakage Testing for Water-Cooled Power Reactors," (Reference 10-30) and IAEA SSR-2/1 (Reference 10-9). Test and vent connections are provided at the CIVs to validate local leak rate limits.

10.2.2.9 Radiological Aspects

PSR Chapter 12 provides information pertaining to measures taken to ensure that occupational exposures arising from the operation or maintenance of the equipment or system are ALARP in operational states.

10.2.2.10 Performance and Safety Evaluation

The CFS is capable of performing its design functions as presented in Section 10.2.1.1 (System & equipment operation), during the modes of operation when the system is intended to function. To ensure containment integrity at the Steel-plate Composite Containment Vessel penetrations, the CIVs, and piping are designed to Seismic Categories A and B respectively; and to the requirements of the ASME BPVC, Section III, Division 1-Subsection NCD.

10.3 Turbine Generator System

The turbine generator consists of a 3,000 rpm turbine (consistent with a 50Hz grid connection), generator, control valves and associated subsystems. The turbine has a single flow HP turbine and two double flow LP turbine units in tandem. The HP turbine, LP turbines, casings, turbine main stop and control valves, and associated piping to the turbine change the steam energy into rotational motion that the Generator and Exciter (N41) turns into electrical energy. Stop Valves, control valves and other valves are used to control steam flow to the turbine allowing output control. The TG accessories include:

- The TGSS supplies sealing steam to the turbine shaft/casing penetrations and to the valve stems of the TSVs and TCVs, TBVs, and Intermediate Stop & Intercept Valves (or Combined Intercept Valves) to prevent the escape of radioactive steam and to prevent air in-leakage through sub atmospheric turbine glands.
- The TLOS provides 100 percent of the lube oil required by the turbine and generator bearings, couplings, and turning gear during all modes of operation. The TLOS also provides jacking-oil to lift the turbine when the turbine is below the rated speed.
- The ESS provides the means to transport extraction steam from the steam turbine to the MSR, N35 first stage reheater and FWHs for regenerative feedwater heating and protect the steam turbine against overspeed and water induction conditions.
- The EHC provides high-pressure hydraulic fluid to actuate the actuators on the TSVs and TCVs, Intermediate Stop and Intercept Valves (or Combined Intercept Valves, if combined), and the TBVs. The EHC subsystem is also used to actuate the trip devices in the trip and overspeed protection circuits for the turbine.

10.3.1 System and Equipment Functions

The system and equipment functions associated with the MTE are identified below.

Normal Functions (Non-Safety Category)

The MTE performs the Non-Safety Category function of converting thermal energy from the main steam and hot reheat steam into rotational torque on a shaft connected to the main generator based on the nominal conditions.

Normal Functions (Safety Category)

The MTE performs the following Safety Category normal functions:

- Modulate position to throttle steam flow using the TCV based on signals from I&C systems
- Close the TSVs and TCVs when signaled to do so by I&C systems

Off-Normal Functions (Non-Safety Category)

This system does not perform any Non-Safety Category functions during off-normal conditions.

Off-Normal Functions (Safety Category)

This system does not perform any Safety Category functions during off-normal conditions.

10.3.2 Safety Design Bases

Chapter 3 describes the classification process for SSCs. The MTE components are DL2 SC3 on the basis of the main turbine being essential to maintaining key reactor parameters within normal ranges.

The main turbine is designed to include a corrosion allowance for materials in contact with water or steam systems.

The design of the MTE considers applicable international standards such as compliance with U.S. Nuclear Regulatory Commission (USNRC) Regulatory Guide 1.115, “Protection Against Turbine Missiles,” (Reference 10-32) which invokes compliance with 10 CFR 50 Appendix A(4), “Environmental and Dynamic Effects Design Bases,” (Reference 10-33).

The design of the MTE System meets International Atomic Energy Agency (IAEA) requirements specified in IAEA SSR2/1, Requirement 77 (Reference 10-9), as it relates to providing provisions for overspeed protection and minimisation of missiles due to a turbine break-up. Minimisation of potential missile impacts is also afforded through the favorable perpendicular orientation of the turbine to the SSC performing safety functions.

10.3.3 Description

The turbine is a 3000 rpm (for 50 Hz grid connection), single-shaft, tandem compound, impulse-reaction, condensing steam turbine. The turbine generator and associated piping, and valves, are located completely within the TB. Refer to Section 10.4 for information pertaining to the MS system interface with the turbine generator. A power cycle schematic is presented in Figure 10-8.

The main turbine is the prime mover for the generator to produce electricity. The BWRX-300 turbine is composed of one (1) HP single flow turbine coupled with two (2) double flow low pressure (LP) turbines in a tandem arrangement. The HP turbine, LP turbines, casings, turbine main stop and control valves, and associated piping to the turbine change the steam energy into rotational motion that the Generator turns into electrical energy. Stop Valves, control valves and other valves are used to control steam flow to the turbine allowing output control. Turbine control valves and turbine bypass valves together modulates the reactor pressure based on demand from the Instrumentation & Control systems. An extraction point in the HP turbine provide first stage heating steam to the Moisture Separator Reheater (MSR) and for heating the FWH. Extraction steam from the HP turbine supplies heating steam to the fourth and fifth stage FWHs. Inlet to the HP turbine is through two (2) casing connections each with a main turbine stop valve and a turbine control valve, four (4) valves in total. The reheated steam (hot reheat) from the MSR is delivered to two (2) LP turbines through two (2) reheat steam stop valve and intermediate control valve (or combined intercept valves), total four (4) valves. Two LP turbines extraction steam provide heating to FWHs 1 through 3. LP exhaust steam is directed to the condenser.

The Main Turbine is equipped with electric (single-speed, AC powered electric motor-driven) turning gear, which is used to rotate the turbine generator shafts slowly whenever the Main Turbine is not in service, and especially during startup and shutdown periods.

The system’s physical layout provides protection to essential systems and components, as required, from the effects of high and moderate energy turbine generator system piping failures or failure of the connection(s) from the low-pressure turbine exhaust hoods to the condenser due to missile protection and overspeed. Failure of turbine generator equipment is not to preclude safe shutdown of the reactor systems. The turbine generator is oriented within the TB to minimize the potential of turbine missiles damaging any equipment that provides a safety function of a classified structure. The turbine generators are orientated such that the containment and SSCs with a safety function are located outside the low trajectory missile hazard zone (see Section 10.3.3 turbine missile probability analysis for discussion of turbine missiles). The design of the TG complies with the following codes and standards:

- The piping and valves of the MTE are designed to meet the requirements of ASME B31.1. The turbine shell is designed to include attached piping loads (i.e., extraction, exhaust and drain piping) based on ASME B31.1 allowable stresses for primary plus secondary stresses.

- Extraction Steam subsystem non-return valves are located five pipe diameters downstream from flow disturbances, such as tees and elbows, and ten pipe diameters downstream from control valves, in accordance with Electric Power Research Institute (EPRI) NP-5479–- "Application Guide for Check Valves in Nuclear Power Plants," (Reference 10-34), and turbine manufacturer recommendations.
- Extraction piping, valves, drains and associated controls are designed in accordance with ASME Standard TDP-2–- "Prevention of Water Damage to Steam Turbines Used for Electric Power Generation: Nuclear-Fueled Plants," (Reference 10-35).

Material and equipment selection for the MTE components is based on a 60-year design life, with appropriate provisions for maintenance and replacement. FAC resistant materials are used for components exposed to wet steam or flashing liquid flow where significant erosion could occur. The degree of FAC resistance of the material is consistent with the temperature, moisture content and velocity of the wet steam to which the component is exposed.

The MTE is designed for an operating life based on continuous plant operation at full power for a 24-month cycle, including a refueling outage of approximately fourteen (14) days.

10.3.3.1 Turbine Gland Seal Subsystem

The TGSS supplies sealing steam to the turbine shaft/casing penetrations and to the valve stems of the TSVs, TCVs, TBVs, and Intermediate Stop and Intercept Valves (or combined intercept valves) to prevent the escape of radioactive steam and to prevent air in-leakage through sub-atmospheric turbine glands.

The system consists of one Gland Steam Condenser (GSC), two 100% GSC exhaust blowers and associated valves, pressure regulators, a steam seal header, relief valves, isolation valves, piping, instrumentation, and control.

The GSC is a shell and tube HX designed to condense the maximum leak-off steam contained within the air-steam mixture withdrawn from the HP and LP turbine gland seals and the stem leak-offs of the TSVs, TCVs, Intermediate Stop and Intercept Valves (or combined intercept valves), and TBVs. The air-steam mixture is drawn into the GSC where steam is condensed on the outside of the tubes and air and NC gases exit to the GSC exhaust blowers. The condensed steam is drained to the main condenser. Heat is rejected to the condensate flowing through the gland steam condenser tubes. The GSC is located far enough below the operating floor and forward of the main condenser so that the piping from the turbine to the condenser has a minimum pitch downward for proper drainage of the gland steam leak-off piping.

Two 100% capacity GSC exhaust blowers maintain a slight vacuum on the GSC shell to remove NC gases and seal the turbine prior to startup. NC gases are then exhausted to the TB Heating, Ventilation, and Cooling System (HVS).

The TGSS independent sources of steam are the MSLs during startup. At higher loads, steam from the pressure packings of the HP turbine is supplied to the vacuum packings of the LP turbine sections.

The MCA receives drained condensed steam from TGSS piping, the GSC, and steam traps for the GSC and GSC exhaust blowers. The MCA receives relief valve discharge from the GSC and steam seal header, as well as excess TGSS steam from the steam seal bypass dump valve.

TGSS piping is designed to meet the requirement of ASME B31.1 (Reference 10-12).

Corrosion/erosion resistant materials are used for components exposed to wet steam or flashing liquid flow where significant erosion could occur. The degree of corrosion/erosion resistance of the material is consistent with the temperature, moisture content and velocity of the wet steam to which the component is exposed.

Relief valves on the seal steam header prevent excessive seal steam pressure, which protects the system from malfunction and mis-operation. The relief valves limit the steam seal header pressure to a safe level.

10.3.3.2 Turbine Lube Oil System Description

The TLOS supplies the lube oil to the turbine, generator, and exciter bush bearings. The TLOS skid includes redundant pumps to continuously supply oil to the bearings to protect against commercial losses. The lube oil skid also contains storage tank and heat exchangers which support the TLOS. An oil conditioning system is provided with TLOS.

10.3.3.3 Extraction Steam Subsystem

The purpose of the Extraction Steam System is to provide the means to transport extraction steam from the steam turbine to the MSR first stage reheater and FW heaters for regenerative FW heating and protect the steam turbine against overspeed and water induction conditions.

Extraction steam from the HP turbine supplies heating steam to the fourth and fifth stage FWHs and the MSR first stage reheater. Extraction steam from the LP turbines provides heating steam to the first, second, and third stage FWHs.

10.3.3.4 Electro-Hydraulic Controls

The EHC subsystem provides HP hydraulic fluid to position the TSVs and TCVs, intermediate stop and intercept valves, and the TBVs. The turbine hydraulic system is also used to actuate the trip devices in the trip and overspeed protection circuits for the turbine.

The EHC system tubing and components are designed to Seismic Category Non-Seismic.

10.3.3.5 Component Descriptions

The following defines the requirements specific to the major equipment items in the MTE System.

Main Steam Turbine Stop and Control Valves

Two hydraulically operated MS turbine stop, and control valves (four valves total) admit steam to the HP turbine. The primary function of the MS TSVs is to isolate the MS from the turbine and quickly shut off the steam flow to the turbine under emergency conditions. The primary function of the control valves is to control steam flow to the turbine in response to the Turbine Generator Control System (TGCS).

The MS turbine stop, and control valves and their supports are designed such that excessive vibration cannot result from excitation caused by turbine operating harmonics and hydraulic instabilities in the valves or steam flows.

Limit switches and valve position logic indication used on these valves are based on proven experience and satisfy triple redundancy criteria. Leak tight enclosures are provided for local turbine control and test logic limit switches and field termination junction boxes. Valves which incorporate a pilot valve are designed based on proven experience.

The disks are unbalanced and cannot open against full differential pressure. A bypass is provided to pressurize the below seat areas of the two valves and supply steam for turbine casing and steam chest warming. Springs provided with the valves are designed to close the MS turbine control valves under emergency conditions.

The stop valves provide a method to allow prewarming during turbine startup.

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

The control valves are designed to provide steam shutoff adequate for turbine speed control. The valves are of sufficient size, relative to their cracking pressure, to require partial balancing.

Each control valve is hydraulically operated by HP fire-resistant hydraulic fluid supplied through a servo valve.

The turbine control valves are capable of full stroke opening and closing times with the reactor at 100% power, including load following.

The turbine control valves are designed to withstand extended periods of operation at less than full load, including load following.

The MS turbine stop, and control valves will not produce unacceptable stress or reactions on the bearings during testing. Valve testing does not result in bearing temperature alarms or vibration alarms.

The MS turbine stop, and control valves are designed to be compatible with control functions of the Steam Bypass control and Turbine Controls System.

Intermediate Stop and Intercept Valves

One hydraulically operated reheat Intermediate Stop and Intercept Valve is provided for each LP turbine. The valves are located as close to the LP turbine as required to control turbine speed and protect the turbine against overspeed from steam and water energy stored between the MS stop and control valves and the intermediate stop and intercept valves.

The reheat intermediate stop and intercept valves are designed to close rapidly to control turbine overspeed. Upon loss of load, the valves first close then throttle steam to the LP turbine as required to control speed. The valves close on a turbine trip or if the valves fail to operate properly to control overspeed. Each valve is capable of opening against full system pressure and capable of opening against a pressure differential of approximately 15 percent of the maximum expected system pressure.

The reheat intermediate stop and intercept valves and their supports are designed such that excessive vibration cannot result from excitation caused by turbine operating harmonics and hydraulic instabilities in the valves or steam flows.

Valve operating mechanisms are of a fail-safe (i.e., fail closed) design that minimises the use of complicated valve linkages and uses components that are based on proven experience.

Limit switches and valve position indication used on these valves is based on proven experience and satisfy the triple redundancy criteria. Leak tight enclosures are provided for local turbine control and test logic limit switches and field termination junction boxes. Refer to PSR Chapter 7 for information pertaining to triple redundancy.

Intermediate stop valves which incorporate a pilot valve are designed based on proven experience.

Main Turbine (High and Low Pressure)

The turbine is capable of startup from cold conditions to full load within twelve hours, including rotor preheating.

The turbine is designed to separate water from the steam and internally drain it to the next lowest extraction point.

The HP turbine receives steam through two steam leads, one from each control valve outlet. The steam is expanded axially across several stages of stationary and moving blades. Extraction steam from the HP turbine is used to supply the fifth stage of FW heating and MSR first stage reheater heating steam. HP turbine exhaust steam is collected in a cold reheat pipe and routed to the MSR inlet.

Two units of LP turbines coupled together with the HP turbine shaft convert thermal energy into mechanical rotational energy to drive the generator. Each LP turbine receives hot reheat steam from its connected MSR outlet through the intermediate stop and intercept valves. Each LP turbine is a double flow with extraction points for FW heating. Each LP turbine exhausts directly to the main condenser connected underneath each LP turbine.

Turning Gear

The main turbine is equipped with a turning gear. The primary function of the turning gear is to rotate the turbine generator shafts slowly and continuously, as needed during shutdown periods. Use of the turning gear during startup eliminates the necessity of “breaking away” the turbine generator from standstill with steam, and thereby provides a more uniform and controlled startup. The turning gear may also be used to rotate the rotor incrementally at desired intervals for inspection and also prevents rotor bowing.

Interlocks preventing turning gear operation under conditions which may cause equipment damage, such as loss of lubricating or lift oil, are included in the design of the main turbine.

The turning gear has the ability to engage and start upon zero turbine rotor speed and sufficient lube oil pressure and disengage at startup.

Extraction Steam Non-return Valves

The extraction check valves are installed in the appropriate turbine extraction lines supplying steam to FW heaters. The valves prevent backflow of steam from FW heaters to the main turbine after sudden load reductions or turbine trip. The disks of the extraction non-return valves are furnished with air operators allowing them to operate freely when the cylinders are supplied with instrument air pressure controlled by the turbine control system. Upon loss of air pressure or upon equalisation of the air pressure on both sides of the piston, the cylinder springs and associated linkage initiate and assist in closure of the valves.

Piping and Valves

The turbine system piping includes the MS connections from the MS control valves to the HP turbine steam inlet nozzles, and HP turbine and LP turbine exhaust hoods instrumentation piping.

Drain piping is provided for each turbine drain location. The drain piping is large enough to ensure an adequate flow area for the maximum amount of water to be handled under any operating condition and minimal pressure differential conditions. Continuous bleed type bypass is used in areas where water can collect during operation.

The flow area of the main turbine piping provides an acceptable steam velocity based on successful operating experience, considering expected fluid conditions (pressure, temperature, and moisture levels) and considering the specified material requirements.

The turbine system piping is designed to the requirements of American Society of Mechanical Engineers (ASME) B31.1 (Reference 10-12).

Pipe thicknesses are calculated with the appropriate erosion-corrosion allowance to preclude failure during design life.

Double isolation valves are provided, where necessary or where required by code, to facilitate online maintenance of HP/high temperature systems.

Wherever possible, long radius bends (1.5 times nominal pipe size) are used. Piping layouts that result in 90˚ elbows, miters, etc. are also minimized.

Gland Steam Condenser

The GSC is a shell and tube heat exchanger designed to condense the maximum leak-off steam as required, contained within the air-steam mixture withdrawn from the HP and LP turbine gland seals and the stem leak-offs of the TSVs, TCVs, intermediate stop and intercept valves, and TBVs as required. The air-steam mixture is drawn into the GSC where steam is condensed on the outside of the tubes and air and non-condensables exit to the GSC exhaust blowers. The condensed steam is drained through a trap to the main condenser. Heat is rejected to the condensate flowing through the GSC tubes.

The outer leak-off annulus region of the glands of the turbine are connected to the GSC.

The GSC drain piping is routed and continuously pitched downward to the main condenser. The drain piping is provided with a loop seal to isolate the GSC from the lower pressure of the main condenser. The GSC loop seal is installed with a telltale. The telltale prevents water from rising in the GSC due to a GSC tube rupture. This excludes the possibility of flooding the GSC, adversely impacting the performance of the exhaust fan and the suction line (leak-off) at the turbine gland seal. The loop seal is filled with water before the GSC exhaust blower is placed in operation. The GSC is mounted on a pedestal, or an opening provided to accommodate the loop seal below the GSC body.

The GSC is a constant flow type, which means the condenser is located in the CFS (Section 10.2.2) auxiliary condensate loop so that it is supplied with a constant amount of condensate during all operation modes. To maintain condensate flow through the GSC, the water box is supplied with a loop seal to limit the flow to the condenser during operation.

Gland Steam Condenser Exhaust Blowers

Two 100% capacity alternating current motor-driven GSC exhaust blowers maintain a slight vacuum on the GSC shell to remove non-condensable gases. The GSC exhaust blowers are centrifugal type.

Non-condensable gases are removed from the GSC and exhausted to the stack by two parallel, redundant, 100% GSC exhaust blowers. The GSC exhaust blower suction piping pitches downward away from the blower to a low point drain before entering the fan. The low point drain is drained to the main condenser and includes a trap, which prevents condensate from running back to the blower from the vent piping and prevents air from being drawn into the main condenser.

The GSC exhaust blowers have a manual butterfly valve at the inlet and a free-swing check valve in the discharge lines. The check valves prevent recirculation of air through the idle blower when the other is running.

Turbine Gland Seal Steam System Piping and Valves

The TGSS includes an air-operated pressure regulating feed valve for the TASS.

The TGSS piping is designed to have sufficient flexibility for expansion of turbine parts due to thermal growth.

A continuous orifice drain to the main condenser is located on the inlet side of the steam seal feed valve extraction, and steam seal feed valve to avoid accumulation of water at the feed valves.

The steam seal feed valve has a bypass which is located at the highest point in its pipeline.

TGSS includes an air-operated seal steam dump valve for the steam seal header. the seal steam dump valve acts as unloading valve when, at higher turbine loads, more steam is leaking from the pressure packing than is required by the vacuum packing.

The seal steam dump valve has a bypass.

The piping to the turbine shaft packing connections is run from the steam seal header piping, between the feed and dump valves. The steam seal header incorporates a minimum of one low point drain. The steam seal header is drained to the main condenser via this low point drain utilizing a continuous drain to prevent the buildup of water in the steam seal header during normal operation.

The TGSS includes test connections to permit performance testing.

Turbine Lube Oil System

The TLOS provides 100% of the oil required by the turbine generator bearings during turning gear, startup, shutdown, normal, and emergency operating conditions. Sufficient flow margin is provided to account for anticipated off design operating conditions and wear.

The TLOS contains lube oil primary and secondary pumps, an emergency Direct Current (DC) powered pump, a lube oil heat exchanger, and a lube oil conditioner system that removes water and impurities from the oil.

A full-flow filtration system downstream is provided to meet the filtration requirements. The system is provided with the capability for cleaning the filters while online without interrupting oil flow by switching from one cooler/filter assembly to the other.

To minimize corrosion due to moisture contamination, a lube oil conditioner system with water removal capability is provided.

TLOS oil coolers and heaters maintain supply oil temperature within operating limits. A high temperature alarm functions during all design operating conditions.

In the event that the Primary and Secondary Alternating Current (AC) Bearing Oil Pumps are inoperative due to AC power loss, or a turbine trip due to loss of lube oil pressure, the DC motor-driven Emergency Bearing Oil Pump is sufficiently sized and automatically starts to ensure the lube oil is supplied to the bearings continuously during rotor coast down to prevent damage. Manual controls for this pump are also provided.

Primary and Secondary Lift Oil Pumps are provided for the turbine and generator bearings for turning gear operation as required.

The top of the Lube Oil Reservoir is provided with gravity-closed doors with seals to prevent contamination.

A means for removal of water from the lube oil at the end of an outage is provided to prevent water contamination.

Provisions for the flushing of the Lube Oil Reservoir, supply lines, and return lines is provided to ensure acceptable contaminant levels for operation.

Provisions for heating the lube oil during flushing are provided on the Temporary Flushing Skid.

The Secondary Lube Oil Vapor Extractor is powered from a different bus than the Primary Lube Oil Vapor Extractor.

Provisions for obtaining representative samples of lube oil are included to ensure requisite quality is maintained.

Lube Oil Pumps

TLOS Primary and Secondary AC Bearing Oil Pump capacities are identical and are sufficient to maintain oil pressure and adequately lubricate the shaft bearing, and turning gear during startup, shutdown, and normal operation.

In the event of either pump failure or maintenance, pumps can be used interchangeably for supplying the TLOS during all modes of operation. The discharge of the Primary and Secondary AC Bearing Oil Pumps enters the Lube Oil Coolers first, then through the full-flow filters, and then is supplied to the bearing header. The Primary and Secondary AC Bearing Oil Pumps are self-venting to prevent air from becoming trapped in the piping.

The DC Emergency Bearing Oil Pump is a DC motor-driven pump that prevents the loss of bearing oil flow by providing emergency backup upon loss of AC power.

Primary and Secondary Lift Pumps are AC motor driven, positive displacement pumps that supply lube oil to the rotor bearings when the turbine is on turning gear.

The Secondary AC Bearing Oil Pump motor is powered from a different bus than the Primary AC Bearing Oil Pump motor.

The power to the Primary and Secondary AC Bearing Oil Pumps is independent and different from that used to control and power the DC Emergency Bearing Oil Pump. This ensures that a failure of a single power source does not affect both the Primary and Secondary AC Bearing Oil Pumps and the DC Emergency Bearing Oil Pump.

The AC and DC motor-driven oil pumps are continuously vented to remove entrained air, and the vent line is of sufficient size to prevent plugging.

Lube Oil Reservoir Skid

The Lube Oil Reservoir Skid contains a reservoir with sufficient capacity to contain all oil required by the system for normal operation, turbine trip and to provide submergence of the pumps located in the reservoir. The capacity of the reservoir results in considerable oil above the pump inlets and a low recirculation rate with positive time for air detrainment.

The Lube Oil Reservoir Skid is located below the turbine operating floor so that all oil drains back to the reservoir by gravity.

Lube Oil Filters

The filtration system consists of two 100% capacity in-line full-flow duplex filters. Contamination or plugging of the filter element in-service requires the backup filter element be manually brought into service. Connected to the filters, an oil vent with orifice to continuously drain lube oil back to the reservoir is provided.

Turbine Lube Oil System Piping and Valves

TLOS supply and drain piping is comprised of all welded construction to the maximum extent possible to eliminate possible leakage pathways such as threaded and flange connections.

Pressurized oil lines in the vicinity of hot parts of the turbine are enclosed in a guard line to the maximum extent possible. The guard lines are designed such that in the event of a ruptured pressure line, the pressurized oil drains into the guarding pipe and returns to the reservoir. Pressurized oil lines not in the vicinity of hot parts of the turbine are not required to be enclosed in guarding lines.

TLOS piping downstream of the full-flow filters are corrosion resistant stainless steel, to prevent contamination of lube oil due to pipe corrosion.

With the Lube Oil Vapor Extractor maintaining a negative pressure in the Lube Oil Reservoir, this arrangement assists in holding a slight negative pressure within all drain enclosures, thereby, preventing oil and vapor leakage from drain piping.

A separate vent for TLOS is provided. Location of the vent is such as to prevent accidental contact of discharge vapors and gases with fire or sparks. The vent is located away from air intakes for facilities or equipment. TLOS vent is provided with a high efficiency mist eliminator and dual vapor extractors, packaged in a single unit mounted on top of the tank.

A Cooler/Filter Selector Valve is used to switch flow from one oil cooler/filter to the standby combination. The Cooler/Filter Selector Valve assembly allows for full volume flow while switching to the alternate cooler/filter.

