10.4.8 Steam Generator Blowdown System (PWR)

The Steam Generator Blowdown System (SGBS) assists in maintaining the chemical characteristics of the secondary water within permissible limits. The SGBS provides the capability for continuous hot blowdown of the secondary side of the steam generators (SG). The SGBS includes equipment for heat recovery, purification and reuse of SG blowdown.

10.4.8.1 Design Bases

The following safety-related functions are performed by the SGBS and are required to function following a design basis accident (DBA):

- Provide blowdown system isolation.
- Provide containment isolation.
- Provide capability for interconnection of SGs.

The SGBS has the following design basis requirements and criteria:

- The safety-related portion of the SGBS is designed and fabricated to codes consistent with the quality group classification in accordance with RG 1.26 and the seismic category in accordance with RG 1.29. The design of the SGBS is Seismic Category I and Quality Group B from its connection to the SG inside primary containment up to and including the isolation valves outside containment (GDC 1).
- The non-safety related portions of the SGBS in the Safeguard Buildings Mechanical Division 4 have a seismic category in accordance with RG 1.29 position C.2 for those non-safety related portions of which failure could reduce the functioning of any safety related or Seismic Category I system components to an unacceptable safety level (GDC 1).
- The non-safety-related portion of the SGBS, downstream of the outer containment isolation valves (CIV), meets the quality standards of RG 1.143, regulatory position C.1.1 (GDC 1).
- The non-safety portions of the SGBS downstream of the outer containment isolation valves (CIVs), meets the radwaste classifications defined in RG 1.143, regulatory position C.5. This portion of the system shall be classified as RW-IIa or RW-IIc using the guidance provided in RG 1.143.
- The safety-related portion of the SGBS is designed to function and is protected from the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods and external missiles (GDC 2).
- The blowdown system is sampled continuously to monitor its demineralization and clean up performance (GDC 13).

- The SGBS is designed to blow down up to one percent of the main steam flow rate of all four SGs or up to two percent of a single SG main steam flow rate to maintain water chemistry (GDC 14).

- Consistent with the requirements of 10 CFR 20.1406, the SGBS is designed to minimize, to the extent practicable, contamination of the facility and the environment; facilitate eventual decommissioning; and minimize, to the extent practicable, the generation of radioactive waste (See Section 12.3.6.5). Radiation monitors are designed to isolate SGBS on high blowdown activity coupled with a partial cooldown signal (See Section 11.5.4.3 and Table 11.5-1). For steam generator tube rupture, radiation monitors are designed to isolate SGBS on main steam high activity coupled with a partial cooldown signal or high steam generator water level above the narrow range; only the SGBS of the affected steam generator will be automatically isolated (See Section 11.5.4.1 and Table 11.5-1).

10.4.8.2 System Description

10.4.8.2.1 General Description

Figure 10.4.8-1—Steam Generator Blowdown System Discharge and Cooling and Figure 10.4.8-2—Steam Generator Blowdown Demineralizing System Flow Diagram provide schematic diagrams of the SGBS. Each SG is equipped with its own blowdown line with the capability of blowing down the hot leg and cold leg of the SG shell side. (The hot and cold legs are blown down at low plant loads; otherwise, only the hot leg is blown down.) The blowdown is directed into a flash tank where the flashed steam is returned to the cycle via the deaerator/feedwater storage tank. The liquid portion flows to heat exchangers cooled in two stages by the main condensate system in the first stage and the component cooling system in the second stage before going to the SG blowdown demineralizer. The SGBS also conveys the water from the exit of the SG blowdown demineralizer to the main condenser. The interfaces with the main condensate system, main condenser and feedwater storage tank are addressed in Section 10.4.7.

Each SG is fitted with two nozzles on the hot leg and one nozzle on the cold leg. Piping connects the three nozzles to one blowdown line per SG.

Two secondary sampling system branches are connected to the blowdown collecting lines, one to the cold leg blowdown line and one to the common hot leg blowdown line.