The Bearing Pressure Regulator Valve self-regulates the bearing header pressure. This valve has an external orifice which provides minimum necessary oil flow when the valve is not in-service. Adjustments and maintenance are performed through an access cover in the tank top.

The Vapor Extractor Inlet Valve is a manual valve that regulates the amount of vacuum created in the tank by the Vapor Extractor. This valve is accessible from the top of the reservoir.

Oil drain lines pitch downward toward the Lube Oil Reservoir.

Extraction Steam System Piping and Valves

FAC resistant materials are used for all components exposed to wet steam or flashing liquid flow where significant erosion could occur. The degree of FAC resistance of the material is consistent with the temperature, moisture content and velocity of the wet steam to which the component is exposed.

Extraction drains consist of a drain pot or orifice and a drain line.

Extraction motor-operated isolation valves are provided to prevent water induction into the turbine. The extraction isolation valves are designed to permit a partial closure functional test during plant operation without inadvertent complete closure of the valve.

The extraction air-assisted non-return valves limit contributions to turbine overspeed from steam and water in the extraction lines and FW heaters in the event of a turbine generator trip signal. The air-assisted non-return check valve air pistons go through full stroke in the closing direction within two seconds of tripping the air relay dump valve.

Non-return valves are located five pipe diameters downstream from flow disturbances, such as tees and elbows, and ten pipe diameters downstream from control valves, in accordance with EPRI-NP-5479 (Reference 10-34).

The Extraction Steam System, where required, has a motor-operated isolation valve and an air-assisted non-return valve located in extraction line from the turbine to the FW heaters to prevent water induction backflow and overspeed of the turbine.

The design of the extraction piping, valves, drains and associated controls are in accordance with ASME TDP-2 (Reference 10-35).

A drain is located at each low point in the extraction steam piping system where water may collect during startup, shutdown, or normal operation. For extraction lines with isolation valves located at an elevation higher than its associated FW heater, the extraction piping between the isolation valve and the FW heater is sloped to eliminate possible low points.

Electro-Hydraulic Control System

The EHC system consists of hydraulic fluid, Hydraulic Power Unit (HPU), Trip Manifold Assembly (TMA), Fluid Actuator Supply tubing, Fluid Actuator Drain tubing, Emergency Trip System tubing, and associated tubing, valves, and instrumentation.

The HPU consists of a fluid reservoir, redundant pumping systems, fluid coolers, accumulators, space heaters, air dryer, and a fluid transfer and filtering unit (transfer and Fuller's earth filtration unit). The transfer and Fuller's earth filtration unit consists of a transfer pump, Fuller's earth filters, backup filter, and associated valves. The HPU Fluid Actuator Supply for the TSVs, TCVs, and intermediate stop and intercept valves is capable of isolation from the fluid actuator supply for the TBVs. The HPU is located at a low elevation. The HPU is located such that all hydraulic Fluid Actuator Drain lines pitch downward.

The TMA consists of two parallel triple redundant circuits (Circuits A and B). Each TMA circuit consists of three Electronic Trip Device solenoid valves. The TMA also includes (total for both circuits) six pairs of isolation valves, a continuous-flow transfer valve assembly, and two air relay dump valves. The TMA is located on the HPU skid.

The EHC system includes in-line full-flow filters for the control of the particulate contaminates in supply lines to ensure 100% of the hydraulic fluid is filtered. Parallel filters and valving are provided to allow cleaning of a filter without interrupting fluid flow while online.

The HPU coolers are water-cooled shell and tube heat exchangers.

The EHC system includes means for the control of hydraulic fluid chemistry and removal of moisture from the hydraulic fluid to prevent corrosion of the system which contaminates the fluid. Provisions for sampling the hydraulic fluid is provided to enable the verification of chemistry and moisture content.

The EHC system design includes redundant instrumentation with a coincident logic trip system to improve system reliability by reducing false and spurious trips.

Each trip initiating signal from the EHC system is monitored to identify the source of the trip signal.

The EHC system provides an independent and redundant backup electrical overspeed trip circuit, to quickly close the TSVs, TCVs, intermediate stop and intercept valves, to quickly shut down the turbine in the event of an unsafe condition. The EHC system is designed to minimize false and spurious trips during normal operation and testing of the trip system.

The EHC system is provided with redundancies such that a failure or malfunction of a single component or power source does not result in an unsafe overspeed or trip actuation of the turbine.

The EHC system includes provisions for online testing of trip devices to verify the system is operable and will function correctly.

The EHC system supports the hydraulic controllers for the TSVs, TCVs, intermediate stop and intercept valves, and TBVs that close or open the valves (as applicable) sufficiently after receipt of a trip signal to preclude an unsafe turbine overspeed. The response of the controllers takes into account the residual steam in the piping between the valves and the turbine.

The EHC includes turbine trip indication devices for an electric solenoid trip.

Hydraulic Power Unit

The major components of the HPU include a fluid reservoir, two independent and parallel pumping systems, fluid coolers, bladder accumulators, electric space heater, air dryer-breather, and a built-in fluid transfer and filtering unit.

The drain for the HPU is manually connected to drums to drain the reservoir.

The HPU supplies HP hydraulic fluid directly to the control solenoid on the TSVs, TCVs, intermediate stop and intercept valves, and TBVs for actuator control, and to the trip devices in the TMA. The unit can accommodate both steady-state and transient requirements.

The fluid is supplied to all components at the correct temperature and required cleanliness. The unit is equipped with chemically active filters to maintain the properties of the fluid over long service times. The two completely redundant pumping systems allow online maintenance of the standby pumping system. The HPU has alarms and pressure transmitters which auto start the standby pumping system. The EHC trips the turbine should a malfunction occur where the EHC cannot maintain and/or develop adequate pressure.

The reservoir has sufficient capacity to hold all of the hydraulic fluid for the turbine hydraulic system.

The reservoir is fabricated out of stainless steel.

The reservoir includes a cover plate to provide access to the reservoir for cleaning and inspection.

The reservoir includes internal baffling to allow any entrapped air in the return fluid adequate time to detrain before passing into the pump suction line and to separate the hot drain fluid from the rest of the fluid.

The reservoir contains a float type level gauge and level transmitter that determines the correct reservoir fluid level. This level transmitter incorporates low-low/low/high level switches that alarm.

The reservoir includes a temperature element that alarms for high and low fluid temperature.

A pressure compensator on each pump maintains a preset pressure throughout the delivery range i.e., as system demand changes, the pump automatically adjusts its stroke to meet the flow demand while maintaining system pressure.

If the pump dead heads, the pump is automatically shut off.

A wire mesh suction strainer is installed in the pump intake. The suction strainer provides a visual condition indicator during operation, showing suction status.

A full-flow HP filter is installed on the outlet of the pump. The full-flow HP filter includes an electric differential pressure switch that will alarm when the differential pressure has reached the maximum set point, indicating that the element requires changing.

Pumping discharge tubing includes relief valves that discharge the pump output back into the reservoir if pump pressure exceeds the setting of the valves.

Pump discharge tubing includes an automatic air bleed valve that discharges into the reservoir.

Two 100% capacity fluid-to-water shell and tube heat exchangers are provided to cool the fluid returning to the reservoir from the valve actuators and trip devices. One fluid cooler is used while the other is on standby.

Bladder type accumulators are connected to the hydraulic header in the supply manifold to provide an immediately available reserve of fluid for transient flow requirements.

Isolation valves in the tubing permit accumulators to be serviced while the HPU is in operation. The valves also permit checking of the pre-charge pressure by isolating an accumulator group and bleeding its fluid contents to drain.

Two redundant electric space heater units are included on the HPU.

The space heater units keep the fluid in the reservoir, accumulators, and tubing of the standby system warm during cold weather operation.

The space heaters are operated automatically by a thermostatic control in the HPU. The control senses temperature in the fluid reservoir and keeps the heaters on whenever the fluid temperature is below the low temperature set point.

An air dryer removes moisture from the air breathed by the fluid reservoir during HPU operation.

A built-in, dual operating-mode transfer and Fuller's earth filtration unit consists of a motor-driven transfer pump, relief valves, a filling and discharge hose, Fuller's earth filters, and a backup filter.

The reservoir is filled and drained by the transfer and Fuller's earth filtration unit.

The transfer filtering operation mode is used to filter the hydraulic fluid to a low particle size and contaminant level while the reservoir is being filled or drained. For this operation, fluid is passed through the Fuller's earth filters and the backup filter to the reservoir.

The Fuller's earth filtering operation mode maintains the fluid at a low neutralisation number by absorbing acids and water and maintaining the chlorine content of the fluid within the recommended specifications. During the filtering operation, fluid from the reservoir flows through the Fuller's earth cartridges in filter housings through the backup filter and then back to the reservoir. The Fuller's earth filtering system is in operation during the Turbine Hydraulics system flush, and then kept in continuous operation when the turbine is in-service. For extended maintenance outages, the Fuller's earth filtering system is operated to maintain fluid operating conditions.

Trip Manifold Assembly

The TMA is designed as the final control element of the TGCS emergency overspeed protection system. The TMA consists of a duplex (parallel) arrangement of two triple redundant Electronic Trip Device solenoid valve circuits, Circuits 'A' and 'B', configured as a single integrated hydraulic circuit. The design is optimized for normal turbine generator operation with both circuits in-service but is capable of operating with one circuit isolated for online maintenance. Refer to PSR Chapter 7 for information pertaining to triple redundancy.

Each TMA circuit includes three Electronic Trip Device valve assemblies, which are arranged hydraulically for two-out-of-three voting. The three pairs of isolation valves per circuit are arranged in a normally closed two-out-of-three voting circuit separating the Fluid Actuator Supply fluid supply from the Emergency Trip System header. Each two-out-of-three hydraulic circuit arrangement results in three parallel flow paths, each path passing through two valves in series. Trip and reset valve position transducers are provided for indication, fault annunciation, and test permissives for online test sequencing.

The TMA has a continuous-flow transfer valve assembly allowing for pressure isolation of either Electronic Trip Device circuit to permit online service.

The Electronic Trip Device solenoid valves direct Emergency Trip System fluid pilot pressure to the air relay dump valves, dump valves, and shut-off valves.

Electro-Hydraulic Control Valves and Tubing

Electronic Trip Device solenoid valves are arranged for two-out-of-three voting logic in the TMA. The Electronic Trip Device solenoids are controlled by TGCS and by the diverse overspeed trip system. When the TMA is in normal operation with the Electronic Trip Devices energized, the Emergency Trip System fluid flows to pilot the air relay dump valves, flow through the fast-acting solenoid valves, hold the dump valves closed with the Emergency Trip System fluid pressure, and flow to pilot the shut-off valves to allow fluid actuator supply fluid to flow either to the applicable solenoid operated test valves or the servo valves.

The fast-acting solenoid valves, solenoid operated test valves, servo valves, dump valves, and shut-off valves are located with their associated actuators on the TSV, TCV, intermediate stop and intercept valves, and TBV.

Emergency trip system header dump valves are pilot operated with customized spools to maintain two separate and isolated flow paths. The dump valves are held closed by the Emergency Trip System fluid pressure. The dump valves have a spring bias to rapid close the TSVs, TCVs, intermediate stop and intercept valves with the release of the Emergency Trip System fluid pressure.

Air relay dump valves are Emergency Trip System fluid pilot-operated valves and used to establish the Emergency Trip Air System pressure in order to operate the extraction system nonreturn check valves. Actuation of the air relay dump valves causes the non- return valves air cylinders to be vented, allowing the non-return valves to close thereby preventing turbine overspeed.

Fluid actuator supply header isolation valves are two-way pilot-operated unbalanced logic cartridge valves arranged in pairs to simulate a single four-way valve. Each valve pair is piloted by a single Electronic Trip Device.

Emergency Trip System header shut-off valves are Emergency Trip System fluid pilot-operated with separate and isolated flow paths to admit the applicable fluid actuator supply fluid supply to the solenoid operated test valves or the servo valves for TSV, TCV, and intermediate stop and intercept valve actuation.

The transfer valve assembly consists of continuous-flow inlet and discharge valves that are used to hydraulically isolate either hydraulic Circuit A or B during normal operation without interruption of the fluid supply to the Emergency Trip System header.

Turbine hydraulic system tubing is designed to the requirements of ASME B31.1 (Reference 10-12).

The design of the hydraulic lines is fail-safe, meaning that loss of hydraulic pressure results in a turbine trip. All hydraulic tubing is constructed of stainless steel. HP hydraulic tubing is installed with welded connections where possible to reduce the potential for leaks. The tubing is supported in such a manner as to prevent vibration yet provide adequate flexibility to permit movement of end connections to valves. Where tubing passes through clearance holes in the floor or walls, the tubing is located such that the maximum tubing motion due to expansion does not result in interference between the tubing and the side of the clearance hole. All vent lines are routed such that air flow is not blocked by fluid pockets.

10.3.3.6 Turbine Overspeed Protection

The normal speed control system comprises a first line of defence against turbine overspeed. The valve arrangements and closure times are such that a failure of any single valve to close does not result in unsafe turbine overspeed in case of a trip signal. An increase in speed above the setpoint closes the TCVs and intermediate stop and intercept valves (or combined intercept valves) in proportion to the speed increase.

The normal speed control system is designed to limit peak overspeed resulting from a loss of full load to at least 1% below the overspeed trip setpoint. Typically, this peak speed is in a range of 106-109% of rated speed, with the overspeed trip setpoint at 110% of rated speed.

In addition to the normal speed control function provided by the TGCS, a separate and redundant, highly reliable turbine overspeed protection system is included to minimize the possibility of turbine rotor failure and turbine missile generation. If the normal speed control fails, the overspeed trip devices close the steam admission valves, including the TSVs and intermediate stop valves, to ensure that turbine speed does not exceed 120% of rated speed. The logic uses two diverse and independent systems to provide sufficient reliability to eliminate the risk of turbine missile generation and to avoid the need for a mechanical overspeed trip.

The failure of any single component does not cause the rotor speed to exceed the emergency overspeed. The overspeed sensing devices are in the turbine front bearing standard and are therefore protected from the effects of missiles or pipe breakage. The hydraulic units are fail-safe, loss of hydraulic pressure results in a turbine trip. The TSVs and TCVs provide full redundancy in that these valves are in series and have independent control signals and operating mechanisms. Closure of both TSVs or both TCVs effectively shuts off all main steam flow to the HP turbine. The intermediate stop and intercept valves are in series and have independent control signals and operating mechanisms. This arrangement is such that failure of a single valve to close does not result in a maximum speed exceeding 120% of the rated speed.

10.3.4 Turbine Rotor Integrity

Materials Selection

The failure of a turbine disk or rotor could produce a high-energy missile. Turbine rotor integrity is provided through the combined use of selected materials with suitable toughness, analyses, testing, inspections, and operating procedures. Turbine rotor material will be forged or welded rotor and be made from a material and by a process that tends to minimize flaw occurrence and maximize fracture toughness properties, such as a NiCrMoV alloy processed by vacuum melting or vacuum degassing. Chemicals such as sulfur and phosphorus are to be controlled to low levels.

The minimum requirements for fracture toughness, high temperature properties and turbine design to be met by the turbine vendor are specified below:

- Turbine material is suitable for the pressure, temperature, moisture, and environmental condition it is subjected to for all operating conditions
- Turbine casing material is suitable for the operating parameters it is subjected to. Casing material is designed for damage mechanisms such as creep, thermal fatigue, interaction of creep-fatigue, embrittlement, and FAC
- Turbine blade material is designed for erosion/corrosion protection. Methods of protection can include induction hardening, flame hardening, shot peening, or coating, as applicable to the operating conditions of the blade
- Turbine rotor material is forged or welded and made from a material and by a process that minimises flaw occurrence and maximises fracture toughness properties.
- For low pressure turbine, a Charpy test performed to American Society for Testing and Materials (ASTM) A-370 for the 50% fracture appearance transition temperature (FATT) shall be not higher than -180C (0F). In lieu of FATT, nil-ductility transition (NDT) temperature by means of ASTM E-208 is an alternative. NDT temperatures shall be no higher than -350C (-300F).Each LP turbine rotor is tested using the Charpy V-notch at the minimum operating temperature in the tangential direction. The Charpy V-notch energy is at least 60 ft-lbs.

- The ratio of the fracture toughness of the LP turbine rotor material to the maximum tangential stress, at speeds ranging from normal to design overspeed, is to be at least 2√in, at minimum operating temperature

Turbine Missile Probability Analysis

Refer to PSR Chapter 15, Section 15.6.1 (Internal & external events and Level 1 PSA) which presents the methodology for determining the probability of turbine generated missiles and associated results.

10.3.5 Interfaces with Other Equipment or Systems

Refer to Table 10-7 for system interfaces.

10.3.6 System and Equipment Operation

Normal Operation

During normal operation, the MS TSVs and intermediate stop and intercept valves are fully open, with control valves modulating as required to maintain reactor pressure. Specifically, in normal operation, the RPC sends a flow demand signal to the turbine generator controller that changes a flow demand signal into a turbine control valve position demand signal. Because strong negative void coefficient of the Boiling Water Reactor (BWR), the control scheme in normal power operation cannot be “boiler follows turbine,” since opening the control valves would lower reactor pressure and increase voiding which lowers reactor power and opposing the desired change. Instead, the design is “turbine follows boiler.” Reactor power is first changed, and the turbine control valves open or close, appropriately increasing or decreasing load.

Operation of the turbine generator is controlled by the TGCS. The reactor pressure controller controls the turbine control valves through the TGCS to regulate reactor pressure. The normal function of the TGCS is to generate the position demand signals for the main stop valves, main control valves, and the intermediate stop and intercept valves.

The Primary AC Bearing Oil Pump automatically supplies the turbine generator bearings and turning gear, if needed, with lube oil at the required pressure and temperature. If the Primary AC Bearing Oil Pump should fail, then the Secondary AC Bearing Oil Pump automatically supplies the system with lube oil.

During all operating modes, the lube oil is purified and conditioned by the integrally mounted lube oil conditioner. Lube oil is continuously circulated to the reservoir by a jockey pump that is located on the lube oil conditioner and drained back to the reservoir by gravity.

During Extraction Steam System normal operation, heating steam is transported to the FWHs and the MSR first stage reheaters. Both the motor-operated isolation valves and air-assisted non-return valves are open. Drain line valves are open and close as a function of the level of condensed steam in the drain pot.

Extraction Steam System normal operation also includes isolating heaters:

1. LP FW Heaters Isolated: The LP FW heater is isolated when a high-high level setpoint is detected by the level transmitters in any of the three stages of LP FW heaters. This isolation protects the turbine from water induction. High-high level FW isolation results in the following actions:
    a. The air-assisted non-return valve is released to close in the extraction line of the effected FW Heater No. 3.
    b. The remaining first and second stage extraction lines remain in normal operation.

   c. The drain valve in the drain line upstream of the air-assisted non-return valve are signalled open.

2. HP FW Heaters isolated: HP FW Heaters No. 4 and No. 5 are individually isolated when a high-high level setpoint is detected by their associated level transmitters. This trip protects the turbine from water induction. High-high level FW heater isolation results in the following actions:

   a. The extraction isolation valves close, and the air-assisted non-return valve are released to close in the extraction lines to the effected FW Heaters No. 4 and No. 5. The sixth stage FW heater does not contain an air-operated non-return valve.

   b. The drain valves in the drain lines upstream of the extraction isolation valves are signalled open.

During normal operation, one pump from the EHC Pump Unit is sufficient to supply the Fluid Actuator Supply fluid for the HP hydraulic system. The pumps have a capacity of 100% duty each. The standby pump provides a reliable backup should the operating pump fail to provide the necessary pressure. Pressurized fluid from the HPU is pumped to the servo valves on the TCVs, intercept valves, and TBVs; the solenoid operated test valves on the TSVs and intermediate stop valves; and to the EHC.

During EHC normal operation, all Electronic Trip Devices are energized open, all shut-off valves are open, and all dump valves are held closed by the Emergency Trip System fluid, enabling the pressurisation of the turbine EHC header. Also, during EHC normal operation, the air relay dump valves are reset to establish the Emergency Trip Air System pressure, which assists the extraction system non-return check valves in fast closure. The EHC system is able to support testing for the fast closure of the TSVs, TCVs, and the intermediate stop and intercept valves and fast opening of the TBVs. The EHC system has the ability to test the TMA when the turbine is online.

Normal and Emergency Shutdowns

In the event of an unsafe operating condition, the TGCS controls initiate trip signals to the turbine. The TGCS provides automatic and manual controls to unload the unit during controlled shutdowns.

The main turbine stop and control valves, and intermediate stop and intercept valves close upon actuation of the Emergency Trip System within a time period to preclude unsafe turbine overspeed.

In the event of a turbine trip with the closure of TSVs and TCVs, TASS provides sealing steam to the turbine until main condenser vacuum break. However, in the event of a turbine trip with a closure of the MSRIVs and/or MSCIV, the main condenser vacuum will break on loss of off-gas steam, but the condenser vacuum pumps will be automatically started.

During a plant shutdown, the Primary or Secondary AC Bearing Oil Pump and the Primary or Secondary Lift Pump supply lube oil to the turbine generator bearings, couplings, and turning gear until the turbine speed is zero. The Primary or Secondary Lift Pump automatically start when the main turbine rotor speed decreases to near the point of an oil wedge breakdown.

During shutdown, the Extraction Steam System motor-operated isolation valves and air-assisted non-return valves are closed. Extraction line drain valves are open during shutdown. The shutdown of the system is carried out with the shutdown of the plant. The condensate produced during shutdown is drained to the condenser.

A turbine trip signal automatically isolates the shell side of FW Heaters No. 4 and No. 5 by closing the motor-operated isolation valves. The air-assisted non-return valves in heaters No. 3, No. 4, and No. 5 extractions are to be released to close. The drain line valves are open.

The turning gear also operates during shutdown as long as the turbine is not under maintenance. During turning gear operation, the Primary Lift Pump supplies lube oil to the turbine generator rotor to reduce the turning gear torque requirements when the turbine is not in operation. If the Primary Lift Pump should fail, then the Secondary Lift Pump supplies oil to the bearings.

During a turbine trip, the HPU continues to supply Fluid Actuator Supply fluid to the servo valves on the TBVs to keep them open to discharge steam to the main condenser.

During shutdown, the HPU continues to supply hydraulic fluid to the TSVs, TCVs, intermediate stop and intercept valves and TBVs for actuation.

Off-Normal Operational Concept

Turbine Overspeed Protection System

The following component redundancies are employed to provide turbine overspeed protection:

- Main stop valves/control valves
- Intermediate Stop and Intercept Valves
- Normal speed control/Primary overspeed trip/Emergency overspeed trip
- Fast-acting solenoid valves/emergency trip fluid system

In addition to the normal speed control function provided by the TGCS, a separate and redundant turbine overspeed protection system is included to minimize the possibility of turbine rotor failure and turbine missile damage. Additionally, the valve arrangements and closure times are such that a failure of any single valve to close will not result in unsafe turbine overspeed in the event of a trip signal.

The normal speed control system comprises a first line of defence against turbine overspeed. This system includes the MS control valves, intermediate stop and intercept valves, and fast-acting valve-closing functions within the TGCS. An increase in speed above the setpoint results in the closure of the main turbine control valves and intermediate stop and intercept valves in proportion to the speed increase. Rapid turbine acceleration resulting from a sudden loss of load at higher power levels normally initiates the fast-acting solenoids via the normal speed control system. The fast-acting solenoids rapidly close the main turbine control and intermediate stop and intercept valves irrespective of the current turbine speed.

The normal speed control system is designed to limit peak overspeed resulting from a loss of full load, to at least 1% below the overspeed trip set point. Typically, this peak speed is in a range of 106-109% of rated speed, with the overspeed trip set point at 110% of rated speed. All turbine steam control valves and intermediate stop and intercept valves are fully testable during normal operation. The fast-closing feature, provided by action of the fast-acting solenoids, is testable during normal operation.

If the normal speed control should fail, the overspeed trip devices close the steam admission valves including the main and intermediate stop valves. This turbine overspeed protection system comprises the second line of defence against turbine overspeed (redundant and highly reliable). The overspeed protection system is designed to ensure that failure of the normal speed control system does not result in turbine speed exceeding 120% of rated speed. In addition, the components and circuits comprising the turbine overspeed protection system are testable when the turbine is in operation.

The failure of any single component does not cause the rotor speed to exceed the emergency overspeed.

The overspeed sensing devices are located in the turbine front bearing standard and are therefore protected from the effects of missiles or pipe breakage.

The hydraulic units are fail-safe, any loss of hydraulic pressure results in a turbine trip.

The main stop valves and control valves provide full redundancy in that these valves are in series and have independent control signals and operating mechanisms. Closure of both or either stop valves or control valves effectively shuts off all MS flow to the HP turbine. The intermediate stop and intercept valves are also in series and have independent control signals and operating mechanisms. Closure of either valve or both valves in each of the two intermediate stop and intercept valves effectively shuts off steam flow to the two LP turbines. This arrangement is such that failure of a single valve to close does not result in a maximum speed exceeding 120% of rated speed. The turbine is designed for a 120% overspeed.

Turbine Lube Oil System Off-Normal Operation

The DC Emergency Bearing Oil Pump starts automatically and provides the lube oil required by the turbine generator in the event that the Primary and Secondary AC Bearing Oil Pumps are inoperative or in a loss of AC power. A controlled shutdown is initiated in the event that the DC Emergency Bearing Oil Pump is the only operable pump supplying lube oil, as failure of this pump will result in loss of oil to the bearings during coast down.

10.3.7 Instrumentation and Control

This section describes the instrumentation associated with the MTE. Instrumentation is provided for monitoring of thermal and hydraulic parameters and initiating alarms and automatic shutdown of the turbine in the event of an unsafe condition.