Each of the four blowdown lines is routed through blowdown flow rate adjusting valves to the blowdown flash tank, located in the Reactor Building. The blowdown flow rate adjusting valves control the blowdown flow rate from each SG. The flashed steam is conveyed from the flash tank through containment penetration to the deaerator/feedwater storage tank. The blowdown liquid is transferred from the flash tank, through the first stage blowdown cooler, through the containment penetration, through the second stage blowdown cooler to the SG blowdown demineralizers and from the demineralizers to the main condenser.

The flash line to the deaerator/feedwater tank and blowdown line to the SG blowdown demineralizer can be isolated inside and outside of the Reactor Building by their CIVs. A swing check valve in the flash line prevents backflow of water from the deaerator/ feedwater storage tank.

The blowdown liquid is cooled to approximately 170°F in the first stage blowdown cooler by main condensate. The blowdown liquid is then further cooled to approximately 120°F for the protection of the SG blowdown demineralizers in the second stage blowdown cooler by the component cooling water system (CCWS). The first stage blowdown cooler is located inside the Reactor Building and the second stage blowdown cooler is located in the Nuclear Auxiliary Building.

The SGBS provides sampling connections at the hot and cold blowdown legs of each SG, downstream of the cartridge filter, downstream of the cation exchanger, and downstream of the mixed bed exchanger. Blowdown samples are normally returned to the SGBS upstream of the blowdown demineralizers.

Sodium is sampled upstream of the flash tank and downstream of the blowdown mixed bed exchanger. Specific conductivity and cation conductivity are sampled upstream of the flash tank. Cation conductivity is also sampled downstream of the cation exchanger and downstream of the mixed bed exchanger. Activity is sampled upstream of the flash tank. Refer to Section 9.3.2.2.1.2 for additional information on the SG blowdown sampling system.

The cooled blowdown liquid is cleaned of corrosion products and ionic impurities in the SG blowdown demineralizers. The SG blowdown demineralizing train consists of a backwashable cartridge filter to eliminate solids and a cation exchanger in series with a mixed bed exchanger, followed by a resin trap to eliminate small bits of resin that escape from the cation and mixed bed exchangers. After the resin trap, the demineralized blowdown liquid goes through the flash tank water level control valve into the main condenser.

Spent demineralizing resins are replaced. If activity is detected in the blowdown system, spent resins are flushed out by the demineralized water distribution system into the coolant purification system and disposed of as radwaste. The compressed air distribution system is used to mix up the mixed bed exchanger resins after they have been refilled.

Effluents from backwashing the cartridge filter are conveyed into a drain buffer tank where a waste water pump conveys it to the liquid radwaste storage system.

10.4.8.2.2 Component Description

Table 3.2.2-1 provides the seismic design and other design classifications for components in the SGBS. Section 3.2 describes how the guidance of RG 1.26 and RG 1.29 is implemented for the U.S. EPR.

SG Blowdown Isolation Valves

There are safety-related, electric motor operated, blowdown isolation valves on the hot and cold leg blowdown lines of each SG and a safety-related, electric motor operated, redundant valve on the common blowdown line from each SG. The common blowdown line isolation valves have a diverse power supply from the upstream hot and cold leg blowdown isolation valves. Closing the blowdown isolation valves prevents loss of SG secondary inventory.

Process controls are provided to automatically isolate if the flash tank water level or pressure exceeds allowable limits, if the flash tank safety relief valve opens, or if the blowdown flow rate from a SG exceeds allowable limits.

SG Transfer Lines

The SG transfer lines are used to depressurize a stagnant SG during an SGTR plus LOOP event. These transfer lines are intended to transfer the content of the affected (i.e., stagnant) SG to the unaffected SG. These transfer lines link SGs 1 to 2 and SGs 3 to 4. For redundancy, each transfer line is equipped with two isolation valves, which are in parallel with each other.

Blowdown Flow Rate Adjusting Valves

The blowdown flow rate adjusting valves are designed to discharge the required SG blowdown flow to the flash tank.