Main Turbine Equipment

The main turbine contains instrumentation to:

- Monitor and control system operations
- Alarm abnormal system operation

Turbine generator supervisory instrumentation is provided for operational analysis and malfunction diagnosis.

The turbine contains Turbine Supervisory Instrumentation which monitors the following parameters:

- Vibration and eccentricity
- Thrust bearing wear
- Exhaust hood temperature
- Bearing metal temperatures
- Shell temperature
- Valve positions
- Shell and rotor differential expansion
- Shaft speed, and control valve inlet pressure indication
- Steam chest pressure

Turbine Gland Seal System

TGSS Main Control Room alarms are to include, but are not limited to, the following:

- High GSC blower suction pressure
- Low steam seal header pressure
- High GSC discharge radiation
- High and low steam source temperature and pressure
- High and low GSC level

A pressure indicator and transmitter is provided for the GSC exhaust blower suction pressure. Temperature indicators and transmitters are provided for the following:

- Steam seal header temperature
- GSC exhaust blowers suction temperature

A level indicator and level transmitter is provided for the GSC.

Turbine Lube Oil System

The following primary TLOS displays are to include, but are not limited to, the following:

- Primary AC Bearing Oil Pump status
- Secondary AC Bearing Oil Pump status
- DC Emergency Bearing Oil Pump status
- Primary Lift Oil Pump status
- Secondary Lift Oil Pump status
- Lube Oil Transfer Pump status
- Main bearing oil header pressure
- Lube Oil Cooler oil discharge temperature
- Vapor Extractor status
- Lube oil tank level and duplex filter differential pressure

Temperature elements are provided for the following:

- Lube Oil Reservoir immersion heater control

Temperature elements and transmitters are provided to indicate the following:

- Cooler outlet oil temperature
- Lube Oil Reservoir temperature
- Main Turbine bearing drain oil temperature (typical for all bearings including the Thrust Bearing)

Level transmitters are provided for the following:

- Lube Oil Reservoir level

Level gauges and transmitters are provided for the following:

- Lube Oil Storage Tank clean compartment

- Lube Oil Storage Tank dirty compartment
- Lube Oil Reservoir
- Lube Oil Conditioner water drain level

Flow gauges and transmitters are provided for the following:

- Lube Oil cooler ‘A’ oil vent flow
- Lube Oil cooler ‘B’ oil vent flow
- Lube Oil filter ‘A’ vent flow
- Lube Oil filter ‘B’ vent flow
- Bearing drain oil flow
- Lube Oil Conditioner drain water flow

Extraction Steam System

The ESS is operated and monitored from the Main Control Room (MCR) N-DCIS. ESS controls and interlocks for the main components are described below:

- The LP extraction line motor-operated block valve located in the FWH No. 3 extraction lines is used for Turbine Water Induction Protection (TWIP). It is to be normally open and is to be controlled from the MCR. The LP extraction motor- operated block valve is automatically close if the turbine trips or upon receipt of an isolation signal from any level transmitter associated with the LP FWH. The valve is to Fail-As-Is (FAI).
- The HP extraction line motor-operated block valve is used for TWIP. It is normally open and controlled from the MCR. The HP extraction motor- operated block valve is automatically close if the turbine trips, upon receipt of an isolation signal from the level transmitters associated with the effected HP FWH, or the condensate isolation valves to the FWH are not 100% open. The valve is to FAI.
- Each air-operated level-controlled drainpipe block valve is normally closed. They are to open automatically if the extraction isolation valve is not open, upon a high-high drain level signal, upon a turbine trip, or a low turbine load. The valves are to Fail Open (FO).
- The air-assisted non-return check valves is used to prevent turbine overspeed. The valves are controlled by the TGCS and when a turbine trip is detected, the valve is to close. The air-assisted non-return check valves are released to close when a high-high level signal is received from the Heater Drain and Vent System (HDVS) via the N-DCIS isolation signal. The valves are to Fail Close (FC)

ESS displays and alarms are to include, but are not limited to:

- MCR displays
- Motor-operated valve position
- Air-assisted check valve position
- Air-operated drain valve position

MCR alarms:

- Low pressure in the extraction line
- Extraction isolation valves not 100% open

- High level in the extraction drain level line

Electro-Hydraulic Control

The EHC system is to provide a signal to maintain water flow through HPU coolers based on hydraulic fluid outlet temperature.

HPU Main Pumps automatic pump control:

- The HPU Main Pumps are arranged in parallel with only one pump operating at a time
- If the operating pump fails, a drop in hydraulic fluid pressure is to provide a signal to automatically start the standby pump

When the TMA system receives a signal from TGCS on a loss of pressurized fluid, the Turbine Hydraulic system is to:

- Trip the turbine by releasing the ETS fluid pressure below each Dump Valve at the TSV, TCV, and Intermediate Stop and Intercept Valve (or CIV, if combined) control pacs
- Trip the pilot operated ARDVs to allow for fast closure of the Extraction System non-return valves

The Main Control Room displays are to include, but are not limited to, the following:

- HPU Main Pumps operating parameters, including discharge pressure, operating mode, and status
- HPU Main Pumps motor operating parameters, including current and electrical equipment status
- Hydraulic header pressure
- Hydraulic fluid reservoir temperature and reservoir level
- Filters differential pressures

The Main Control Room alarms are to include, but are not limited to, the following:

- Low hydraulic fluid header pressure
- Low HPU fluid reservoir temperature
- High HPU fluid reservoir temperature
- Low HPU fluid reservoir level
- Low-low HPU fluid reservoir level
- High HPU fluid reservoir level
- High HPU full-flow filter differential pressure

Main Turbine Equipment

The following turbine system conditions are alarmed in the MCR:

- Loss of speed signal
- High thrust bearing wear
- Excessive rotor/shell/differential expansion
- High exhaust hood temperature

- High condenser pressure
- Overspeed
- High vibration
- High bearing temperature
- Zero rotor speed
- High rotor eccentricity
- Power Load Unbalance

The turbine stop and control valves and the intermediate stop and intercept valves close to trip the turbine on the following signals:

- Emergency trip push buttons in control room
- High moisture separator level
- High condenser pressure
- Low lube oil pressure
- High LP turbine exhaust hood temperature
- High reactor water level
- Excessive thrust bearing wear
- Overspeed (Primary and Emergency trip systems)
- Manual trip from the front standard
- Loss of stator coolant
- Low hydraulic fluid pressure
- Any generator trip
- Loss of TGCS electrical power
- Excessive turbine shaft vibration
- Loss of two speed probes – both within the primary set, or within the emergency set
- Loss of two pressure control channels
- MSIV Close Trip Signal from SC3 DCIS

Turbine Gland Seal System

TGSS MCR Alarms include the following:

- High GSC blower suction pressure
- Low steam seal header pressure
- High GSC discharge radiation
- High and low steam source temperature and pressure
- High and low GSC level

TGSS MCR displays include the following:

- Status of blowers
- Status of all steam feed valves
- Status of all steam feed isolation valves
- Steam seal header pressure and temperature
- Pressure and temperature of steam sources
- GSC blowers suction pressure

The following paragraphs describe key control features of the turbine system.

The turning gear is provided with manual and automatic controls. When in automatic control, the turning gear engages and starts upon zero turbine rotor speed and sufficient lube oil pressure and disengages at startup.

During low load operations, the air-operated pressure control steam seal feed valve provides steam seal header pressure control using steam taken from the TASS. The TASS comes off of the MSL equalizing header which is upstream of the TSV/TCV. This valve fails open on loss of signal or air. The steam seal feed valve feed steam to packing heads to seal the turbine by up to 50% and 100% rated throttle pressure operating conditions. The steam seal feed valve can also operate with 100% rated throttle pressure during a full-load rejection. The steam seal feed valve has the ability to reduce the TASS source pressure by throttling.

At light loads and startup, the seal steam dump valve is closed, and the steam seal feed valve regulates the steam seal header pressure. A manually controlled isolation valve is located upstream of steam seal feed valve.

Steam is supplied by the air-operated pressure control Steam Seal Auxiliary Feed Valve. A manually controlled, air-operated valve is located downstream for auxiliary steam isolation.

The valves are arranged for fail-safe operation to protect the turbine. The feed valves fail open on the loss of either signal or supply air, and the seal steam dump valve closes with diaphragm failure. If, for any reason the automatic valves are out of order, control of the steam seal header pressure is achieved by operation of the bypass.

One GSC blower is operating whenever the TGSS is in-service with the other in standby. The standby blower automatically starts on trip of the lead blower.

The blower automatically stops on detection of blower discharge high radiation level and its associated damper is to auto close.

Turbine Lube Oil System

TLOS provides a signal to control cooling water through the Lube Oil Coolers based on lube oil outlet temperature.

Primary and Secondary AC Bearing Oil Pumps automatic pump control:

1. The Primary and Secondary AC Bearing Oil Pumps are arranged in parallel with only one pump operating at a time.
2. Should the operating pump fail, the standby pump automatically starts due to low discharge oil pressure.

DC Emergency Bearing Oil Pump automatic pump control:

1. Should both the Primary and Secondary AC Bearing Oil Pumps fail, the DC Emergency Bearing Oil Pump automatically starts upon low oil pressure.
2. The DC Emergency Bearing Oil Pump automatically starts upon loss of all AC power.

TLOS design includes the ability to test the LP standby start functions of the Primary and Secondary AC Bearing Oil Pumps, and DC Emergency Bearing Oil Pump. The design also includes the ability to test the trip function of the Lift Pumps.

The following primary TLOS displays include the following:

- Primary AC Bearing Oil Pump status
- Secondary AC Bearing Oil Pump status
- DC Emergency Bearing Oil Pump status
- Primary Lift Oil Pump status
- Secondary Lift Oil Pump status
- Lube Oil Transfer Pump status
- Main bearing oil header pressure
- Lube Oil Cooler oil discharge temperature
- Vapor Extractor status

MCR Alarms include the following:

- Low bearing header oil pressure
- Low-low bearing oil pressure (turbine trip)
- Low Lube Oil Reservoir temperature
- High Lube Oil Reservoir temperature
- Low Lube Oil Reservoir level
- Low-low Lube Oil Reservoir level
- High Lube Oil Reservoir level
- High full-flow duplex filter A/B differential pressure
- Low Primary or Secondary Lift Pump discharge pressure
- High bearing oil drain temperature
- Lube Oil Cooler high discharge oil temperature
- Any Lube Oil pump auto start
- Trip of any TLOS pump

Extraction Steam System

The Extraction Steam System is operated and monitored from the MCR. Extraction Steam System controls and interlocks for the main components are described below:

- The LP extraction line motor-operated block valve located in FW Heater No. 3 extraction line is used for Turbine Water Induction Protection. It is normally open and controlled from the MCR. The LP extraction motor-operated block valve is automatically closed if the turbine trips or upon receipt of an isolation signal from any level transmitter associated with the LP FW heater. The valve is fails-as-is.
- The HP extraction line motor-operated block valve is used for Turbine Water Induction Protection. It is normally open and controlled from the MCR. The HP extraction motor

operated block valve is automatically closed if the turbine trips, upon receipt of an isolation signal from the level transmitters associated with the effected HP FW heater, or the condensate isolation valves to the FW heater are not 100% open. The valve is fails-as-is.

- Each air-operated level-controlled drain-pipe block valve is normally closed. They open automatically if the extraction isolation valve is not open, upon a high-high drain level signal, upon a turbine trip, or a low turbine load. The valves fail open.
- The air-assisted non-return check valves are used to prevent turbine overspeed. The valves are controlled by the TGCS and when a turbine trip is detected, the valve closes. The air-assisted non-return check valves are released to close when a high-high level signal is received. These valves fail close.

Extraction Steam System displays, and alarms include, but are not limited to:

- MCR displays
- Measurements from all instruments described in Section 10.1.7
- Motor-operated valve position
- Air-assisted check valve position
- Air-operated drain valve position
- FW heaters turbine water induction prevention valves in test

MCR Alarms

- LP in the extraction line
- Extraction isolation valves not 100% open
- High level in the extraction drain level line

Electro-Hydraulic Control

The EHC system provides a signal to maintain water flow through the HPU coolers based on hydraulic fluid outlet temperature.

HPU Main Pumps automatic pump control:

- The HPU Main Pumps are arranged in parallel with only one pump operating at a time
- If the operating pump fails, a drop in hydraulic fluid pressure provides a signal to automatically start the standby pump

When the TMA system receives a signal from TGCS on a loss of pressurized fluid, the turbine hydraulic system:

- Trips the turbine by releasing the Emergency Trip System fluid pressure below each Dump Valve at the TSV, TCV, and Intermediate Stop and Intercept Valve control solenoid
- Trips the pilot-operated air relay dump valves to allow for fast closure of the extraction system non- return valves

The MCR displays include, but are not limited to, the following:

- HPU Main Pumps operating parameters, including discharge pressure, operating mode, and status

- HPU Main Pumps motor operating parameters, including current and electrical equipment status
- Hydraulic header pressure
- Hydraulic fluid reservoir temperature
- Filters differential pressures

The MCR Alarms include, but are not limited to, the following:

- Low hydraulic fluid header pressure
- Low HPU fluid reservoir temperature
- High HPU fluid reservoir temperature
- Low HPU fluid reservoir level
- Low-low HPU fluid reservoir level
- High HPU fluid reservoir level
- High HPU full-flow filter differential pressure

10.3.8 Monitoring, Inspection, Testing, and Maintenance

Turbine Water Induction Prevention valve testing for FWHs is performed as required.

Component level inspections consist of visual, surface, and volumetric examination as discussed below:

- Visual, magnetic particle, and ultrasonic examination of all accessible surfaces of rotors
- Visual and magnetic particle or liquid penetrant examination of all turbine blades
- Visual and magnetic particle examination of couplings and coupling bolts

The ISI of valves important for avoiding overspeed includes the following:

- The MS TSVs and control valves, and intermediate stop and intercept valves are tested under load. Test controls installed on the MCR panel permit full stroking of the stop valves, control valves and intermediate stop and intercept valves. Valve position indication is provided on the panel. Testing considers all resulting impacts, including level disturbances in the FW heaters due to fluctuating extraction pressures.
- MS turbine stop and control valves, and intermediate stop and intercept valves are exercised at least once within each calendar quarter (or as required by the turbine missile probability analysis) by closing each valve and observing the remote valve position indicator for fully closed position status. This test also verifies operation of the fast-close function of each MS turbine stop and control valve and intermediate stop and intercept valves during the last few percent of valve stem travel. Fast closure of the intermediate stop and intercept valves is tested in a similar way if they are required to have a fast-close function different from the test exercise. This testing frequency complies with the Boiling Water Reactor Owners Group (BWROG) turbine surveillance test program.
- Tightness tests of the MS turbine stop and control valves are performed at least once per maintenance cycle by checking the coast down characteristics of the

turbine from no load with each set of two valves closed alternately or using warm-up steam as an indicator with the valves closed.

- All MS TSVs, control valves, and intermediate stop and intercept valves are disassembled and visually inspected once during the first three refueling or extended maintenance shutdowns. Subsequent inspections are scheduled in accordance with the BWROG turbine surveillance test program. The inspections are conducted for:
  - Visual and surface inspections of valve seats, disks and stems including:
    - Wear of linkages and stem packings
    - Erosion of valve seats and stems
    - Deposits on stems and other valve parts which could interfere with valve operation
    - Distortions, misalignment, or cracks
  - Inspection and cleaning of valve bushings
  - Confirmation of bore diameters for proper clearance

Routine testing of the TLOS is conducted in accordance with normal power plant requirements for demonstrating system and component operability and integrity. Routine testing includes tests of the AC pumps and Emergency DC pump.

Routine testing of the EHC is conducted in accordance with normal power plant requirements for demonstrating system and component operability and integrity. The EHC is tested while the turbine is online to verify the system functions properly.

10.3.9 Radiological Aspects

PSR Chapter 12, Section 12.3.1 (Facility layout general design considerations for maintaining radiation exposures ALARP) provides information pertaining to measures taken to ensure that occupational exposures arising from the operation or maintenance of the equipment or system are ALARP in operational states.

PSR Chapter 12, Section 12.2 describes the radioactive source terms in the BWRX-300 TB. The main potential source of airborne radioactivity within the TB is leakage from valves on large lines carrying HP steam. Noble gas airborne concentrations are expected to be negligible throughout the TB except for inside the SJAE cubicles. These areas are not normally occupied during operation, and the exhaust from these cubicles is exhausted to the environment after filtration to eliminate the possibility of contamination of adjoining areas.

As stated in PSR Chapter 11, Section 11.5.5 (Main turbine equipment) the PREMS provides radiation monitoring for the Main Turbine Gland Seal Steam Condenser Exhaust flow path (via the Process Radiation Monitor subsystem) and general monitoring in the TB (via the Area Radiation Monitoring subsystem).

10.3.10 Performance and Safety Evaluation

The turbine generator is not needed to affect or support a safe shutdown of the reactor. The turbine is designed, constructed, and inspected to minimize the possibility of any major component failure. The turbine has a redundant, diverse, and testable overspeed trip system to minimize the possibility of a turbine overspeed event.

Instruments, controls, and protective devices are provided to confirm reliable and safe operation. Redundant, fast actuating controls are installed to prevent damage resulting from overspeed and/or full-load rejection. The control system initiates a turbine trip upon reactor trip.

The turbine generator equipment shielding requirements and the methods of access control for required areas of the TB ensure that the dose limits for operating personnel are not exceeded. All areas in proximity to TG equipment are zoned according to expected occupancy times and radiation levels anticipated under normal operating conditions.

The MTE’s physical layout provides protection to essential systems and components, as required, from the effects of high and moderate energy turbine generator system piping failures or failure of the connections(s) from the LP turbine exhaust hoods to the condenser due to missile protection and overspeed. Failure of turbine generator equipment does not preclude safe shutdown of the reactor systems.

10.4 Turbine and Condenser Systems

10.4.1 Main Condenser

The following information is consistent with 006N7757 "Main Condenser and Auxiliaries System SDD," (Reference 10-38). The MCA System (Reference 10-38) is the heat sink for the power generation and normal reactor cooldown and plant startup activities. The MCA System consists of the main condenser, two SJAE skids (one in service and one in a standby condition), and one condenser vacuum pump skids as well as associated piping, valves, instrumentation, and controls. The main condenser consists of two shells located beneath the low-pressure turbines which drains to cross-connected hotwells.

10.4.1.1 System and Equipment Functions

The MCA performs the function listed below during normal and off-normal conditions.

Normal Functions (Non-Safety Category)

The MCA provides the following Non-Safety Category functions during normal conditions:

1. The MCA System provides a main condenser with interfaces to other systems as needed to condense steam exhaust from the main turbine and main turbine bypass. Removes dissolved gases from the condensate during reactor startup.
2. The main condenser includes a reservoir (hotwell) in which the condensate is collected as a suction source for the condensate pumps.
3. The main condenser collects equipment drains, vents, and relief valve discharges from other plant equipment.
4. The condenser vacuum pump draws a vacuum and remove non-condensable gases from the condenser shell during startup.

Normal Functions (Safety Category)

The MCA provides the following Safety Category functions during normal conditions:

1. The MCA provides the capability to measure main condenser vacuum (pressure).
2. The MCA provides a heat sink to condense steam exhausted from the main turbine or vented from other sources .
3. Maintain the concentration of non-condensable gases in the main condenser within an acceptable range for all conditions of plant operation .
4. The MCA provides a reservoir of condensed steam or condensate drained from other sources to allow for redistribution of water for other plant systems with a sufficient volume to provide a hold up time allowing for the decay or radioactivity to reduce dose to plant personnel.

Off-Normal Functions (Non-Safety Category)

The system does not perform any Non-Safety Category functions during off-normal conditions.

Off-Normal Functions (Safety Category)

The system does not perform any Safety Category functions during off-normal conditions.

10.4.1.2 Safety Design Bases

The MCA System components support and act as make-ready and supporting function to other safety classified components that perform fundamental safety functions. Components and piping associated with measuring condenser vacuum pressure monitoring are classified as SC2. Components and piping associated with maintaining the condenser pressure boundary that allow the following functions to be maintained: heat sink to condense reactor steam or accept drainage from the feedwater (FW) heaters and other steam supply users; draw a vacuum and remove non-condensable gases from the condenser shell; and provide a condensate supply to the condensate pump suction are classified as SC3.

Non-safety classified components and their related piping are those that are not directly associated with any SC3 function.

Codes and standards related to pressure boundary are identified in the component descriptions in Section 10.4.1.3 (Component Description) as applicable. MCA System equipment is categorised as Non-Seismic.

The MCA is not required to operate during or after a design basis event. The design of the MCA meets IAEA requirements specified in SSR-2/1 Requirement 7 (Reference 10-9) as it relates to design for Defence-in-Depth and SSG-30 (Reference 10-10) as it relates to classification of SSC.

10.4.1.3 Description

Figure 10-9 depicts the MCA system. The main condenser is a single-pressure, two-shell, unit. Each shell is located beneath its respective LP turbine. The two condenser shells operate at the same pressures and drain to hotwells that are cross connected. Circulating water flows through each of the two single-pass tube bundles to condense the turbine exhaust steam into the hotwells. The main condenser receives and condenses turbine exhaust steam and turbine bypass steam during all modes of operation. The main condenser provides hold-up for N16 decay, and supplies condensate to the condensate pumps. The main condenser also serves as a collection point for other steam cycle miscellaneous drains, vents, and relief valve discharges.

Two 100% capacity SJAEs are used to maintain the turbine backpressure and remove NC gases from the main condenser. Non-condensable gases extracted from the condenser are exhausted to the Off-gas System.

During startup, the condenser vacuum pump draws the initial condenser vacuum and exhaust the gases to the TB Heating, Ventilation, and Air Conditioning System (PSR Chapter 9A, Section 9A.5.4). Refer to PSR Chapter 3, Section 3.9 for information pertaining to equipment qualification of BWRX-300 SSC.

Component Description

The following paragraphs provides information that pertains to the major MCA components.

Main Condenser

The main condenser is located in the TB. The main condenser has two shells each mounted beneath and connected to a LP turbine by an expansion joint. The condenser is designed in accordance with the Heat Exchange Institute Standard for Steam Surface Condensers.

Vacuum breaker(s) are provided to break the vacuum and maintain atmospheric pressure within the condenser during shutdown. Connections are provided on each condenser shell to allow for the removal of air and other non-condensable gases.

The main condenser provides connections for the condensate pump minimum recirculation flow lines. The condenser hotwell receives makeup water from the CST. Excess water volume in the condenser hotwell is drawn off by the condensate pumps and transferred to the CST. The hotwells of the two condenser shells are interconnected. The condensate pumps take suction from one of the hotwells.

Corrosion resistant alloys are used for condenser components exposed to steam or condensate where particularly severe duty is expected. The condenser tubes and their tubesheets are titanium or low-cobalt stainless steel alloys which are compatible with the water chemistry.

Connections are provided to allow draining and cleaning of the condenser hotwell during plant shutdown. The shielded area and controlled access for the main condenser is provided to protect personnel from radiation.

LP turbine exhaust steam, turbine bypass steam, and other miscellaneous power cycle drains, and vents are routed to the main condenser.

Condenser Vacuum Pump

One 100% capacity vacuum pump is used as a rapid evacuator, to remove the air from the condenser shells and associated turbine, creating the initial vacuum which allows the startup of the turbine unit.

A check valve at the outlet of the condenser vacuum pump prevents reverse flow to protect the condenser vacuum when the condenser vacuum pump stops.

Steam Jet Air Ejectors

The SJAEs are sized in accordance with the "Venting Equipment Capacity" of Heat Exchange Institute's “Standards for Steam Surface Condensers,” (Reference 10-39). Additionally, radiolytic oxygen and hydrogen entrained in the main condenser is removed by SJAEs.

The SJAEs function by using MS through the Turbine Auxiliary Steam System. The motive steam that condenses in the steam jet air ejector intercondenser flows through the loop seal to the condenser. The second stage air ejector is non-condensing. The air ejectors provide adequate motive force for the Off-gas System (PSR Chapter 11, Section 11.4).

The steam supply to the second stage SJAEs ensures adequate dilution of hydrogen (less than 4% by volume) and prevent the non-condensable gases from reaching the flammable limit of hydrogen.

Piping and Valves

Any sections of pipe that may carry potentially explosive mixtures of hydrogen and oxygen are designed to contain the explosion. All other piping is designed in accordance with ASME B31.1 (Reference 10-12). Valves exposed to higher hydrogen/oxygen mixture have bellows stem seals, double stem seals, or equivalent.

10.4.1.4 Materials

Material and process control requirements for the BWRX-300 components ensure the reliability of plant operations through its design life by minimising irradiation of the plant components, corrodents and mitigating the degradation of materials specifically from corrosion through material chemistry, heat treatment, contamination, and material processes controls.

10.4.1.5 Interfaces with Other Equipment or Systems

Refer to Table 10-8 for system interfaces.

10.4.1.6 System and Equipment Operation

The MCA is designed to operate during all modes of normal power plant operation and startup. The general operating logic for each of the operating modes is provided.

Normal Operational Concept

Normal Startup

The main condenser hotwell is filled from the CST, if drained, to the normal water level by automatic control of the normal and emergency makeup valves.

Prior to placing the condenser vacuum pump in operation, the seal water separator is filled to the normal level and cooling water is flowing through the tube side of the seal water heat exchanger.

The condenser vacuum pump is started to evacuate air from the condenser before the TGSS is placed into operation and the expansion joint seal water trough has been filled, if provided. The condenser vacuum pump shuts off automatically if abnormal levels of radioactivity are detected in the MSL and/or TB vent stack. Refer to Section 10.3.2 for information pertaining to TGSS.

Upon establishing a sufficient initial vacuum in the condenser, the condenser vacuum pump remain in-service and hold the partial vacuum until motive steam is available for use by an SJAE skid. Steam flows from the RCS through the TASS to the SJAE.

Prior to placing an SJAE skid into operation, condensate is flowing through the tube side of the associated SJAE intercondenser.

The CWS is in operation prior to admitting any high energy fluids into the main condenser. Refer to Section 10.4.5 for information related to the CWS.

The condenser hotwell and its level control system are designed to accommodate the reactor vessel inventory shrink and swell associated with pressurisation/de-pressurisation during normal startups and shutdowns.

The main condenser acts as a heat sink in the initial phase of reactor cooldown during a normal plant shutdown. Condenser vacuum breaker(s) are opened, slowing the turbine during shutdown.

Normal Operation

The main condenser condenses the LP turbine exhaust steam, stores condensate, acts as a condensate surge volume, and supplies condensate to the condensate pumps. The main condenser also accepts vents and drains discharge from various points in the cycle.

SJAE units removes air in-leakage and radiolytic gases from the condenser shells, and in conjunction with the CWS, maintains a vacuum in the condenser shells.

Off-Normal Operational Concept

Transient Operation

The main condenser hotwell acts as surge volume in the following events:

1. Tube failure of FW heaters, SJAE intercondensers, MSRs, and other miscellaneous heat exchangers
2. High-water level in the FW heaters and reheater drain tanks
3. Relief valve discharge for system overpressure protection

The condenser accepts steam and drains from various points in the turbine cycle, including those that require steam dumps during turbine generator load rejection. The condenser hotwell receives overboard flow from SDC via CUW (described in PSR Chapter 9, Section 9A.2.3) during reactor heat up. The CUW can overboard to the LWM (PSR Chapter 11, Section 11.2) or MCA depending on radiation monitoring. The primary flow path is to MCA with the option for diverting to LWM.

Load Rejection

The main condenser accepts up to 25% rated steam flow via the TBS (PSR Chapter 10, Section 10.4.3) in the event of a turbine trip or load reject. There is enough condensate stored in the hotwell to allow operation of the condensate pump(s) during this transient.

High Condenser Backpressure

The pressure in the condenser may rise during normal operation due to low circulating water flow, high circulating water temperature, or high condenser duty. In any case, as condenser pressure increases above normal levels, an alarm annunciates. A further increase in pressure to the turbine trip limit results in a turbine trip. As pressure increases further beyond an established condenser limit, the turbine steam bypass valves are inhibited from opening and if open, they close to prevent over-pressurisation of the condenser shell. If the pressure continues to increase, the MSCIVs close.

The SJAE skid on standby may be brought online if a high absolute pressure exists in the condenser.

Loss-of-Offsite Power

The main condenser accommodates the turbine bypass flow for at least six seconds following a trip of the circulating water pumps due to a loss of preferred power without exceeding the TBV isolation pressure setpoint in the condenser.

10.4.1.7 Instrumentation and Control

The MCA provides the instrumentation to control and monitor (indicate and alarm) system operation. Package (skid) instrumentation is provided to verify vacuum pumps and steam jet air ejector performance in addition to normal operation and control. Instrumentation is included and installed to provide an accurate plant heat balance.

Instrumentation

Major system parameters, i.e., hotwell levels; and process flow rate, pressures, and temperatures are indicated and alarmed as required to provide operational information and performance assessment.

Controls

The MCA is operated and controlled from the MCR. Major system control functions, i.e., hotwell level, SJAE performance, and valve positioning logics, are based on system operating parameters.

10.4.1.8 Monitoring, Inspection, Testing and Maintenance

The equipment and components of the MCA are designed for easy inspection and maintenance with the intent to reduce or eliminate radiation exposure potential. Routine testing of the MCA is conducted in accordance with normal power plant requirements for demonstrating system and component operability and integrity.

10.4.1.9 Radiological Aspects

PSR Chapter 12, Section 12.1.1 (Approach to ALARP) and Section 12.3. (Design Features for Radiation Protection) provide information pertaining to measures taken to ensure that occupational exposures arising from the operation or maintenance of the equipment or system are ALARP in operational states and in accident or post-accident conditions.

10.4.1.10 Performance and Safety Evaluation

The MCA is capable of performing its Safety Category normal functions as presented in Section 10.4.1. The MCA does not perform any Safety Category off-normal functions.

The MCA is capable of measuring main condenser vacuum (pressure) to meet Safety Category 2 and Safety Category 3 requirements. The system also provides a heat sink, removes non-condensable gases from the condenser shell and supplies condensate to meet Safety Category 3 requirements listed in Section 10.4.1.

10.4.2 Moisture Separator Reheater

The following information is consistent with 006N7745, “Moisture Separator Reheater System SDD,” (Reference 10-40). The MSR (Reference 10-40) is composed of one moisture separator reheater, three drain tanks and the piping from the HP turbine exhaust (cold reheat) to the MSR, from the MSR to LP turbines (hot reheat) inlet, piping up to the intermediate stop valves and intercept valves as well as piping and valves from MSL equalising header for 2nd stage reheating. The MSR has one stage of moisture separation and two stages of reheating.

10.4.2.1 System and Equipment Functions

The MSR System performs the following functions during normal and off-normal conditions.

Normal Functions (Non-Safety Category)

The MSR System does not provide any Non-Safety Category functions during normal conditions.

Normal Functions (Safety Category)

The MSR System provides the following Safety Category functions during normal conditions:

1. The MSR System provides heating to the steam exhaust from the high-pressure turbine prior to it being supplied to the low-pressure turbines
2. The MSR System provides hot condensate for FW heating
3. The MSR System provides indication of Moisture Separator Reheater Drain Tank water level

Off-Normal Functions (Non-Safety Category)

The MSR System does not provide any Non-Safety Category functions during off-normal conditions.

Off-Normal Functions (Safety Category)

The MSR System does not provide any Safety Category functions during off-normal conditions.

10.4.2.2 Safety Design Bases

MSR components are primarily SC3 and are categorised as Non-Seismic. The remaining components are SCN. The MSR System routes steam exhaust from the high-pressure turbine through the MSR prior to it being supplied to the low-pressure turbines as a Safety Category 3 function.

10.4.2.3 Description

Figure 10-10 depicts the MSR. The MSR is located in the TB. The MSR reheats the HP turbine exhaust and then directs the reheated steam into the LP turbine. The purpose of this system is to dry and reheat the expanded steam from the HP turbine exhaust (cold reheat steam) to improve the cycle efficiency and reduce liquid impingement erosion and FAC in the LP turbines.

The MSR is protected by a pressure relief valve that ensure that it is not over-pressurised under the most adverse operating conditions associated with the turbine generator operations. The relief valve is located on the shell of the MSR with an outlet discharging to the condenser.

Steam from the HP turbine exhaust (cold reheat steam) enters the bottom of the MSR where steam separators remove entrained moisture before passing the steam to the reheater sections. Heating steam to the first stage of reheat in the MSR is supplied by the Extraction Steam Subsystem. Refer to Section 10.3.2 for additional information pertaining to the Extraction Steam Subsystem. The second stage reheating steam to the MSR is supplied by the MS subsystem (Section 10.1). Hot reheat steam is supplied to the two LP turbines through the reheat intermediate stop and intercept valves, which are located upstream of the LP turbines inlet nozzles.

Removed moisture is drained to the drain tank. Steam condensed from the reheater stages of the MSR is also drained to drain tanks.

Provisions are made to evacuate and purge all reheater tube bundles prior to pressurisation to minimise distortion when heating steam is admitted to the tube bundle.

Drains are provided at the low points in the cold and hot reheat piping. These drains are placed as close to the turbine as possible and are designed in accordance with ASTM TDP-2 standard (Reference 10-35). Two valves are provided in series in each drain line. The upstream valve is air-operated (fail open). This drain valve is located as close as possible to the drain pot to minimise the amount of water trapped upstream from the closed valve. The second valve is manually operated.

A power operated non-return valve and control valve is installed in the supply piping to the first stage reheater.

A control valve is installed in the supply piping to the second stage reheater tube bundle. A control valve is installed upstream of this valve and a manual valve downstream. Piping containing a control valve is installed to bypass the control valve station.

Refer to PSR Chapter 3, Section 3.9 for information pertaining to equipment qualification of BWRX-300 SSC.

Component Description

The following paragraphs describe the major components of the MSR.

Moisture Separator Reheaters

The MSR has one stage of moisture separation and two stages of reheating.

The MSR has cylindrical, horizontal, combined moisture separator shells with steam separators and closed U-tube reheater tube bundles. Steam separators are made of stainless steel and are adequately supported to resist aerodynamic, fluid elastic or any other type of vibration. Analyses supported by testing is performed to ensure good flow distribution to the inlet face of the moisture separator to maximise effectiveness and to eliminate the possibility of structural damage from locally high steam velocities.

The MSR is designed in accordance with ASME BPVC, Section VIII, Division 1, (Reference 10-20) Unfired Pressure Vessels, and Thermal Exchanger Manufacturers Association Standards.

The reheater tube supports are designed and spaced to prevent wear or damage due to aerodynamic, fluid elastic or any other type of vibration of the reheater tubing.

Layup provisions which are appropriate for the MSR materials are provided. Tube side layup is performed with treated water, nitrogen, or dry clean air according to paragraph 304 of ASME

NQA-1 "Quality Assurance Requirements for Nuclear Facility Applications," (Reference 10-41). Shell side layup is performed with treated water or dry clean air.

The MSR is protected by a pressure relief valve to prevent over-pressurisation.

The relief valve is located on the shell of the MSR with outlets discharging to the condenser.

MSR Drain Tanks

The MSR includes three drain tanks; one for the moisture separation stage, one for the first stage of reheat, and one for the second stage of reheat.

The drain tanks are designed in accordance with ASME BPVC, Section VIII, Division 1. Moisture separators drain tank piping is designed to handle two-phase flow.

Piping and Valves

MSR piping is designed to the requirements of ASME B31.1 (Reference 10-12).

A power operated non-return valve and control valve is located in the supply piping to first stage reheater tube bundle for isolation purposes.

An air-operated control valve is located in the MS supply piping to each second stage reheater tube bundle to modulate the steam flow. A control valve is located upstream of this valve and a manual valve is located downstream for isolation purposes. Piping containing a control valve is provided to bypass the control valve in the event it is unavailable.

Steam shutoff, and control valves have both automatic and manual control to regulate the second stage reheater temperature. Manual control includes the capability to manually open and close the shut-off valve and position the control valve.

Drains

Each moisture separator and reheater tube bundle has its own separate drain system.

Moisture separator drains are sized for self-venting gravity downflow into the moisture separator drain tanks to allow the system to vent properly during plant operating conditions. In addition, a separate vent is taken from above the water level in each drain tank back to the moisture separator to avoid any possibility of lock-up during plant operating conditions.

Vents

Venting and/or other arrangements are provided to ensure the continuous removal of non-condensable gases from the reheater tube bundle and also ensure the steady removal of condensate from the reheater tubes with minimum subcooling. Thermal-hydraulic instabilities in the reheater tube bundle is minimized to such an extent no short or long-term operational or reliability problems occur. Vent piping has no low points and is sloped to ensure adequate drainage.

10.4.2.4 Materials

Material and equipment selection for the MSR is based on the range of normal environmental conditions that may exist at the location of the system equipment and components.

The effects of FAC should be considered when selecting the piping material. The degree of FAC resistance of the material is consistent with the temperature, moisture content and velocity of the wet steam to which the component is exposed.

10.4.2.5 Interfaces with Other Equipment or Systems

Refer to Table 10-9 for MSR interfaces.

10.4.2.6 System and Equipment Operation

The MSR is designed to operate during modes of normal power plant operation, including startup and shutdown. The general operating logic for each of the operating modes is provided below.

Normal Operational Concept

System Startup

During startup, the main turbine stop and control valves, first stage reheater isolation valve, and second stage reheater control valve are closed. As the main turbine stop and control valves begin to open allowing steam to be admitted to the turbine, cold reheat steam enters the MSR. The first stage reheater isolation valve is opened allowing HP extraction steam to enter the first stage reheater. The second stage reheater control valve is slowly opened to increase the hot reheat temperature until the second stage reheater control valve is fully open.

Normal Operation

The MSR receives steam from the HP turbine exhaust. Moisture is removed and the steam is reheated for use in the LP turbine. HP turbine extraction steam is directed through open isolation valves to the first stage reheater.

MS is directed through open control valves to the second stage reheater. The second stage heating medium is HP steam supplied by the MS subsystem as discussed in Section 10.4.2.3. This steam supply is regulated by flow control valves to control the temperature of the steam at the outlet of the MSRs.

Off-Normal Operational Concept

Turbine Trip

Upon a turbine trip, the first stage reheater isolation valve and the second stage reheater control valve should close. Hot reheat steam is isolated by closing the reheat steam stop and intermediate control valves (or combined intercept valves, if combined). Hot reheat drain lines should open to drain condensate from the steam lines. The MSR is isolated, and condensate is drained from the MSR.

Turbine Shutdown

The main turbine stop, and control valves remain open and the MSR continues to receive cold reheat steam from the HP exhaust and supply hot reheat steam to the LP turbine until the main turbine falls below the manufacturer’s specified kW output. At this point, the main turbine stop and control valves, the first stage reheater isolation valves, and the second stage reheater control valves are closed.

10.4.2.7 Instrumentation and Control

The MSR loop contains sufficient instrumentation to:

- Monitor and maintain appropriate heating steam flow for proper reheater operation
- Monitor and operate all drain pot drain valves
- Verify reheater heat transfer quality
- Initiate turbine trip upon two-out-of-three coincident logic for high water level in the moisture separator section of the moisture separator reheater (TWIP requirement)
- Provide necessary status indication of key valves and annunciation of abnormal conditions during operation

Instrumentation

The instrument features of the MSR System are as follows:

- The moisture separator section will be equipped with triple redundant level instruments mounted on cross connected independently valved bridles. The instruments initiate turbine trip based on high moisture separator water level.
- The hot reheat (MSR steam to LP turbines) steam piping will be equipped with pressure instrumentation and triple redundant temperature instrumentation.
- The steam supply piping to the reheaters will also be equipped with pressure and temperature instrumentation
- The MSR will be equipped with differential pressure transmitters to measure the pressure drop across the MSR

The MSR includes the sensors recommended in ASME PTC 12.4.

Refer to PSR Chapter 7 for information pertaining to triple redundancy.

Control

Key control features of the MSR are included below. Manual initiation and shutdown of the System is provided from the MCR.

Cold reheat drain valves manually open and close from the MCR. The cold reheat drain valves are fail open valves that auto open when level instruments in their respective drain pots give a high or high-high level signal, turbine trip, load rejection, or drain group open signal and auto close on drain group close signal.

Hot reheat drain pot air-operated drain valves manually open and close from the MCR. The hot reheat drain valves are fail open valves that auto open when level instruments in their respective drain pots give a high or high-high level signal and auto close on drain group close signal.

The control valve in the supply piping to the first stage reheater tube bundle automatically and manually opens and closes from the MCR. No temperature control is carried out for first stage heating steam. Flow rate and steam conditions are dependent upon the heat and mass balance of the HP turbine.

The control valve located in the MS supply piping to the second stage reheater tube bundle automatically and manually opens and closes from the MCR and is designed to fail closed. The NBS control valve upstream of the MSR control valve is designed to open manually from the MCR.

The following primary MSR displays, and alarms are provided:

- Main Control Console Displays:
  - Heating steam flow, pressure, and temperature
  - Reheat steam pressure and temperature
  - Valve positions
  - MSR Shell and all drain tank levels
- MCR Alarms:
  - Drain pot high or high-high level
  - High level in the moisture separator section

10.4.2.8 Monitoring, Inspection, Testing, and Maintenance

Tube leak detection is performed by monitoring the tube side of the 1st stage and 2nd stage reheaters. The steam supply piping to the reheaters is equipped with pressure and temperature instrumentation. Leaks are also identified by monitoring the level control valve position from the MSR Shell Side drain tank. Higher than normal level control valve position indicates increased flow from the tube side drains which should be evaluated for potential tube leakage. Routine testing includes inspection for liquid impingement erosion and heat exchanger tube integrity inspections per applicable codes and standards. The equipment and components of the MSR are designed for easy inspection and maintenance during shutdown/refueling.

The MSR is directly accessible by the TB crane. Lift capability and space is provided to permit removal and replacement of an entire MSR as well as tube bundles without requiring the removal of any other major component or large size piping.

Tube bundle replacement does not require removal of permanent walls, major piping, or cables trays. Adequate space is provided for laydown of replacement MSR tube bundles and associated equipment. MSR tube bundle pull fixtures are specifically designed for each location.

Flow restriction orifices are located to allow ease of access for replacement.

10.4.2.9 Radiological Aspects

PSR Chapter 12, Sections 12.1.1 (Approach to ALARP) and 12.3. (Design Features for Radiation Protection) provide information pertaining to measures taken to ensure that occupational exposures arising from the operation or maintenance of the equipment or system are ALARP in operational states and in accident or post-accident conditions.

10.4.2.10 Performance and Safety Evaluation

The MSR is designed to operate during modes of normal power plant operation, including startup and shutdown.

The Safety Category functions associated with the MSR provide:

- A route for hot condensate from the MSR to FW heating to the steam exhaust from the high-pressure turbine prior to it being supplied to the low-pressure turbines
- An alternative drain path from the MSR drain tanks to the condenser
- Indication of MSR Drain Tank water level

10.4.3 Turbine Auxiliary Systems

The following information is consistent with 006N7749, “Turbine Bypass System SDD,” (Reference 10-42). This section describes the Turbine Bypass System (TBS) (Reference 10-42). The TBS takes excess steam from the NBS or Main Steam System (PSR Chapter 5), expands the steam to lower pressure, then uses spargers to deliver the steam to the condenser (Section 10.4.1).

10.4.3.1 System and Equipment Functions

Normal Functions (Non-Safety Category)

The TBS does not perform any Non-Safety Category functions during normal conditions.

Normal Functions (Safety Category)

The TBS performs the following Safety Category functions during normal conditions:

- Provides a flow path from the main steam lines to the condenser with flow control provided by TBVs to bypass the main turbine for steam flow capacities no less than 25% of the rated steam flow
- Modulate steam flow using the TBVs based on signals from I&C systems
- The TBVs close when signalled to do so by the I&C systems
- Remove decay heat from the reactor and discharge to the condenser

Off-Normal Functions (Non-Safety Category)

The TBS does not perform any Non-Safety Category functions during off-normal conditions.

Off-Normal Functions (Safety Category)

The TBS has three Safety Category functions during off-normal conditions:

- TBVs will fast open in response to a turbine trip when demanded by I&C systems in Mode 1 (Power Operation)
- TBVs will close on high main condenser pressure when demanded by the I&C system in Modes 1 (Power Operation) and 2 (Startup)
- Maintains reactor pressure control while the turbine is brought up to rated speed and synchronized under its speed-load control

10.4.3.2 Safety Design Bases

The TBS is SC3 and is designed to operate in modes of normal power plant operation and startup. As part of Defense Line 2 (DL2) the TBVs receive a signal from the SC2 and SC3 I&Cs System to open and close when signaled to do so.

The design of the TBS meets IAEA requirements specified in SSR-2/1 Requirement 4 (Reference 10-9) as it relates to maintaining the plant in a normal operational state.

10.4.3.3 Description

The TBS provides the capability to discharge steam from the reactor directly to the main condenser. This minimises step load reduction transient effects on the NBS. The TBS is used to assist in plant heat-up, cool-down, turbine trips and load rejection to maintain reactor pressure. The TBS, in combination with the reactor systems, provides the capability to provide for a 25% load rejection without a reactor scram. The ability to reject 25% of rated thermal power is intended to accommodate the plant conditions during startup, grid synchronisation and shutdown sequences such that a turbine trip during startup would not cause a reactor scram. This supports the fundamental safety function of core heat removal.

The TBS is located in the TB and consists of two TBVs connected in parallel to the MS subsystem equalisation header, and discharges to the main condenser. The system also includes TBV hydraulic actuators, supply and drain piping, servo valves, solenoid valves, check valves, and position transmitters. It is shown in Figure 10-11.

The TBVs are control valves operated by hydraulic actuators equipped with springs capable of shutting the valves against the design steam pressure. The TBVs are designed to fail closed upon loss of control power or loss of hydraulic pressure to their operators.

During startup, the TSVs and TCVs are initially closed. The TBVs open as required, bypassing steam to the main condenser to allow the reactor to operate in a steady-state condition and to minimize pressure transients in the reactor during initial steam admission to the turbine. As steam is admitted to the turbine, the TBVs close as required to bring the turbine online while maintaining reactor pressure.

During normal operation, the TBVs are maintained in the closed position. The TBVs open as required to maintain reactor pressure following a load reduction or load rejection.

The MS piping and components downstream of the outboard MSCIVs are protected from system overpressure using the turbine bypass valves, the SC1 I&C system/insertion of control rods, the Isolation Condenser System (ICS), and the increased design pressure and temperature for the selected piping material, precluding the need for additional overpressure protection design features.

Upon a turbine trip, the TBVs initially open, then modulate as required to maintain reactor pressure. During shutdown, reactor power is reduced by rod insertion at specified rates and sequences. The TSVs and TCVs remain open until the MTE power falls below the manufacturer's specified output. At this point, the TSVs and TCVs close and the TBVs modulate to control steam pressure.

The TBVs open in response to redundant bypass demand signals received from the SC3 DCIS whenever the steam pressure exceeds the preset steam pressure by a small margin. This occurs when the amount of steam generated by the reactor cannot be entirely used by the turbine. The number of TBVs required to open for bypass operation is determined by the SC3 DCIS and the TBVs modulate as required in response to changes in the bypass demand to discharge steam to the main condenser.

Material and equipment selection for the TBS is based on the range of normal environmental conditions that may exist at the location of the system's equipment and components.

Component Description

Turbine Bypass Valves

Two (2) TBVs are provided. Each TBV is a control valve operated by a hydraulic actuator. The actuator is equipped with a spring which is capable of shutting the valve against the design steam pressure. The TBVs are capable of modulating steam flow to meet system requirements.

Individual TBVs are designed to fail closed upon loss of control power or loss of hydraulic pressure to their operators. Individual TBV hydraulic accumulators have the capability to stroke the valves with HPU failure and meet opening time and duration requirements. The accumulators in combination with hydraulic check valves ensure that no single hydraulic failure disables more than 50% of the TBVs. The accumulator hydraulic supply is also designed to ensure that upon Loss-of-Preferred Power (LOPP) or station auxiliary power, TBVs can still be opened for a minimum time of six (6) seconds and reclose.

American National Standards Institute (ANSI FCI 70-2) Class V leakage class is specified for bypass valves to minimize wire drawing and other damage to the valve caused by leakage across the seat.

Turbine Bypass System Piping

TBS piping is designed to ASME B31.1, Non-Seismic requirements (Reference 10-12). Piping supports are designed for water-filled line loads under static loading conditions that may be encountered in plant operations. In addition, provisions are made for conveniently supporting (e.g., by pinning hangers) the dead weight loads imposed during hydrostatic testing.

The MS piping from the equalisation header slopes upward to the TBV inlets and the discharge piping downstream of the TBVs slopes downward to the main condenser with a slope of at least 1/100 of run with no low points. Suitable low point drains are provided by the NBS to prevent excessive moisture from accumulating upstream of the TBVs. Spargers distribute the steam within the main condenser as required.

10.4.3.4 Materials

Material and equipment selection for the TBS is based on the range of normal environmental conditions that exist at the location of the system’s equipment and components.

10.4.3.5 Interfaces with Other Equipment or Systems

Refer to Table 10-10 for TBS interfaces.

10.4.3.6 System and Equipment Operation

The TBS is designed to operate in all modes of normal power plant operation and startup.

Normal Operational Concept

Startup Mode

During startup, the turbine stop, and control valves are initially closed. The RPC opens the TBVs as required, bypassing steam to the main condenser, to control reactor pressure allowing the reactor to operate to a rated condition and to minimize pressure transients in the reactor during initial steam admission to the turbine. As steam is admitted to the turbine, the TBVs close as required to maintain reactor pressure.

Normal Operation

During normal operation, the TBVs are maintained in the closed position.

The TBVs open as required to maintain reactor pressure following a load reduction or load rejection. The TBS is capable of accommodating a 25% (+/- 2%) load rejection with the TBVs modulating as required to maintain reactor pressure and support operation of the turbine under reduced load.

System Shutdown

The TBVs initially open upon turbine trip, then modulate as required to maintain reactor pressure. During shutdown, reactor power is reduced by rod insertion at specified rates and sequences. The turbine stop and control valves remain open until the main turbine power falls below the manufacturer’s specified kW output limit. At this point, the turbine stop and control valves close, and the TBVs open and modulate as required to control steam pressure.

10.4.3.7 Instrumentation and Control

The TBVs open in response to redundant bypass demand signals received from the SC3 DCIS (PSR Chapter 7) whenever the actual steam pressure exceeds the preset steam pressure by a preset amount, NEDO-34169 (Reference 10-13). This occurs when the amount of steam generated by the reactor cannot be entirely used by the turbine. The number of TBVs required to open for bypass operation will be determined by the DCIS, and the TBVs modulate as required in response to changes in the bypass demand, discharging steam to the main condenser.

The following signals are monitored in the MCR:

- Temperature in each bypass line for bypass steam leakage detection
- Valve position indication for each TBV
- TBV operable status and annunciation of any signals that cause the valves to become inoperable
- Monitors line pressure upon discharge of steam into the condenser

Three SC3 valve open/close sensors are provided by the SC2 and SC3 I&C System and installed at each TBV detects the 10% open position and provides valve status to the SC2 and

SC3 I&C System reactor protection logic. These position sensors are fail-safe such that they cannot prevent actuation of the reactor protection function.

SC3 valve position transmitters are provided and installed at each TBV. These valve position transmitter signals are used to perform input voting as applicable and are used for the reactor pressure controller of the SC3 DCIS. The TBV operational status are used for monitoring functions in SC3 DCIS.