Blowdown Flash Tank

Internal volume is sufficient to control the flash tank pressure and level within a narrow range. Nozzles are welded into the vertical shell, top and bottom. Four of the nozzles on top of the tank are for the SG blowdown inlet. The flashed steam is removed from a separate nozzle on the top head. The liquid drains from a nozzle on the lower head. There is an impurity pipe trap on the bottom of the flash tank. The tank is protected against overpressure by the flash tank safety relief valve, in conformance with the ASME Boiler and Pressure Vessel (BPV) Code, Section III-NC (Reference 1).

First Stage Steam Generator Blowdown Cooler

The first stage SG blowdown cooler is a duplex cooler. The blowdown liquid flows through the tubes with the main condensate on the shell side. Nozzles are welded into the shell and water chamber. The tube side of the heat exchanger is protected together with the flash tank against overpressure by the flash tank safety relief valve. The shell side is protected against overpressure by one or more safety relief valves.

Second Stage Steam Generator Blowdown Cooler

The second stage SG blowdown cooler is a duplex cooler. The blowdown liquid flows through the tubes with the component cooling water on the shell side. Nozzles are welded into the shell and water chamber. The tube side of the heat exchanger is protected against overpressure by one or more relief valves. The shell side is protected against overpressure by one or more valves.

Flash Tank Water Level Control Valve

The flash tank water level control valve is designed to discharge the required blowdown liquid flow. It is located in the Turbine Building downstream of the SG blowdown demineralizer and upstream of the main condenser.

Flash Tank Pressure Control Valve

The flash tank pressure control valve is designed to discharge the required flash tank steam flow to the deaerator/feedwater storage tank to hold the pressure in the flash tank to its operating pressure. It is located in the Turbine Building upstream of the deaerator/feedwater storage tank.

Main Condensate Adjusting Valve

The main condensate adjusting valve is designed to adjust the required main condensate flow for the first stage blowdown cooler. See Section 10.4.7 for further details on main condensate system.

Component Cooling Water Adjusting Valve

The component cooling water adjusting valve is designed to adjust the required component cooling flow for the second stage blowdown cooler. See Section 9.2.2 for further details on component cooling system.

SG Blowdown Demineralizer

The SG blowdown demineralizer treats SG blowdown with filtration and ion exchange, and then returns it to the power cycle. It is located in the Nuclear Auxiliary Building.

The main components of the blowdown demineralizer are the cartridge filter, cation exchanger and mixed bed exchanger. Other minor components include compressed air buffer tanks for backwashing the cation and mixed bed exchangers and operating solenoid valves; a drain buffer tank and pump to send backwash effluents to the liquid radwaste storage system, and a resin trap to collect any resin bits that escape from the mixed bed and cation exchangers.

Cartridge Filter

The cartridge filter filters out solid particles from the blowdown. This filter is directly downstream of the second stage blowdown cooler. The filter is bypassable and backwashable. After a certain flow rate has gone through it or after it reaches an unacceptable differential pressure, the blowdown flow bypasses the filter. Then air from the backwash air vessel creates a reverse air-water flow to clean the filter elements. The effluents from backwashing the cartridge filter are sent to the drain buffer tank. When backwashing is complete, the cartridge filter is returned to service.

Cation Exchanger

The cation exchanger is located directly downstream of the cartridge filter. It removes ammonia dissolved in the water. The blowdown sampling system monitors the water quality just downstream of the cation exchanger. If the conductivity of the cation exchanger exceeds allowable values, the resins in the cation exchanger are regenerated or replaced.

Mixed Bed Exchanger

The mixed bed exchanger is located directly downstream of the cation exchanger. It removes cations as well as anions from the blowdown water. The blowdown sampling system monitors the water quality downstream of the mixed bed exchanger. If the conductivity of the mixed bed exchanger exceeds allowable values, the resins in the mixed bed exchanger are replaced. During replacement, both the cation exchanger and mixed bed exchanger are bypassed. New anion and cation resins are put into the mixed bed exchanger and mixed by compressed air (if needed) prior to return to service.