Temperature elements installed in each TBV discharge pipe near the main condenser inlet provides temperature signals to the SC3 Reactor Control System for bypass steam leakage detection.

Triply redundant bypass valve position transmitters installed at each TBV provide valve position signals to the SC3 Reactor Control System. Control and monitoring of the TBS is accomplished by the SC3 Reactor Control System, and the logic contained therein.

Servo valves and fast-acting solenoid valves provide hydraulic actuation of the TBVs upon receiving demand signals from the SC3 Reactor Control System.

The RPC determines bypass operating conditions and setpoints which require fast opening of the TBVs and provides the corresponding demand signals to the TBS.

Automatic and manual control of the TBS is provided. TBV controls, including manual initiation and shutdown, are located in the MCR to facilitate system operation.

10.4.3.8 Monitoring, Inspection, Testing, and Maintenance

The equipment and components of the TBV are designed for ease of inspection and maintenance. The TBVs are oriented to facilitate maintenance activities. Testing shall be in accordance with ASME OM Code, Technical Specifications, and all applicable regulatory commitments. Periodic inspections are performed on a rotating basis within a preventive maintenance program in accordance with manufacturer’s recommendations. Testing is in accordance with ASME OM Code.

10.4.3.9 Radiological Aspects

PSR Chapter 12, Sections 12.1.1 (Approach to ALARP) and 12.3. (Design Features for Radiation Protection) provide information pertaining to measures taken to ensure that occupational exposures arising from the operation or maintenance of the equipment or system are ALARP in operational states and in accident or post-accident conditions.

10.4.3.10 Performance and Safety Evaluation

The TBS is designed to operate in all modes of normal power plant operation and startup. As part of DL2, the TBVs receive a signal from the SC3 Reactor Control System to open and close when required.

The TBVs are:

1. The TBVs are capable of modulating steam flow to meet system requirements
2. The TBVs are designed to fail closed upon loss of control power or loss of hydraulic pressure to their operators
3. The TBV hydraulic accumulators have the capability to stroke the valves with hydraulic power and meet opening time and duration requirements after loss of power to the EHC pumps
4. The accumulators in combination with hydraulic check valves ensure that no single hydraulic failure disables more than 50% of the TBVs

5. The accumulator hydraulic supply is also designed to ensure that upon LOPP or station auxiliary power, TBVs can still be opened for the minimum time and re-closed

10.4.4 Generator Auxiliary System

The following information is consistent with 006N7753, “Generator and Exciter SDD,” (Reference 10-43). The Generator and Exciter System converts the rotational energy of the BWRX-300 turbine into electrical power that is transmitted to the Non-Safety Electrical Distribution System and utility power grid 006N7753 (Reference 10-43). The generator consists of a synchronous electric generator (including rotor, stator, and stator frame), collector, generator shaft seals, generator bearings, generator heat exchangers, neutral grounding resistor and associated neutral grounding transformer, potential transformers, current transformers, surge protection, generator protection panel and relaying (shared with Non-Safety Electrical Distribution System), the generator field winding, and instrumentation. Additionally, this system includes the Generator Excitation System that consists of a field exciter and Automatic Voltage Regulator that function to provide rated output voltage.

10.4.4.1 System and Equipment Functions

Normal Functions (Non-Safety Category)

This system does not perform any Non-Safety Category functions during off-normal conditions.

Normal Functions (Safety Category)

The functions of the generator exciter, in conjunction with the voltage regulator, are:

- Convert mechanical energy from rotation of the main turbine into electrical power at a gross nominal output of 300 Mwe
- Distribute electrical power to the Switch Yard
- Distribute electrical power to the plant’s internal electrical distribution system

Off-Normal Functions (Non-Safety Category)

This system does not perform any Non-Safety Category functions during off-normal conditions.

Off-Normal Functions (Safety Category)

This system does not perform any Safety Category functions during off-normal conditions.

10.4.4.2 Safety Design Bases

The system contains SC3 SSC except for the following SCN components, Neutral Grounding Transformer, Neutral Grounding Resistor, AVR Cabinet, and Excitation Cabinet. The system is categorized as Non-Seismic.

The generator provides input signals of system operating parameters to DCIS for monitoring.

The generator is able to withstand a sudden three-phase short circuit at the output terminals of the generator under a worst-case condition of the generator operating at full rated load, at rated power factor overexcited and up to the fabrication ratings of the machine.

Instrumentation is provided to monitor the operating parameters of the generator and excitation system over its anticipated ranges of normal and abnormal performance to facilitate plant operation and ensure safety.

The design of the MTE System meets IAEA requirements specified in SSR-2/1 Requirement 77 as it relates to providing provisions for overspeed protection, minimisation of missiles due to a turbine break-up and inspection and testing, 006N7717 (Reference 10-2). Minimisation of potential missile impacts is also afforded through the favorable perpendicular orientation of the reactor to the turbine.

10.4.4.3 Description

The generator produces its rated electrical output power at rated torque produced by the turbine and design condenser vacuum conditions.

The Generator and Exciter System 006N7753 (Reference 10-43) provides electricity to be distributed to the grid via the isophase bus ducts and the generator step up transformer in Mode 1 and to the station loads via the Unit Auxiliary Transformer.

The generator operates at a 300 MW rating at 21 kV not more than five percent above or below rated voltage with a rated speed of 3000 rpm (for 50 Hz grid connection). The generator, exciter and generator control system are designed to be capable of responding to grid frequency changes.

The generator stator frame is fabricated of steel and is designed such that no damaging frame vibration occurs during normal operation and transients. The Generator Excitation System static exciter supplies and controls the direct current for the field winding of the generator and controls the voltage and reactive volt-ampere output of the generator. The DC current is supplied by a 250Vdc uninterruptible control power source. The neutral grounding is composed of a neutral grounding transformer with a secondary resistor and a current transformer dedicated to the stator earth fault protection. The Automatic Voltage Regulator monitors and adjusts the field excitation to maintain the output voltage within the specified range.

Refer to PSR Chapter 3, Section 3.9 for information pertaining to equipment qualification of BWRX-300 SSC.

Component Description

Generator

The generator is capable of operating without air cooler cooling water flow at a level and duration determined by the manufacturer to not incur any damage. All the moving parts are provided with machine guards and barriers.

Generator Exciter

The generator exciter is designed to supply and control the direct current for the field winding of the generator and control the voltage and reactive volt-ampere output of the generator during normal plant operation and startup.

The power potential excitation transformer is protected by at least (and against):

- Transformer differential current
- Phase overcurrent
- Lightning strikes with appropriate surge protection and basic insulation level rating

Automatic Voltage Regulator

The voltage regulator, in conjunction with the generator exciter, maintains the output voltage of the generator at 21 kV +/- 5%.

Neutral Ground Resistor

The neutral grounding resistor is sized such that, in the event of a ground fault, the maximum current experienced by the neutral phase is between 3 and 25 amps.

Neutral Ground Transformer

The neutral grounding transformer in conjunction with the neutral grounding resistor, limits the maximum stator ground fault to between 3 and 25 amps.

10.4.4.4 Materials

Material and equipment selection for the Generator and Exciter System is based on the range of environmental conditions that exist at the plant location.

10.4.4.5 Interfaces with Other Equipment or Systems

Refer to Table 10-11 for information pertaining to Generator and Exciter System interfaces.

10.4.4.6 System and Equipment Operation

The generator is designed to operate during modes of normal power plant operation, including startup and shutdown activities. The generator is also designed to trip based on abnormal conditions. For all operating modes, automatic controls are provided for equipment and components to minimize operator action while ensuring optimum system performance. The system also operates in conjunction with the turbine auxiliary controller and generator auxiliary controller to perform system operations as needed.

10.4.4.6.1 Normal Operational Concept

Startup

The generator is controlled by the TGCS. The TGCS synchronises the initial loading by:

- Matching turbine speed to the grid frequency
- Matching generator voltage to the grid
- Ensuring generator phase angle leads the grid phase angle
- Closing generator output breakers

Normal Operation

During normal operation, the TGCS controls the generator by operating in coordination with the Plant Automation System and RPC. During normal operation the TGCS utilises the capabilities of the Automatic Voltage Regulator and the exciter to provide consistent generator output to the SCN Electrical Distribution System. The turbine and generator auxiliary controllers can also assist with the control of generator output as required.

10.4.4.6.2 Off-Normal Operational Concept

Off-Normal Operation

During off-normal operation, the TGCS causes the generator to experience a load runback or trip of the generator, depending on the condition and the signals received from the Plant Automation System. These signals perform the following, based on conditions:

- Initiate runback or trip signals
- Provide signals for generator and switchyard breaker control, including tripping
- Runback the turbine generator to a safe operating condition based on input signals
- Provide automatic and manual controls to unload the unit during controlled shutdowns

10.4.4.7 Instrumentation and Control

Instrumentation

Instrumentation is provided to monitor the operating parameters of the generator and excitation system over anticipated ranges of normal and abnormal performance to facilitate plant operation and ensure safety, NEDO-34169 (Reference 10-13).

Manual and automatic controls are provided to maintain generator parameters within prescribed operating ranges and, specifically, to control the voltage and reactive volt-ampere output of the generator.

The following alarms and trip signals are generated based on inputs provided to the DCIS:

A. Sequential trip signals (dry contacts and power contacts)
B. Generator differential protection
C. Volt/Hertz protection for generator
D. Field ground fault protection
E. Distance backup protection
F. Negative phase sequence currents
G. Stator winding fault
H. Stator overcurrent
I. Stator overvoltage/undervoltage
J. Stator current unbalance
K. Loss of excitation
L. Field overexcitation
M. Neutral overvoltage
N. Reverse power (time delayed)
O. Under-frequency
P. Loss of synchronism
Q. Journal bearing vibration high
R. Inadvertent energisation

Upon sensing any of the following abnormal generator conditions, an alarm is actuated in the MCR based on generator parameters that are provided to the DCIS:

A. Generator voltage
B. Generator current
C. Generator frequency
D. Generator active power
E. Generator reactive power
F. Generator power factor
G. Generator output, volts/hertz
H. Generator field current
I. DC excitation potential
J. Excitation field ground

K. Shaft voltage
L. Rotor winding ground
M. Bearing rotor vibration
N. Stator winding temperatures
O. Journal bearing metal temperatures
P. Bearing drain oil temperature
Q. Collector-ring cooling-air inlet and outlet temperatures
R. Air cooler gas outlet temperature

A zero (0) speed indication signal is supplied to reset the alarm for generator protection equipment or generator health monitoring equipment.

The following signals are sent from the static exciter to the generator protection panel:

A. Generator voltage
B. Generator DC excitation voltage
C. Generator DC excitation current
D. Volts/Hertz
E. Power potential transformer lockout relay status
F. Instantaneous DC current
G. Bridge temperature
H. Bridge AC phase angle
I. Phase voltage

The power potential excitation transformer is protected by at least (and against) the following:

A. Transformer differential current
B. Phase overcurrent
C. Lightning strikes with appropriate surge protection and basic insulation level rating

Control

As part of the Generator and Exciter System design, controls and protection signals are capable of being multiplexed based on interfacing system requirements. Fire Protection signals are provided to the Main Fire Alarm Panel and the DCIS and can be used in the coordination with other plant equipment and all cyber security requirements are followed.

The generator protection system design includes redundant instrumentation with a coincident logic trip system. Initiation devices for all trips have a separate set of contacts that can be used for DCIS monitoring. DCIS Human Machine Interface screen displays are provided for each trip initiating signal to identify the source of the trip signal.

10.4.4.8 Monitoring, Inspection, Testing, and Maintenance

The equipment and components of the generator are designed for ease of inspection and maintenance during plant operation. Generator and Exciter System components are arranged, sized, and selected to facilitate their replacement during a normal maintenance outage. Individual components are manufactured to standard sizes and gauges to the greatest extent possible.

Routine testing of the generator is conducted in accordance with normal power plant requirements for demonstrating system and component operability and integrity. An inspection of the generator is performed per the vendor's supplied maintenance and inspection requirements.

The Generator and Exciter System supports online inspection activities to the extent practical. Condition monitoring equipment and instrumentation is included where appropriate to ensure equipment performance and health is as desired. Maintenance can be performed online where redundant components can be bypassed or taken out of service one at a time without affecting plant operation.

10.4.4.9 Radiological Aspects

PSR Chapter 12, Sections 12.1.1 (Approach to ALARP) and 12.3. (Design Features for Radiation Protection) provide information pertaining to measures taken to ensure that occupational exposures arising from the operation or maintenance of the equipment or system are ALARP in operational states and in accident or post-accident conditions.

10.4.4.10 Performance and Safety Evaluation

The Generator and Exciter System is provided with sufficient I&C channels such that the system can continue operation in the event of the failure of a single instrumentation channel, NEDO-34169 (Reference 10-13). The generator protection system design includes redundant instrumentation with a coincident logic trip system.

10.4.5 Circulating Water System

The following information is consistent with 006N7761, "Circulating Water System," SDD (Reference 10-44). The Circulating Water System (CWS) has two subsystems, the condenser cooling water (CCW) and the Service Water (SW). The CCW subsystem uses 2x50% pumps to provide cooling water to the MCA (Section 10.4.1) during all modes of condenser heat removal.

The SW subsystem uses 2x100% pumps to provide cooling water to the PCW (PSR Chapter 9A, Section 9A.2.1) heat exchangers for all normal and abnormal operating modes.

All CWS pumps are located in bays in the intake structure of the Normal Heat Sink (NHS) (PSR Chapter 9A, Section 9A.2.5).

10.4.5.1 System and Equipment Functions

The CWS performs the functions listed below during normal and off-normal conditions.

Normal Functions (Non-Safety Category)

The CWS performs the following Non-Safety Category functions during normal conditions:

- Removes accumulated air and other gases from the water boxes through water box vent valves
- Provides the means to drain all condenser water boxes

Normal Functions (Safety Category)

The CWS performs the following Safety Category functions during normal conditions:

- Provides means to reject heat from the MCA to the environment through the NHS
- Provides means to reject heat from the PCW heat exchangers to the environment through the NHS

Off-Normal Functions (Non-Safety Category)

The CWS does not perform any Non-Safety Category functions during off-normal conditions.

Off-Normal Functions (Safety Category)

The CWS continues to provide its Safety Category functions during off-normal conditions. Upon a LOPP, the NHS continues to provide a cooling water source and heat rejection functions to support CWS interface with PCW. The two SW pumps are powered from the diesel generators via the SC3 Electrical Distribution System, during a LOPP.

10.4.5.2 Safety Design Bases

CWS components are primarily SC3 as described below, the remaining components are SCN. CWS system equipment is categorized as Non-Seismic.

The design of the CWS meets IAEA requirements specified in SSR-2/1 Requirement 53 (Reference 10-9) as it relates to the ability to transfer heat during normal operation.

10.4.5.3 Description

Figure 10-12 depicts the CWS. The CWS is a recirculating system that supplies cooling water to the main condenser from the NHS. The circulating water pumps located in the intake structure of the NHS, take suction from the forebay and discharge through a common underground pipe. In the TB, the piping comes above grade and routes into the tube side of the main condenser to act as the cooling flow for condensing main turbine exhaust steam. Circulating water exiting the main condenser is piped back underground to the NHS.

A hot circulating water return line is also provided to recycle water returning from the condenser in cold weather conditions as required to prevent freezing in the NHS forebay and moderate cold water into the condenser to improve turbine performance. The CWS include water box vent valves to help fill the condenser water boxes during startup and remove accumulated air and other gases from the water boxes during normal operation.

The SW pumps (PSR Chapter 9A, Section 9A.2.1) have 100% redundancy and can provide water to the PCW heat exchanger at all modes of operation. During normal operation only one PCW heat exchanger is in-service, and the corresponding plant cooling water supply pump is used to provide cooling. During a plant shutdown, both PCW heat exchangers and SW pumps can be in-service to facilitate a plant shutdown. With the loss of a SW pump the plant shutdown may take longer due to the reduction in heat removal. In the event of a LOPP, the PCW portion of CWS is powered by the standby diesel generators to provide continuous cooling support to PCW.

The CWS drains the condenser water boxes via the water box drain pump. The CWS is designed for continuous operation and to provide sufficient circulating water to the condenser to support full power operation.

The CWS must be in operation before any steam or high energy sources are routed into the condenser. The CWS supplies cooling water at a flow rate that allows the steam entering the condenser the ability to condense.

A CWS pump may be taken out of service if the remaining pump is capable of supplying sufficient circulating water to cool the main condenser when operating at reduced load or the circulating water temperature is low enough.

The CWS, together with the NHS, provide circulating water to the main condenser in support of rated or greater turbine generator power operation. The CWS and NHS also supply circulating water to the main condenser sufficient to support 100% reactor power operation when operating up to 2% exceedance temperatures of the normal heat sink.

The SW pump(s) must be in operation before any cooling water is required by the PCW. Only one pump is required to be in operation at a time to provide sufficient cooling capacity.

The SW pumps provide sufficient cooling water to meet the performance requirements of the heat exchangers within the PCW. The PCW supply pumps are 100% capacity pumps. One pump can remain in standby while the operating pump provides the required cooling water flow.

Measure(s) are applied to control macrofouling of the circulating cooling water systems.

Refer to PSR Chapter 3, Section 3.9 for information pertaining to equipment qualification of BWRX-300 SSC.

Component Description

The following paragraphs describe major equipment items that comprise the CWS.

Circulating Water Pumps

The circulating water pumps are 50% capacity pumps. The pumps are arranged in parallel with suction from the NHS forebay. There are two individual pump discharge lines, and they combine into one circulating water supply line to the main condenser.

Service Water Pumps

The SW pumps are 100% capacity pumps. These pumps take suction from the NHS forebay.

The individual PCW supply pump discharge lines supply the independent PCW heat exchangers.

Water Box Drain Pump

The water box drain pump is sized to drain the CWS piping, pumps, and condenser water boxes. The water box drain pump discharge is routed to the CWS piping downstream of the condenser discharge isolation valves.

Piping and Valves

The CWS piping is designed to meet the requirements of ASME B31.1 (Reference 10-12).

Valves installed at the discharge of the circulating water pumps are the motor-operated butterfly type. In the event of a trip of a circulating water pump, the closing characteristics of these valves limit the water hammer pressure to limits that are acceptable by the piping system.

All major CWS valves are operable by both local and remote controls located in the MCR.

Underground piping from the circulating water pumps to the main condenser is made of a corrosion resistant material.

Pipe coating, lining, and cathodic protection is provided as appropriate based on-site specific conditions.

Condenser Water Boxes

The main condenser water boxes are constructed of carbon steel. The exterior surfaces are coated as appropriate based upon site-specific conditions.

The water box vacuum breakers open automatically to prevent excessive pressure transients caused by multiple circulating water pump trips.

Cathodic protection may be provided to protect the water boxes based on-site specific conditions.

10.4.5.4 Materials

Material and equipment selection for the CWS is based on the range of environmental conditions that exist at the plant location.

10.4.5.5 Interfaces with Other Equipment or Systems

Refer to Table 10-12 for CWS interfaces with other systems.

10.4.5.6 System and Equipment Operation

The CWS is designed for continuous operating for the following plant operating modes:

1. Normal operation and to provide sufficient circulating water to the condenser to support full power operation throughout the year
2. Off-normal operation

Normal Operational Concept

The two 50% capacity circulating water pumps will be in operation during normal operation. One pump may be manually stopped for cleaning or maintenance activities during normal operation; however, power output would need to be reduced to within the capacity of a single CWS pump prior to stopping one pump.

Only one of two 100% capacity SW pumps are in normal operation at a time with the other in standby. This does not preclude two pump operation under normal operations.

Off-Normal Operational Concept

The CWS is designed to maintain reactor operation during a turbine trip or a 25% load rejection, whereby 25% of the MS bypasses the turbine to the condenser.

Cold Weather Operation

When required for cold weather operation, the system is designed to support cold weather startup by maintaining a minimum basin temperature. A hot-water recirculation line is included to prevent frazil ice in the NHS forebay.

Freeze protection is provided for above ground components that contain stagnant water.

Circulating Water Pump Trip

If a circulating water pump trips, the associated pump discharge valve automatically closes to avoid water backflow. The trip of a circulating water pump alarms in the MCR. Tripping of the pump initiates a drop in power output and an increase in condenser back pressure due to an increase in circulating water temperature.

Service Water Pump Trip

If a SW pump trips, the backup pump auto starts, and the process cooling water system will realign and put the associated heat exchanger in service. The trip of the pump alarms in the MCR.

Isolation of the Condenser Due to Tube Leak

If a main condenser tube leak is detected, the power output of the plant may need to be reduced to a value that accounts for the reduced cooling flow through the condenser tubes.

Flooding in the Turbine Building

In the event that two of the three level transmitters in the condenser area detect a high-water level, a trip signal is sent to the circulating water pumps thereby tripping the pumps and the unit.

Isolation of the PCW System Due to High Radiation Levels

In the event of high radiation levels detected downstream of either of the PCW heat exchangers, a signal is sent to the valves downstream of the heat exchangers. The valves close to prevent contaminated water from reaching the NHS.

10.4.5.7 Instrumentation and Control

The CWS provides the instrumentation to control and monitor (indicate and alarm) system operation.

Instrumentation

Major system parameters, i.e., forebay and water box levels; and process flow rate, pressures, and temperatures are indicated and alarmed as required to provide operational information and performance assessment.

Control

The CWS is operated and controlled from the MCR. Major system control functions, i.e., pump start/stop and valve positioning logics, are based on system operating parameters. For example, high radiation levels downstream of each PCW heat exchanger result in valve closure.

10.4.5.8 Monitoring, Inspection, Testing, and Maintenance

Routine testing of the CWS is conducted in accordance with normal power plant requirements for assuring component operability and integrity.

Equipment and components of the CWS are designed for ease of inspection and maintenance during plant operation. The CWS is provided with a water box drain pump with capability to drain the main condenser water boxes. Condenser inlet and outlet isolation block valves are provided to allow for isolation of condenser tube bundles for maintenance.

Each circulating water pump discharge has the ability to be individually isolated for service and maintenance. Manholes are provided for maintenance and cleaning of the circulating water piping and condenser water boxes.

10.4.5.9 Radiological Aspects

PSR Chapter 12, Sections 12.1.1 (Approach to ALARP) and 12.3. (Design Features for Radiation Protection) provide information pertaining to measures taken to ensure that occupational exposures arising from the operation or maintenance of the equipment or system are ALARP in operational states and in accident or post-accident conditions.

10.4.5.10 Performance and Safety Evaluation

The CWS has two subsystems, the CCW and SW. The CWS is capable of performing its Safety Category functions as presented in Section 10.4.5.1. The CWS provides sufficient circulating water to the main condenser to support full power operation. A pump may be taken out of service if the remaining pump is capable of supplying sufficient circulating water to cool the main condenser when operating at reduced load.

The 2x 100% SW pumps provide water to the PCW heat exchangers to remove PCW heat loads. The SW pumps are powered by the standby diesel generators in the event of a LOPP to provide continuous cooling support to PCW. The PCW heat exchanger discharge is monitored to ensure the water returning to the NHS is free of radionuclides. High radiation levels would result in isolation of the discharge by automatic valve closure.

10.5 Implementation of Break Preclusion for the Main Steam and Feedwater Lines

Refer to NEDO-34165 (Reference 10-3) Attachment 1 Section 3.4.4 for information pertaining to break exclusion.

Table 10-1: Design Features and Representative Performance Characteristics of the Steam and Power Conversion System

Parameter	Value
Reactor	
Core Thermal Power, MWt	870
Turbine Generator (nominal gross rating), MWe	300
Type	1 single-flow HP turbine 2 double-flow LP turbines (tandem)
Operating speed, rpm	3000
Pressure at turbine stop valve, bar(absolute)	69
Saturation temperature at turbine inlet, ºC	285
Moisture Separator Reheaters	
Number of MSRs per unit	1
Stages of moisture separation	1
Stages of reheating	2
Main Condenser	
Type	Single pressure, 2-shell
Circulating Water/Normal Heat Sink	
Number of circulating water pumps	4 – 25% capacity each
Circulating water flow rate, m^3/s	15
Circulating water temperature rise, ºC	9
Normal heat sink type	Seawater
Condensate Pumps	
Number of pumps	2 – 100% capacity each
Feedwater Pumps	
Number of pumps	2 – 100% capacity each
Normal flow, m^3/s	0.5
Feedwater Heaters	
Number of heaters	3 LP, 3 HP
Feedwater temperature, ºC	242

Note: Values provided in this table to be updated as appropriate following turbine vendor selection.

Table 10-2: Main Steam System Subsystem Interfaces

Interface System	Interface Description	Interface Boundary
Non-safety Instrumentation and Control System	The Non-Safety DCIS along with plant automation functions provide a distributed control and instrumentation data communication network to support non-safety portion of MS subsystem.	Interface is at the non-safety DCIS termination cabinet.
Process Radiation and Environmental Monitoring System	In the event of a large steam line pipe break outside containment, the plant's PREMS is designed to continuously monitor to detect such an occurrence.	PREMS Termination Cabinets.
Condensate and Feedwater Heating System	MS subsystem provides steam from the MSLs to the FW Heater No. 6.	MS subsystem block valve to CFS piping to FW Heater No. 6.
Main Turbine Equipment	The NBS supplies steam to the main turbine during power operation and transients such as load variations.	MSL to TSVs connection.
Moisture Separator Reheater System	MS supplies of steam for the MSR System.	NBS block valve to MSR piping to MSR.
Turbine Bypass System	MS supplies steam to the TBVs via piping between the equalizing header and the TBVs.	MSL piping to TBV A and TBV B.
Main Condenser and Auxiliaries	During startup and up to approximately 40% power operation, the main condenser via the MS drain lines receives steam, steam condensate, and non-condensable gases from the RPV and MSLs.	NBS block valve to MCA piping to condenser & NBS block valve to MCA piping to condenser.
Safety Category N Electrical Distribution System	The Non-Safety Electrical Distribution System provides power to the Safety Category N valves in the MS subsystem. These valves are all located in the TB.	The interface point will be the electrical terminations of the power cables at the valve actuator.
Equipment and Floor Drain System	The Equipment and Floor Drain System (EFS) provides sumps or drain tanks to the NBS system.	Interface is the connection from the NBS to the EFS in the TB.
Turbine Building Structure	The TB provides the necessary space and structural support for the NBS MSLs and MS drain lines and components.	Interfaces are the pipe support attachments to the TB structures.

Table 10-3: Condensate Filter and Demineralizer System

Parameter	Standard Plant Value*
Condensate Filters:	
Filter type	High efficiency
Number of vessels	3
Condensate Demineralizers:	
Demineralizer type	Deep bed polisher
Number of vessels	3
Other System Features:	
New resin addition hopper	1
Fresh resin storage tank	1

Table 10-4: Condensate Filter and Demineralizer System Interfaces

Interfacing System	Interface Description	Interface Boundary
Safety Category 3 Instrumentation and Controls	Safety Category 3 I&C provides control, valve logics, instrumentation (pressure, flow, temperature, level)	Safety I&C System DCIS termination cabinet
Non-Safety Instrumentation and Controls	Non-Safety I&C provides control, valve logics, instrumentation (pressure, flow, temperature, level)	Safety Category N I&C System DCIS termination cabinet
Process Radiation and Environmental Monitoring System	PREMS provides sample locations to test for process quality and conductivity	Isolation valves
Liquid Waste Management System	LWM provides the CST water for resin transfer, resin washing, and filter backwash processes	Isolation valve to the Sluice Water header
Solid Waste Management	SWM receives and stores condensate filter backwash waste in sludge tank, and demineralizer, spent resin waste in the spent resin tank	Backwash and Spent Resin discharge isolation valves
Condensate and Feedwater Heating System	CFS provides condensate water flow to CFD for filtration and demineralisation. CFD provides clean effluent for FW heating process	Condensate Filters inlet header and outlet of the Condensate Demineralizers
Plant Pneumatics System	Provides air to pneumatically operated valves and compressed air for filter cleanup and resin transfer	Isolation valve to the air surge tank and valve actuators
Non-Safety Electrical Distribution System	Non-Safety Electrical Distribution System provides Safety Category N low and medium voltage power	Electrical terminals of the power cables at the load end
Equipment and Floor Drain System	EFS provides location for drains and relief valve blowdowns	Interface is at the piping that is routed EFS

Table 10-5: Condensate Feedwater Heating System Major Components

Condensate Pumps	
Number of Pumps	2 (1 normally operating)
Pump Type	Fixed speed, centrifugal
Driver Type	Motor
Low Pressure Feedwater Heaters	
No. 1 and No. 2:	
Number per stage	1 duplex per stage for a total of 2
No. 3	
Number per stage	1
High Pressure Feedwater Heaters	
No. 4	
Number per stage	1
No.5:	
Number per stage	1
No.6:	
Number per stage	1
Reactor Feedwater Pumps	
Number of Pumps	2 (1 normally operating)
Pump Type	Variable speed, centrifugal
Driver Type	Motor

Table 10-6: Condensate Feedwater Heating System Interfaces

Interfacing System	Interface Description	Interface Boundary
Nuclear Boiler System	CFS provides FW to NBS at required flow rate, pressure, and temperature. CFS receives MS from the NBS to the HP FW Heater No. 6	At the inlet of the outboard reactor vessel isolation valve. At the inlet of the temperature control valve
SC1 Instrumentation and Control System	Provides CFS Containment Isolation signals and FW isolation signals, and receives signals from SC1 instrumentation	SC1 I&C System DCIS termination cabinet
SC2 and SC3 Instrumentation and Control System	Provides inputs to and receives signals from the SC2 and SC3 I&C System	SC2 and SC3 I&C System DCIS termination cabinet
Non-Safety Instrumentation and Controls	Non-Safety I&Cs provides non-safety I&C Control for pumps, valves, and instrumentation	Non-Safety I&C System DCIS termination cabinet
Process Radiation and Environmental Monitoring System	Samples taken continuously to monitor water quality	Second isolation valve from CFS process stream
CRD System/HP Injection System and Hydraulic Control Units	CFS provides primary source of treated water to the CRD pump suction	Outlet of air-controlled isolation valve
Shutdown Cooling	The shutdown cooling return lines tie into the FW lines upstream of the outboard CIV	At the inlet of the AOVs

Interfacing System	Interface Description	Interface Boundary
Reactor Water Cleanup System	CFS provides cooling water for CUW regenerative heat exchanger and receives water from CUW for processing through CFD	At the inlet and outlet of the CUW heat exchanger At the outlet of the CUW isolation valve
Liquid Waste Management System	CFS provides condensate reject to the CST	At the inlet to the CST isolation valve
Off-gas System	CFS provides cooling to off-gas condenser	At the inlet and outlet of the off-gas condenser
Condensate Filters and Demineralizers	CFS provides condensate water for purification and receives condensate after purification	At the inlet and outlet of the CFD header
Main Turbine Equipment	MTE provides steam to the FW heaters. CFS provides cooling to gland seal condenser	At the inlet to the FW heaters from the MTE extraction system At the inlet and outlet of the gland seal condenser
Moisture Separator Reheater System	MSR drains to shell side of the FW heaters	At the inlet to the FW heaters from the MSR drains
Main Condenser and Auxiliaries	MCA provides condensate source. CFS provides cooling to SJAE intercondensers	All connections to MCA are located at the outlet/inlet with the main condenser At the inlet and outlet of the SJAE Intercondensers A/B

Interfacing System	Interface Description	Interface Boundary
Plant Cooling Water	Plant Cooling Water (PCW) provides cooling water to the condensate pump and FW pump motors	At the pump cooling water inlet and outlet
Plant Pneumatics System	Provides control air for valves	At the inlet to the CFS AOVs
Hydrogen Water Chemistry	CFS provides injection port(s) for Hydrogen Water Chemistry	The Hydrogen Water Chemistry interfaces at the outlet of the isolation valves in Hydrogen Water Chemistry
Online NobleChem™	CFS provides injection port(s) for Online NobleChem™	Online NobleChem™ interfaces downstream of the isolation and root valves to a shared flange with CFS
SC2 and SC3 Electrical Distribution System	SC2 and SC3 Electrical Distribution System provides Safety Category low and medium voltage power	Electrical terminals of the power cables at the load end
SC1 Electrical Distribution System	SC1 Electrical Distribution System provides safety category 1 low and medium voltage power	Electrical terminals of the power cables at the load end
Non-Safety Electrical Distribution System	Non-Safety Electrical Distribution System provides Non-Safety Category low and medium voltage power	Electrical terminals of the power cables
Equipment and Floor Drain System	EFS receives discharged water from CFS drains	At the outlet of drain valves to EFS

Table 10-7: Main Turbine Equipment Interfaces

Interfacing System	Interface Description	Interface Boundary
Nuclear Boiler System	NBS provides steam to MTE	Turbine Stop Valve
Safety Class 3 Instrumentation and Controls	1E Position switches on Stop Valves	Position Switches on Stop Valves
Non-Safety Instrumentation and Controls	RPC (Steam Bypass and Pressure Control) and Turbine Controls System	Control system for MTE valves and pumps
Process and Radiation Monitoring System	Radiation monitoring of GSC and process sampling for radiological analysis and chemistry control	GSC exhaust and operational sampling point to be determined
Control Panel System	Monitor all equipment	Turbine and auxiliaries
Off-gas System	Provide heating steam to the Off-gas System recombiner preheater section	Flange connection for Off-gas System recombiner preheater
Condensate and Feedwater Heating System	Extraction steam and LP exhaust feed into Condensate and FW	HP Extraction Nozzles LP Extraction Nozzles
Moisture Separator Reheater	HP turbine extraction and exhaust goes into MSR to be reheated and then feed into the LP turbine intake	HP Extraction Nozzles HP Exhaust Nozzles LP Inlet Nozzles
Turbine Bypass System	MTE provides hydraulic pressure to actuate TBVs	TBV hydraulic actuator
Generator and Exciter	Generator Rotor connected to turbine, to generate power. MTE supply lube oil to generator bearings.	Generator Rotor coupling to turbine

Interfacing System	Interface Description	Interface Boundary
Main Condenser and Auxiliaries	LP turbine discharges into condenser. MTE provides steam of SJAE. Provides steam for steam seals	LP turbine exhaust flange and the condenser inlet flange
Plant Cooling Water System	Provides cooling water to Lube oil and EHC coolers/heat exchangers	Inlet and outlet nozzle connections of Lube oil and EHC coolers/heat exchangers
Plant Pneumatics Equipment	Air supply for AOVs	Connection at the AOV port
Non-Safety Electrical Distribution system	Power for solenoid valves and pumps, uninterruptible AC power, uninterruptible DC power	Terminal connections at the electrical component for power
Heating Ventilation and Cooling System	Receives non-condensable gases from N31 GSC Exhaust Fan (Blower) at the Combine Exhaust Air Plenum	Flange at end of GSC Exhaust Fan (Blower)
Equipment and Floor Drain System	Incidental waste from oil systems	Equipment drain tub
Turbine Building Structure	Accommodate loads for the MTE System	Turbine anchors with the TB Structure pedestal
Water, Gas, and Chemicals Pads	Provides water through a hose for GSC drain loop seal	Temporary connections

Table 10-8: Main Condenser and Auxiliaries System Interfaces

Interfacing System	Interface Description	Interface Boundary
Nuclear Boiler System	The NBS steam line drains any condensate to the main condenser	At the main condenser
SC2 and SC3 Instrumentation and Controls	Main condenser SC2 and SC3 instrumentation is used for controls	At MCA equipment
Non-Safety Instrumentation and Controls	Main condenser non-safety instrumentation is used for controls	At MCA equipment
Control Panel System	Main condenser operation status alarms and indications	At MCA equipment
PREMS	The PREMS conductivity in the condenser hotwell	At MCA equipment
CRD System	Drain for CRD pump minimum flow line return to MCA	At the main condenser
Shutdown Cooling System	The main condenser receives overboard flow from the SDC	At the main condenser
Reactor Water Cleanup System	The main condenser receives overboard flow from the CUW	At the main condenser
Liquid Waste Management System	Makeup water to the main condenser via the CST	At the main condenser
Off-gas System	SJAE discharge to the Off-gas System	At the SJAE exhaust
Main Turbine Equipment	The LP turbine exhaust steam discharges to the main condenser. The TASS provides MS to the SJAEs	At the main condenser At the SJAEs
Condensate and Feedwater Heating System	The main condenser hotwell supplies condensate to the condensate pumps. The main condenser receives the pump recirculation flow, drains, and vents from the CFS system	At the main condenser
Moisture Separator Reheater System	The main condenser receives drains and vents from the MSR System	At the main condenser
Turbine Bypass System	The main condenser receives turbine bypass steam	At the main condenser
Circulating Water System	Cooling water to the main condenser	At the main condenser
Plant Cooling Water	Cooling water for condenser vacuum pump	At the condenser vacuum pump
Plant Pneumatics Equipment	Provides dry compressed air for valves and instrumentation	At MCA equipment
Preferred Power System	Provides SCN low voltage power	At MCA equipment
Heating Ventilating and Cooling System	The Heating Ventilating and Cooling System will receive gaseous discharge from the condenser vacuum pump separators	At the condenser vacuum pump

Interfacing System	Interface Description	Interface Boundary
Equipment and Floor Drain System	Receives drains from the main condenser hotwell and the condenser vacuum pump	At MCA equipment
Water Gas and Chemical Pads	Provides fill and makeup demineralized water to the condenser vacuum pump	At MCA equipment

Table 10-9: Moisture Separator Reheater System Interfaces

Interfacing System	Interface Description	Interface Boundary
Nuclear Boiler System	Provides steam for second MSR reheat stage	MSR 2nd stage heating
SC3 Instrumentation and Distributed Controls and Information System	MSR SC2 and SC3 I&C System SC3 DCIS controls and the MSR valves	Control for MSR System valves and drains MSR Shell Level transmitters with setpoint “Initiate Turbine Trip on High Level”
Process Radiation and Environmental Monitoring System	Samples taken continuously to monitor water quality	Drain Tank Drain Line
Condensate and Feedwater Heating System	MSR Drain tanks drain into FW heaters shells	FW heaters shell inlets
Main Turbine Equipment	Provides HP turbine exhaust to be reheated and extraction steam for heating. Discharges reheated steam to LP turbine	HP Turbine Exhaust nozzles to MSR Shell Downstream of HP Extraction Steam isolation valve LP turbine supply steam up to intermediate stop and intercept valves
Main Condenser and Auxiliaries	Relief valve, MSR Drain Tank, 1st Stage Reheater Drain Tank, and 2nd Stage Reheater Drain Tank, and drain pots drain into the condenser	MSR system owns piping up to the condenser nozzle/flange for the following: MSR Shell Relief valve, MSR Drain Tank alternate drain line, 1st Stage Reheater Drain Tank, and 2nd Stage Reheater Drain Tank alternate drain line, and drain pots discharge piping
Plant Pneumatics System	Air supply for AOVs and Non-Return Valves	AOV, Non-Return Valves
Non-Safety Classified Electrical Distribution System	Power for MOVs	MOV
Turbine Building Structure	Accommodate loads for the MTE System	Structure
Equipment and Floor Drain System	Drainage for the system during Maintenance	Local drain hubs or Sump

Table 10-10: Turbine Bypass System Interfaces

Interfacing System	Interface Description	Interface Boundary
Nuclear Boiler System	The NBS provides steam to TBS when bypass is necessary	TBVs
SC3 Reactor Control System	SC3 valve position transmitters on each TBV. Control of TBVs	Turbine Bypass Valve
Turbine Generator Auxiliaries Control System	Temperature Sensors for leakage detection and TBV performance monitor	Temperature instruments
SC3 Industrial PC Platform	Instruments mounted on racks outside the TB shielded area for cycle access	Temperature instrumentation
Main Turbine Equipment	TGSS provides sealing steam and draws vacuum for leak-off steam Electro-hydraulic oil pressure for TBV valve actuators	TGSS connections at TBV EHC connections at TBV
Main Condenser and Auxiliaries	Sparger into condenser	Sparger inlet connection

Table 10-11: Generator and Exciter System Interfaces

Interfacing System	Interface Description	Interface Boundary
SC2 and SC3 Instrumentation and Control System	Monitoring of Generator and Exciter System bearing vibration. Performs steam turbine and generator protection functions	Turbine Generator Control Equipment
Non-Safety Instrumentation and Control System	Monitoring of Generator and Exciter System parameters returned for indication purposes	Turbine Generator Control Equipment
Main Turbine Equipment	Generator Rotor connected to turbine, pass forces back and forth along the turbine/generator drivetrain. Includes system connections	Generator Rotor and Main Turbine Shaft coupling; Lube oil supply and discharge connections
Plant Cooling Water System	Provides cooling to generator air coolers	Inlet and outlet connections
SC2 and SC3 Electrical Distribution System	Provides power to Automatic Voltage Regulator and Excitation Cubicle	Automatic Voltage Regulator and Excitation Cubicle
Non-Safety Electrical Distribution System	Provides power to the Unit Auxiliary Transformer and Generator step up for distribution to the plant and switchyard, respectively	Connection between Generator Terminals and Isophase Equipment Terminals Generator Protective Equipment and Relaying
Heating Ventilation and Cooling System	Generator and Exciter System is air cooled by building heat removal	Exterior shell of generator and excitation cabinets
Turbine Building Structure	Equipment is supported by the building structure	TB Structure

Table 10-12: Circulating Water System Interfaces

Interfacing System	Interface Description	Interface Boundary
SC2 and SC3 Instrumentation and Controls	SC2 and SC3 I&Cs provides control for the CWS and SW pumps, valves and instrumentation.	At CWS equipment
Non-Safety Instrumentation and Controls	Non-Safety I&Cs provides all Non-Safety I&C Control for pump, valves, and instrumentation	At CWS equipment
Process Radiation and Environmental Monitoring System	Radiation monitoring provides chemical and radiation monitoring of the CWS system. Process sampling of the CWS pumps for chemistry control	Downstream of the Condenser and PCW heat exchangers
Liquid Waste Management System	LWM outfall connects to CWS at the exit of the main condenser	At Outlet of Condenser
Main Condenser and Auxiliaries	The CWS provides cooling water to the main condenser	At MCA Inlet/Outlet connections
Plant Cooling Water System	The CWS provides cooling water to PCW heat exchangers	At PCW heat exchanger Inlet/Outlet connections
Plant Pneumatics System	Provides instrument quality control air for control valves	At CWS AOVs
SC2 and SC3 Electrical Distribution System	Provides SC2 and SC3 related low and medium voltage power for the SW pumps	At CWS equipment
Normal Heat Sink	The NHS provides debris free water for the circulating water pumps	At NHS forebay and discharge structures
Preferred Power System	Provides Safety Class 3 medium voltage power to the MCA circulating pumps and non-safety low voltage power supply to non-safety components	At CWS Equipment
Turbine Building	The condenser circulating water and service water piping feed equipment located within the turbine building. Level instrumentation to detect flooding of the condenser pit.	At turbine building foundation and pit

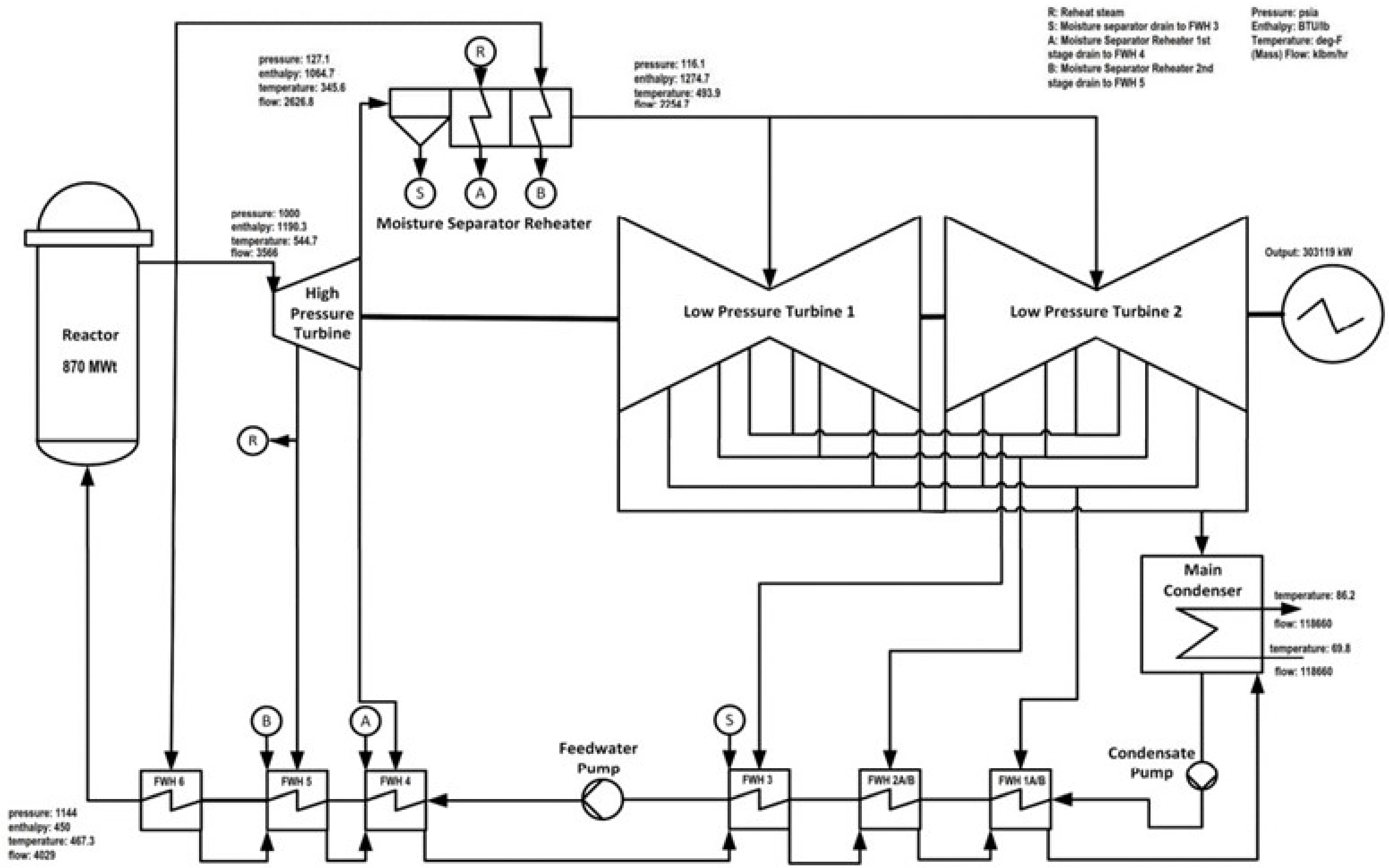


Figure 10-1: Simplified Flow Diagram with Representative Heat Balance of the Steam and Power Conversion System.

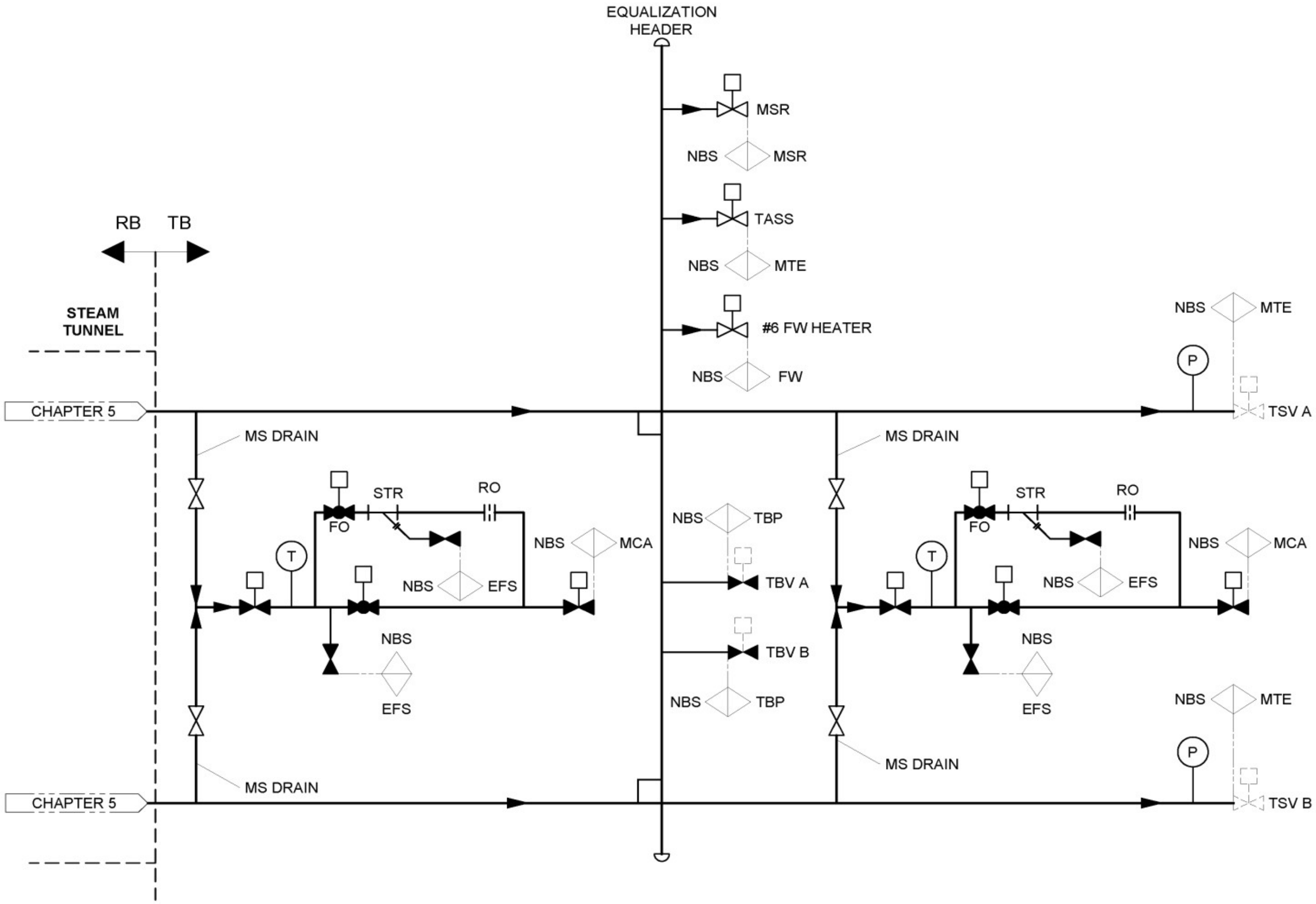
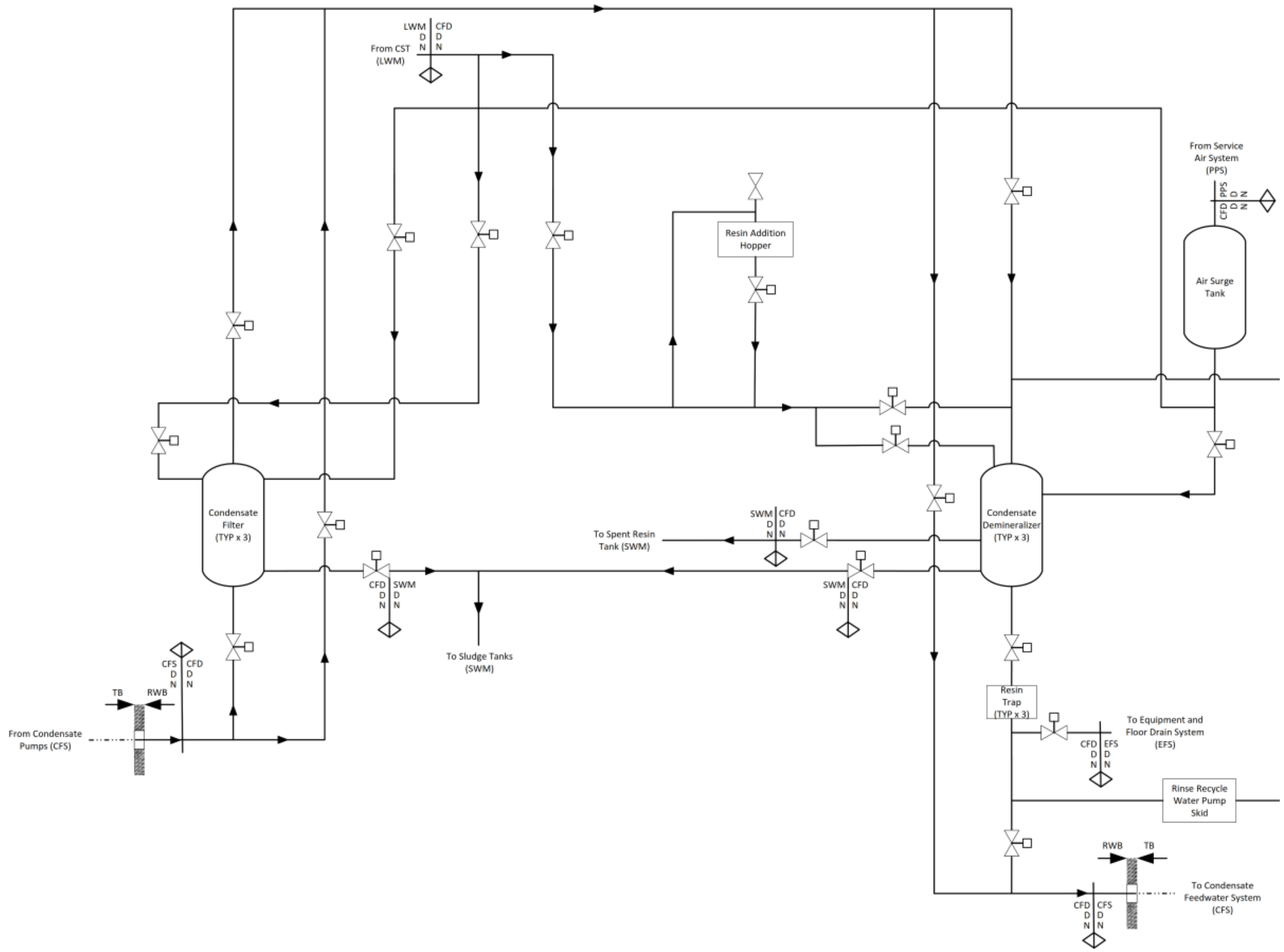


Figure 10-2: Main Steam System



Note - Figure version taken from Reference 10-15

Figure 10-3: Condensate Filters and Demineralizer System

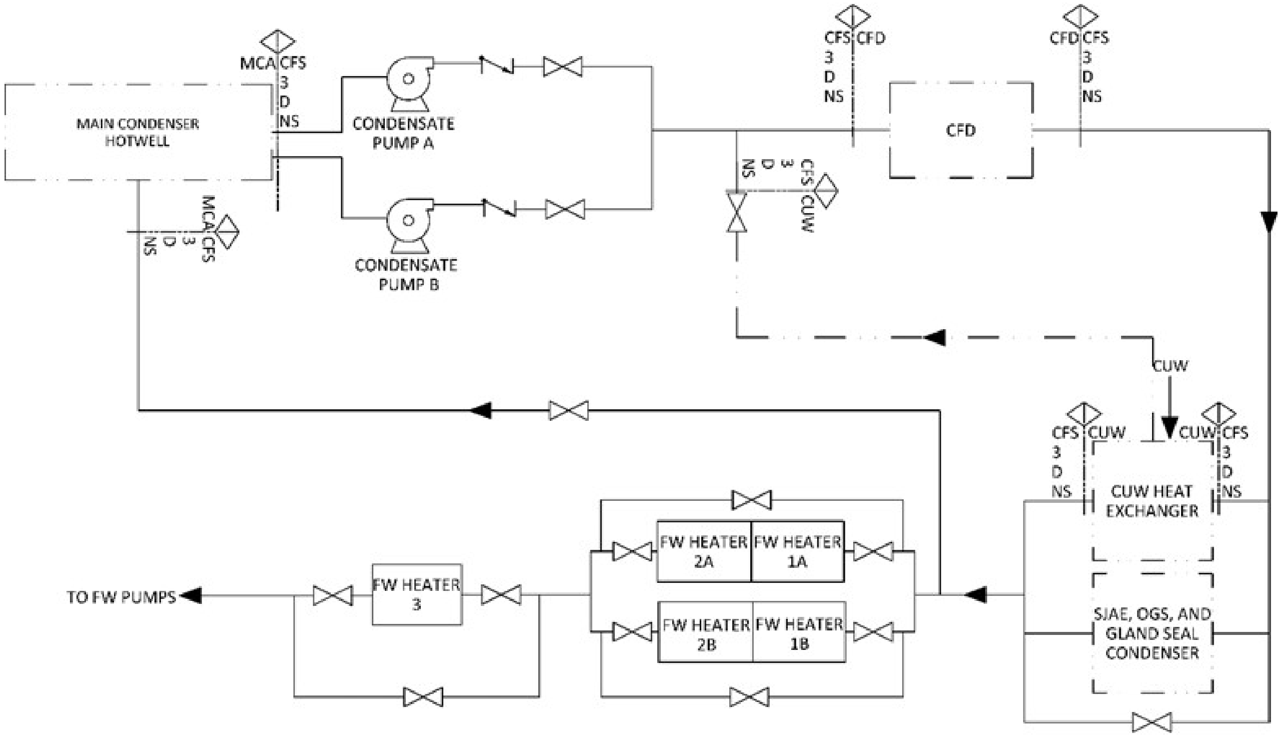
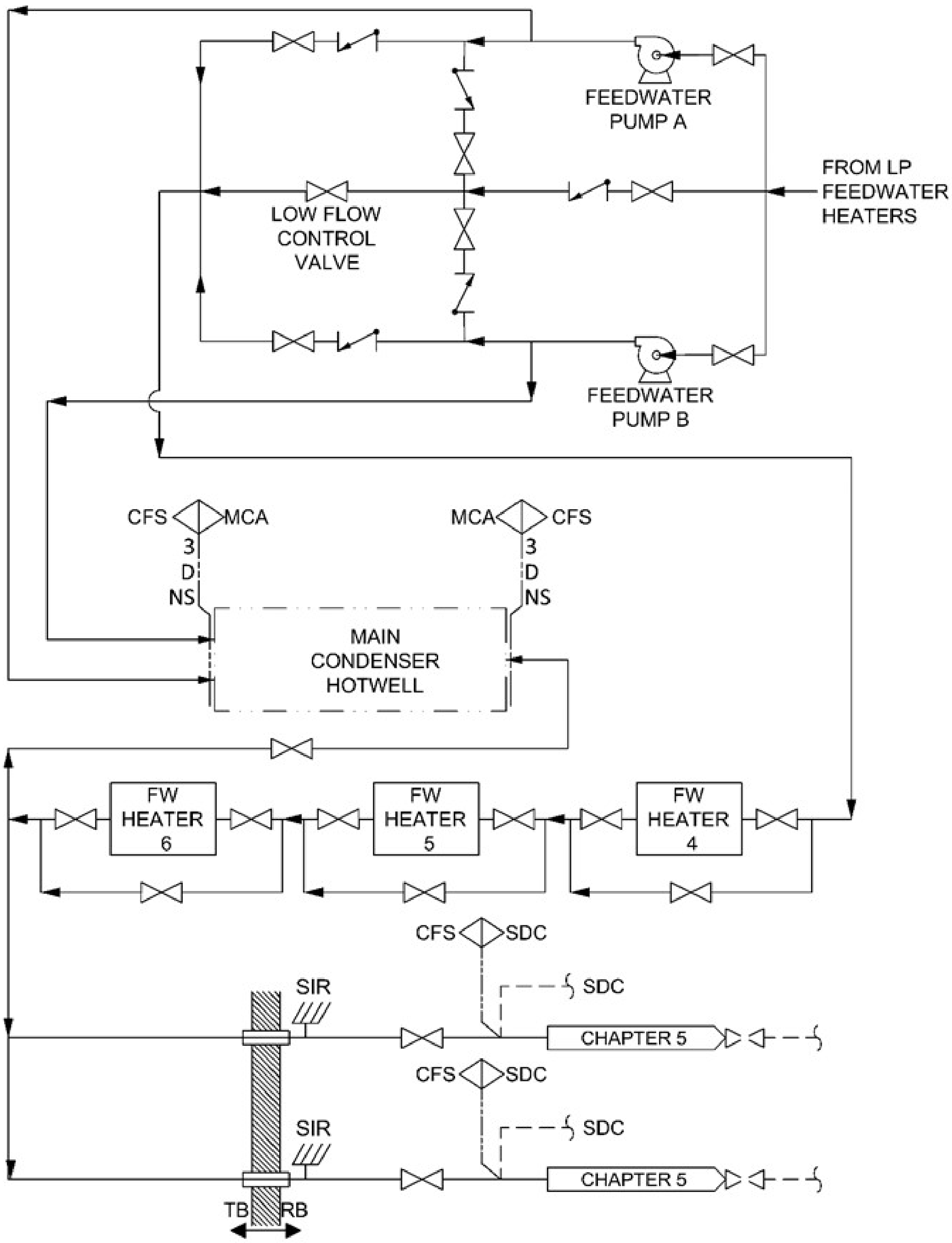


Figure 10-4: Condensate Portion of Condensate and Feedwater Heating System



1. PIPING IN THE RB IS SC1, QUALITY GROUP B, SEISMIC CATEGORY I. PIPING IN THE TB IS SC3, QUALITY GROUP D, SEISMIC CATEGORY NS.
2. PIPING IN THE RB UP TO THE SIR IS DESIGNED TO ASME SECTION III, CLASS 2. THE SIR IS DESIGNED TO ASME SECTION III, CLASS NF. PIPING IN THE TB IS DESIGNED TO ASME B31.1.

Figure 10-5: Feedwater Portion of Condensate and Feedwater Heating System

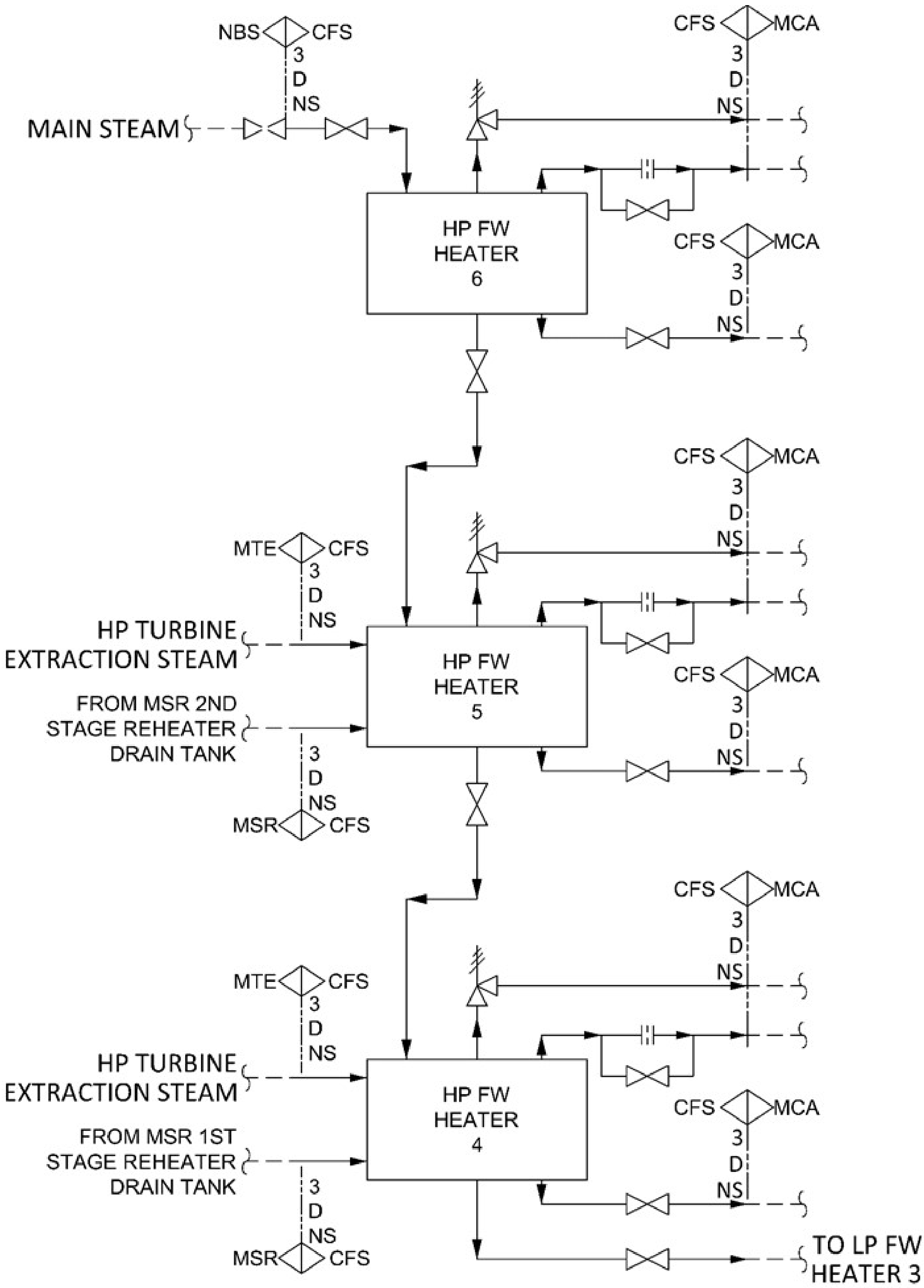


Figure 10-6: Vents and Drains for High Pressure Heaters in Condensate and Feedwater Heating System

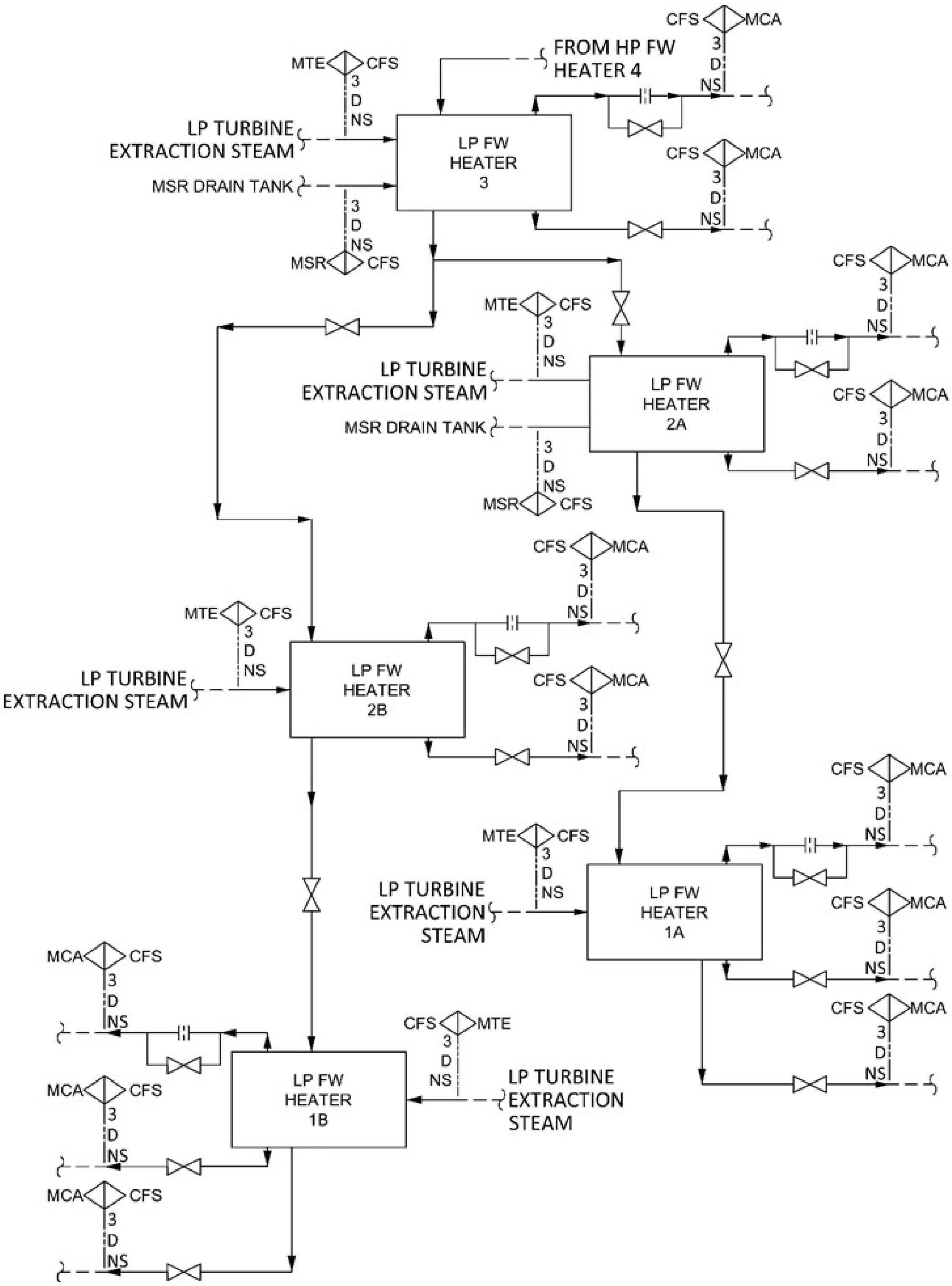


Figure 10-7: Vents and Drains for Low Pressure Heaters in Condensate and Feedwater Heating System

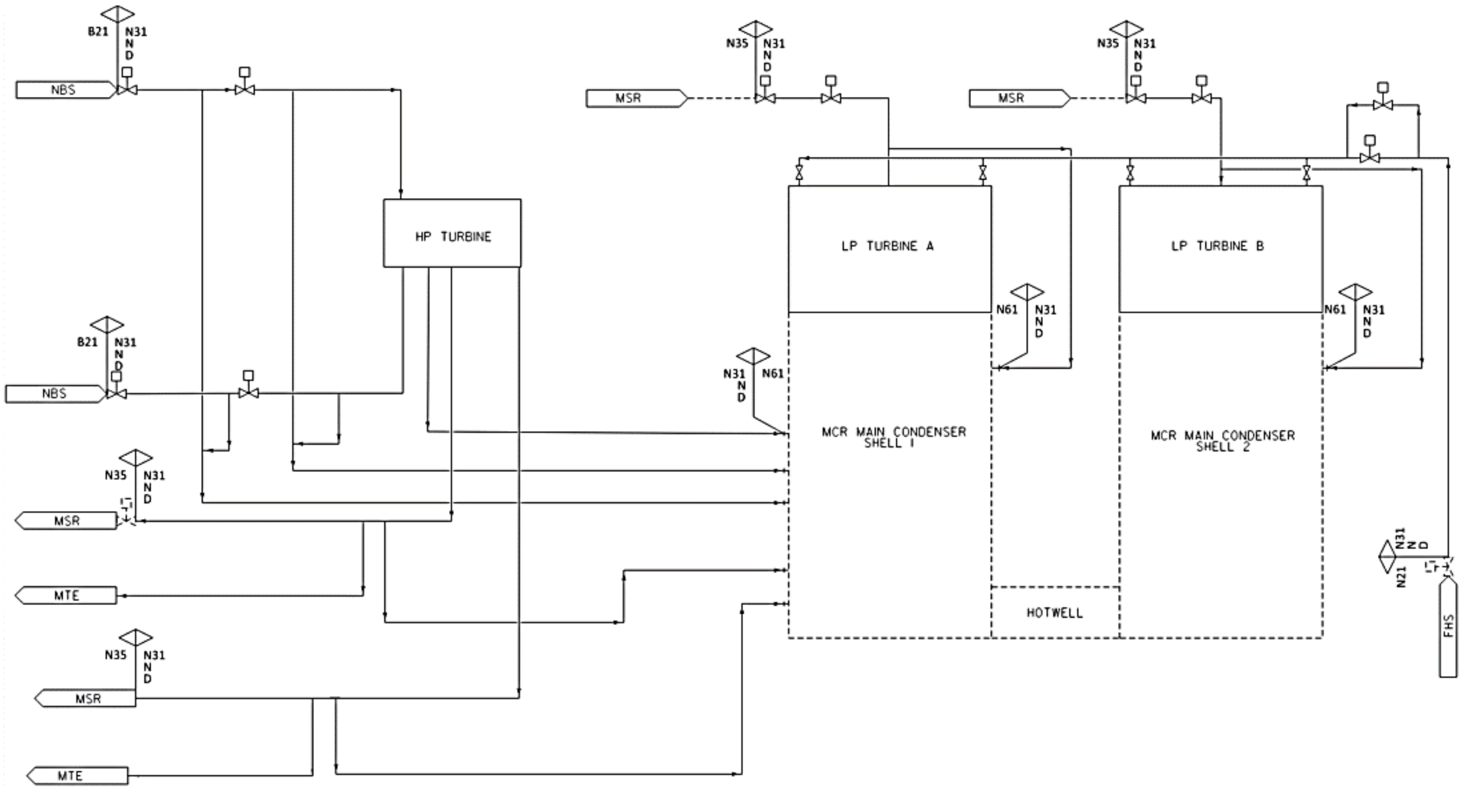


Figure 10-8: Power Cycle Schematic

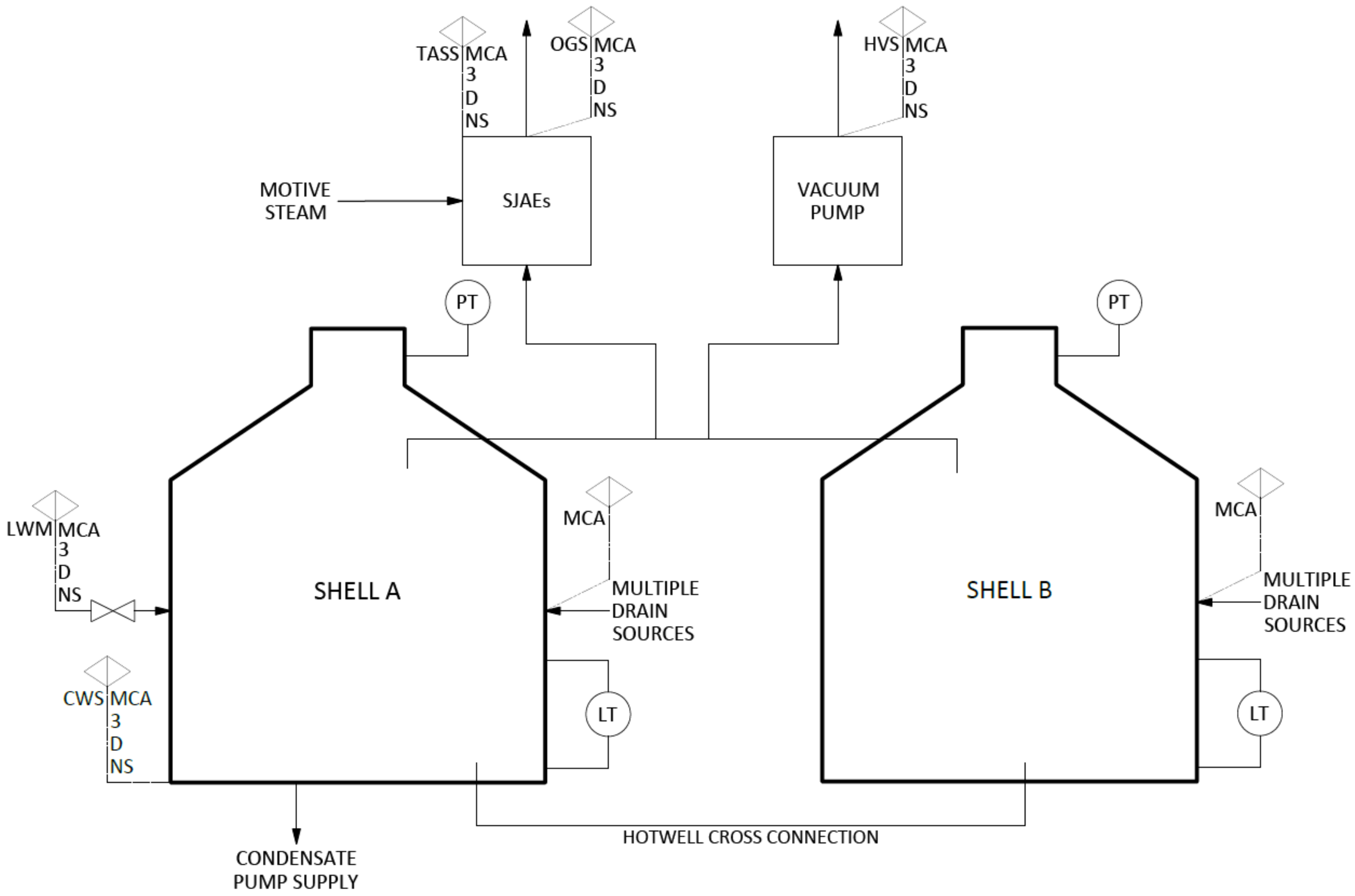


Figure 10-9: Main Condenser and Auxiliaries System

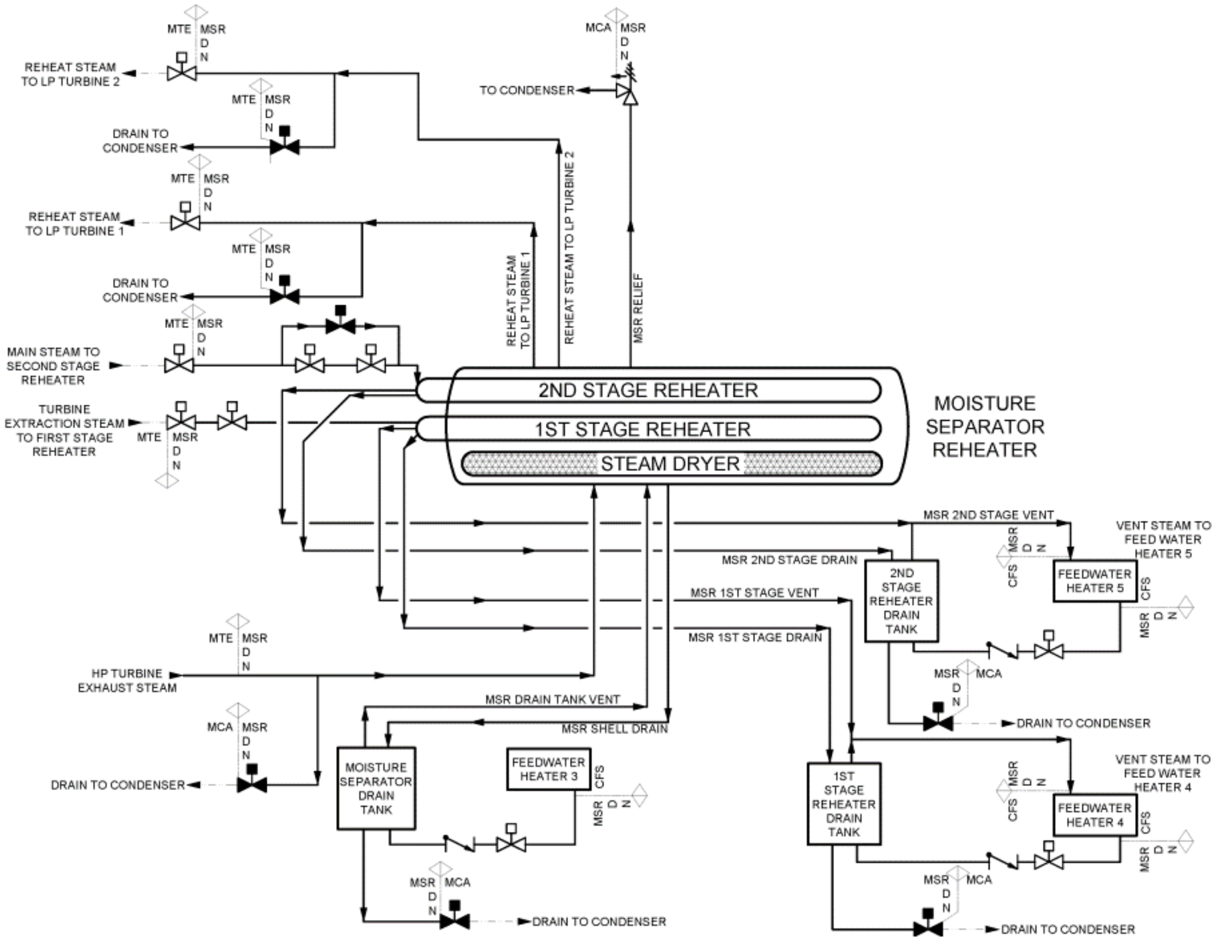


Figure 10-10: Moisture Separator Reheater System 1

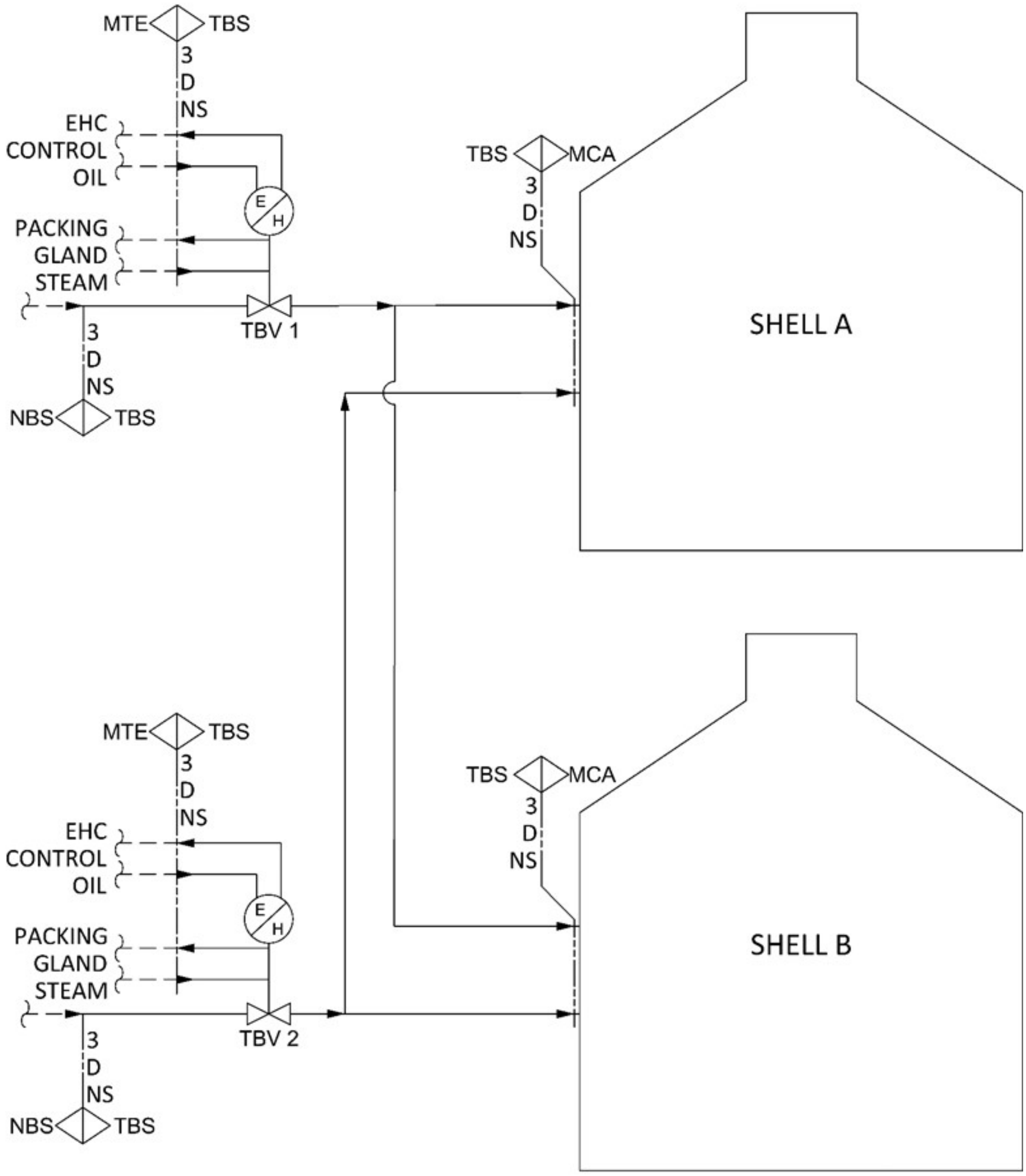


Figure 10-11: Turbine Bypass System Interfaces

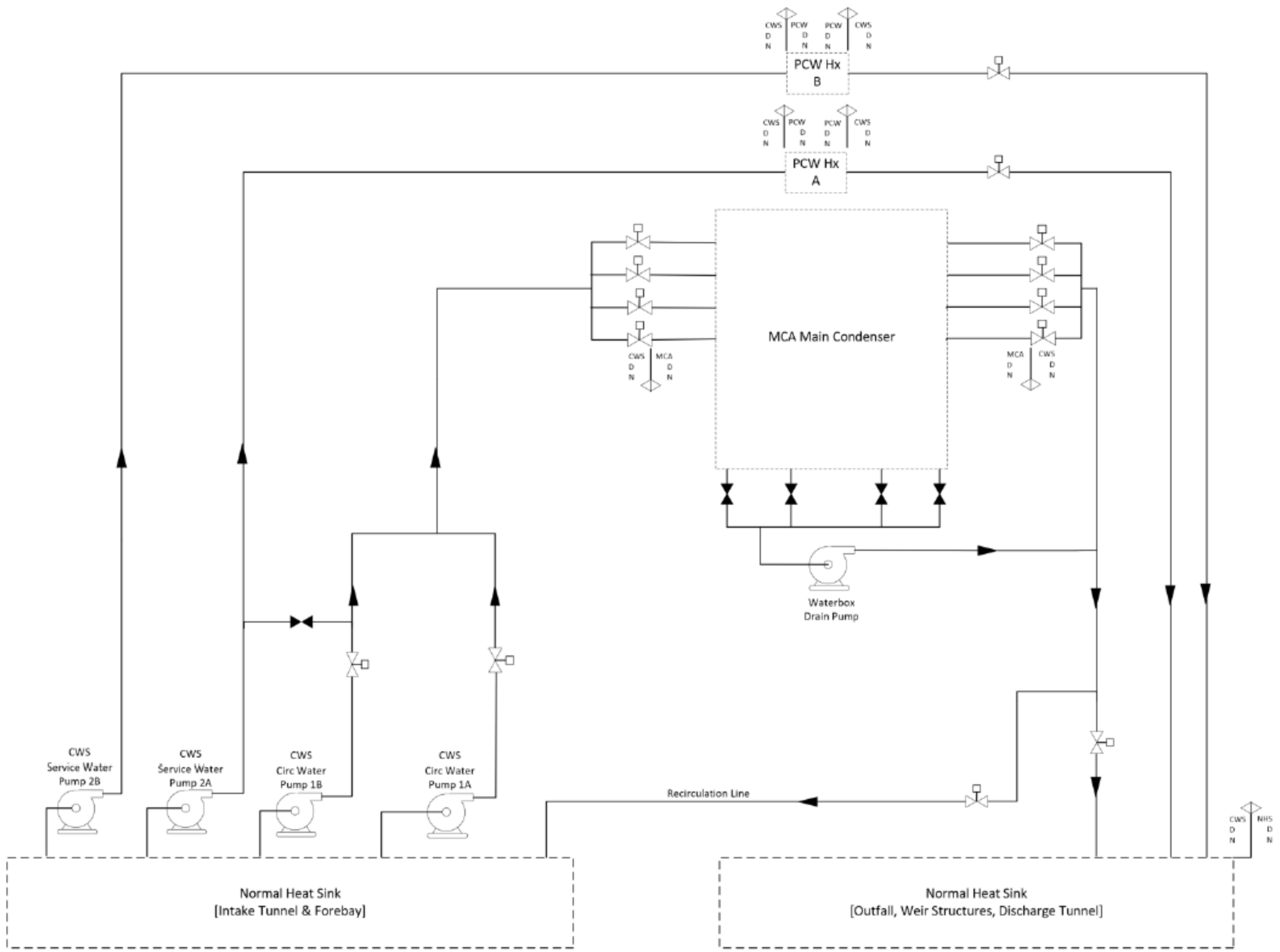


Figure 10-12: Circulating Water System

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10-48 006N3441, "BWRX-300 Applicable Codes, Standards, and Regulations List," Revision 3, GE-Hitachi Nuclear Energy.

10-49 NEDC-34149P, "BWRX-300 UK Codes and Standards Assessment," Revision 1, GE-Hitachi Nuclear Energy.

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10-51 DBR-0066822, “BWRX-300 System Functional Requirements (A11),” Revision 4, GE-Hitachi Nuclear Energy.

10-52 006N8706, "BWRX-300 Construction Strategy Report," Revision A, GE-Hitachi Nuclear Energy, November 2021.

10-53 006N6279, "BWRX-300 In Service Inspection Requirements," Revision 1, GE-Hitachi Nuclear Energy, 10th November 2023.

10-54 NEDO-34193, "BWRX-300 UK GDA Chapter 21: Decommissioning and End of Life Aspects," Rev B, GE-Hitachi Nuclear Energy, Americas, LLC.

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APPENDIX A CLAIMS, ARGUMENTS AND EVIDENCE

Claims, Argument, Evidence (CAE)

The ONR (Office for Nuclear Regulation) "Safety Assessment Principles for Nuclear Facilities," (SAPs) 2014 (Reference 10-45) identify ONR's expectation that a safety case should clearly set out the trail from safety claims, through arguments to evidence. The CAE approach can be explained as follows:

1. Claims (assertions) are statements that indicate why a facility is safe.
2. Arguments (reasoning) explain the approaches to satisfying the claims.
3. Evidence (facts) supports and forms the basis (justification) of the arguments.

The Generic Design Assessment (GDA) CAE structure is defined within NEDC-34140P, "BWRX-300 Safety Case Development Strategy," (SCDS) (Reference 10-46) and is a logical breakdown of an overall claim that:

> *"The BWRX-300 is capable of being constructed, operated and decommissioned in accordance with the standards of environmental, safety, security and safeguard protection required in the UK."*

This overall claim is broken down into Level 1 claims relating to environment, safety, security, and safeguards, which are then broken down again into Level 2 area related sub-claims and then finally into Level 3 (chapter level) sub-claims.

The Level 3 sub-claims that this chapter demonstrates compliance against are identified within the SCDS and are as follows:

> *2.1.2: The design of the system/structure has been substantiated to achieve the safety functions in all relevant operating modes.*
>
> *2.1.3: The system/structure design has been undertaken in accordance with relevant design codes and standards and design safety principles and taking account of Operating Experience to support reducing risks ALARP.*
>
> *2.1.4: System/structure performance will be validated by suitable testing throughout manufacturing, construction, and commissioning.*
>
> *2.1.5: Ageing and degradation mechanisms will be identified and assessed in the design. Suitable examination, inspection, maintenance, and testing will be specified to maintain systems/structures fit-for-purpose through-life.*
>
> *2.1.6: The BWRX will be designed so that it can be decommissioned safely, using current available technologies, and with minimal impact on the environment and people.*
>
> *2.4.1: Relevant Good Practice (RGP) has been taken into account across all disciplines.*
>
> *2.4.2: Operational Experience (OPEX) and Learning from Experience (LfE) has been taken into account across all disciplines.*
>
> *2.4.3: Optioneering (all reasonably practicable measures have been implemented to reduce risk).*

In order to facilitate compliance demonstration against the above Level 3 sub-claims, this PSR chapter has derived a suite of arguments that comprehensively explain how their applicable Level 3 sub-claims are met (see Table A-1 below).

It is not the intention to generate a comprehensive suite of evidence to support the derived arguments, as this is beyond the scope of GDA Step 2. However, where evidence sources are available, examples are provided.

Risk Reduction As Low As Reasonably Practicable

It is important to note that nuclear safety risks cannot be demonstrated to have been reduced ALARP within the scope of a 2-Step GDA. It is considered that the most that can be realistically achieved is to provide a reasoned justification that the BWRX-300 Small Modular Reactor (SMR) design aspects will effectively contribute to the development of a future ALARP statement. In this respect, this chapter contributes to the overall future ALARP case by demonstrating that:

- The chapter-specific arguments derived may be supported by existing and future planned evidence sources covering the following topics:
  - RGP has demonstrably been followed
  - OPEX has been taken into account within the design process
  - All reasonably practicable options to reduce risk have been incorporated within the design.
- It supports its applicable level 3 sub-claims, defined within the SCDS NEDC-34140P (Reference 10-46).

Consideration of the probabilistic safety aspects of the ALARP argument are out of the scope of this chapter. Probabilistic safety aspects of the ALARP argument are addressed within PSR Chapter 15.

The BWRX-300 approach to the design of steam and power conversion systems draws on the extensive OPEX of similar BWR and ABWR systems. All components comply with IAEA and USNRC requirements and are code compliant with ASME where required. RGP has been followed by ensuring that the design of the Main Steam subsystem minimises the occurrence of water hammer and the build-up of Non-Condensable gases, by facilitating venting and drainage. RGP has also been incorporated by utilizing corrosion/erosion/FAC resistant material for components exposed to wet steam or flashing liquid flow. The degree of material resilience is consistent with the temperature, moisture content and velocity of the wet steam to which the components are exposed.

Table A-1: Claims, Arguments, Evidence Route Map

L3 No.	Level 3 Chapter Claim:	Chapter 6 Arguments:	Sections and/or reports that evidence the arguments:
2.1: The functions of systems and structures have been derived and substantiated taking into account RGP and OPEX, and processes are in place to maintain these through-life. (Engineering Analysis)			
2.1.2	The design of the system/structure has been substantiated to achieve the safety functions in all relevant operating modes.	Safety functions associated with the relevant SSC have been substantiated during normal operating conditions (including design codes and standards compliance).	Safety function will be identified in PSR Chapters 3 & 15. Means of substantiation will be included in a future update of PSR Chapter 10. 10.2.2 Turbine Safety Functions: Main Turbine Equipment. The effects of potential high energy missiles are discussed in Section 3.5 of PSR Chapter 3.
		A record of safe BWR plant operation and continuous improvement demonstrates a well-founded design.	NEDC-34137P, “BWRX-300 Design Evolution,” (Reference 10-47).
		Safety functions associated with the relevant SSC have been substantiated during hazard and fault conditions.	Safety function will be identified in PSR Chapters 3 & 15. Means of substantiation will be included in PSR Chapter 10.
		Any shortfalls in safety function substantiation have been identified and assessed to identify any reasonably practicable means to reduce risk.	This argument is out of the scope of a 2-Step GDA and will be addressed during a site-specific stage (when more detailed evidence is developed).
2.1.3	The system/structure design has been undertaken in accordance with relevant design codes and standards (RGP)	Design evolutions to SSC have been considered taking into account relevant BWR OPEX, and any reasonably practicable changes to reduce risk have been implemented.	NEDC-34137P, “BWRX-300 Design Evolution” (Reference 10-47).

L3 No.	Level 3 Chapter Claim:	Chapter 6 Arguments:	Sections and/or reports that evidence the arguments:
	and design safety principles, and taking account of Operating Experience to support reducing risks ALARP	The SSC have been designed in accordance with relevant codes and standards (RGP).	006N3441, "BWRX-300 Applicable Codes, Standards, and Regulations List," (Reference 10-48). NEDC-34149P, "BWRX-300 UK Codes and Standards Assessment," (Reference 10-49).
		The SSC have been designed in accordance with an appropriate suite of design safety principles.	The GEH Safety and Design Principles are documented in the BWRX-300 Safety Strategy. These principles are also be presented within PSR Chapter 3: 006N5064, "BWRX-300 Safety Strategy," (Reference 10-50)
2.1.4	System/structure performance will be validated by suitable testing throughout manufacturing, construction, and commissioning.	SSC pre-commissioning tests (e.g., NDT) validate the relevant performance requirements.	This is considered to be beyond of the scope of a 2-Step GDA to define.
		SSC commissioning tests (e.g., system level pressure and leak tests) validate the relevant performance requirements.	This is considered to be beyond of the scope of a 2-Step GDA to define.
		SSC are manufactured, constructed, and commissioned in accordance with QA arrangements appropriate to their safety classification.	NEDC-34149P (Reference 10-49) "BWRX-300 System Functional Requirements (A11)" describes how safety categorisation and SSC classification are linked to quality group (QA arrangement) definition. 006N8706, (Reference 10-52) "BWRX-300 Construction Strategy Report" describes the high-level construction quality assurance and quality control arrangements and responsibilities.
2.1.5	Ageing and degradation mechanisms will be identified and assessed in the design. Suitable examination, inspection, maintenance, and testing will be specified to maintain	SSC ageing and degradation mechanisms will be identified during SSC design. These will be assessed to determine how they could potentially lead to SSC failure.	This is considered to be out of the scope of a 2-Step GDA, where the design maturing is at a concept stage. However, there is an intention to identify SSC ageing and degradation mechanisms, taking into account operational experience. Some early examples of how ageing and degradation have been addressed include materials selection, radiation shielding and water chemistry considerations. BWRX-300's ageing management arrangements are described in: PSR Chapter 3 Sections 3.1.13, 3.4.4.1, 3.9.1, 3.9.2 and 3.9.3.

L3 No.	Level 3 Chapter Claim:	Chapter 6 Arguments:	Sections and/or reports that evidence the arguments:
	systems/structures fit-for-purpose through-life		PSR Chapter 13 Section 13.3.8.
		Appropriate Examination, Maintenance, Inspection and Testing (EMIT) arrangements will be specified taking into account SSC ageing and degradation mechanisms.	This is considered to be out of the scope of a 2-Step GDA, where the design maturing is at a concept stage. However, early project examples of such considerations are included within the following report: 006N6279, “BWRX-300 In Service Inspection Requirements” (Reference 10-53). BWRX-300's ageing management arrangements are described in: PSR Chapter 3 Sections 3.1.13, 3.4.4.1, 3.9.1, 3.9.2 and 3.9.3. PSR Chapter 13 Section 13.3.8.
		The SSCs that cannot be replaced have been shown to have adequate life.	PSR Chapter 3 and Chapter 13 describe BWRX-300's ageing management arrangements for systems. Specifically, PSR Chapter 3 Sections 3.1.13, 3.4.4.1, 3.9.1, 3.9.2 and 3.9.3 apply, along with Chapter 13 Section 13.3.8.
		Ageing and degradation OPEX will be considered as part of the design stage component/materials selection process in order to mitigate SSC failure risk.	PSR Chapter 3 and Chapter 13 describe BWRX-300's ageing management arrangements for systems. Specifically, PSR Chapter 3 Sections 3.1.13, 3.4.4.1, 3.9.1, 3.9.2 and 3.9.3 apply, along with Chapter 13 Section 13.3.8.
2.1.6	The BWRX will be designed so that it can be decommissioned safely, using current available technologies, and with minimal impact on the environment and people	SSC decommissioning is considered at the design stage to ensure that safe decommissioning may take place.	OPEX demonstrates that decommissioning of reactor facilities is facilitated if the following are considered during the design phase: [1] Materials are selected to minimise the quantities of radioactive waste and assisting decontamination, [2] Plant layout is designed to facilitate access for decommissioning or dismantling activities, [3] Future potential requirements for storage of radioactive waste. See NEDO-34193, “BWRX-300 UK GDA Chapter 21: BWRX 300 Decommissioning and End of Life Aspects,” planning (Reference 10-54).
		SSC are designed in order to minimise impacts on people and	See PSR Chapter 21: BWRX 300 Decommissioning planning (Reference 10-52).

L3 No.	Level 3 Chapter Claim:	Chapter 6 Arguments:	Sections and/or reports that evidence the arguments:
		the environment during decommissioning.	
2.4 Safety risks have been reduced as low as reasonably practicable			
2.4.1	Relevant Good Practice (RGP) has been taken into account across all disciplines	Relevant SSC codes and standards (RGP) are identified.	"BWRX-300 Applicable Codes, Standards, and Regulations List" (Reference 10-48). "BWRX-300 UK Codes and Standards Assessment" (Reference 10-49).
		SSC have been designed in accordance with relevant codes and standards (RGP).	"BWRX-300 Applicable Codes, Standards, and Regulations List" (Reference 10-48). "BWRX-300 UK Codes and Standards Assessment" (Reference 10-49). The descriptions included within this chapter identify how the SSC have been designed in accordance with relevant codes and standards.
		Any shortfalls in codes and standards compliance are identified and assessed to reduce risks ALARP.	Out of the scope of this PSR chapter.
2.4.2	Operational Experience and Learning from Experience has been taken into account across all disciplines	Design improvements to SSC have been identified considering relevant OPEX and LfE.	NEDC-34137P, "BWRX-300 Design Evolution" (Reference 10-47). The BWRX-300 Design Plan (006N3139, Rev 5 section 4.7 (Reference 10-55)) mentions the GEH OPEX process CP-16-101. The design process incorporates applicable OPEX to mitigate nuclear design and construction risk, in accordance with CP-16-101 and the BWRX-300 OPEX/lessons learned programme. Operating experience sources include INPO, EPRI and BWROG. Construction experience and improved construction methods from previous large projects are also used to improve the quality and efficiency of the construction effort.
		Any reasonably practicable design changes to reduce risk have been implemented.	NEDC-34137P, "BWRX-300 Design Evolution" (Reference 10-47).
2.4.3	Optioneering (all reasonably practicable measures have been	Design optioneering has been performed in accordance with an approved process.	006N3139, "BWRX-300 Design Plan," (Reference 10-55).

L3 No.	Level 3 Chapter Claim:	Chapter 6 Arguments:	Sections and/or reports that evidence the arguments:
	implemented to reduce risk)	Design optioneering has considered all reasonably practicable measures.	006N3139 (Reference 10-55). NEDC-34137P, “BWRX-300 Design Evolution” (Reference 10-47).
		Any reasonably practicable design changes to reduce risk have been implemented.	NEDC-34137P, “BWRX-300 Design Evolution” (Reference 10-47).

APPENDIX B FORWARD ACTION PLAN ITEMS

The Forward Action Plan (FAP) is not required to capture the 'normal business' of Safety, Security, Safeguards and Environmental case development as the design progresses from concept to design for construction and commissioning. FAP items can arise from several sources:

- Assumptions and commitments made in the GDA submissions that will require future verification/ implementation, for example, by the future constructor and/or plant operator.
- A gap in the underpinning of the GDA submissions currently under development.
- A potential gap in a future phase of submissions if additional work is not performed.
- A gap identified by the regulators and communicated to the Requesting Party (RP) through a Regulatory Query or Regulatory Observation.

There are no FAP items identified associated with PSR Chapter 10.