10.4.8.3 System Operation

10.4.8.3.1 Normal Operating Conditions

Operation of the deaerator/feedwater storage tank, and at least one main condensate pump and the second stage blowdown cooler (component cooling water system) are required for blowdown system operation. After opening all blowdown system CIVs and then the blowdown isolation valves, the blowdown rate adjusting valves upstream of the flash tank are partially opened to warm up the flash tank, and then opened until the required total blowdown flow rate is obtained. The flash tank level control valve stays closed until the operating water level in the flash tank is obtained. The flash tank pressure control valve controls the pressure in the flash tank at its operating setpoint pressure.

The blowdown water is flashed in the blowdown flow rate adjusting valves, routed to the flash tank and separated into a steam and water phase. The steam phase flows to the deaerator/feedwater storage tank.

The liquid phase is cooled by the first and second stage blowdown coolers and flows to the SG blowdown demineralizer, which then filters, treats and recycles the blowdown to the main condenser.

During normal operating conditions at plant load greater than 15 percent, the four SGs are blown down continuously on only the hot leg. At plant load of less than 15 percent, the four SGs are blown down on both the hot and cold leg. The normal blowdown flow rate is adjustable up to one percent of main steam flow per SG at full power. If required, the blowdown of three SGs can be interrupted and the fourth SG can be blown down with a maximum flow rate of two percent of the fourth SGs main steam flow.

If the plant is shut down, the outside CIVs and SG blowdown isolation valves are closed.

The SGs may be drained with the SGBS when a wet and cold storage or a dry storage of SGs is required.

10.4.8.3.2 Abnormal Operating Conditions

The effect of loss of the SGBS has no immediate consequences on plant operation. Depending on the water chemistry parameters, the plant may be shut down if specified values are exceeded. The secondary water chemistry program is described in Section 10.3.5.

Normally, the flash tank pressure control valve maintains the pressure in the flash tank by controlling the flow of steam exiting the flash tank. In case of flash tank pressure control valve malfunction leading to excessive pressure in the flash tank, the blowdown is reduced or stopped by closing the SG blowdown flow rate adjusting valves and/or SG blowdown isolation valves. Valves are closed automatically upon reaching a setpoint pressure to prevent opening the flash tank safety relief valve and subsequent loss of SG secondary inventory through the safety relief valve.

Normally, the flash tank water level control valve maintains the level in the flash tank by controlling the flow of water leaving the tank. In case of flash tank water level control valve malfunction leading to excessive high water level in the flash tank, blowdown is reduced or stopped by closing the SG blowdown flow rate adjusting valves and/or SG blowdown isolation valves. Valves are closed automatically upon reaching a setpoint water level to prevent the water hammer that could occur inside the flash tank if the water level were to reach the flash tank inlet nozzles.

The isolation valve downstream of the demineralizer is automatically closed to protect the SG blowdown demineralizer resin if the temperature of the blowdown water downstream of the second stage blowdown coolers reaches 131°F. The temperature limit could be exceeded if the main condensate flow or component cooling water flow (or both) is too low; or if the main condensate temperature or component cooling water temperature (or both) is too high; or if the flash tank pressure is too high. When the blowdown demineralizer isolation valve closes, the flash tank water level increases and the blowdown operation is stopped by the automatic closure of the SG blowdown adjusting valves or SG blowdown isolation valves.

In special cases, the entire SG blowdown demineralizing system can be bypassed around to the main condenser, or the blowdown can also be bypassed to the liquid waste storage system instead of to the main condenser. The blowdown can be manually discharged to the liquid waste management system if radioactivity is detected in the blowdown. Radiation monitors are designed to isolate SGBS on high blowdown activity coupled with a partial cooldown signal; only the SGBS of the affected steam generator will be automatically isolated (See Section 11.5.4.3 and Table 11.5-1).

10.4.8.3.3 Accident Conditions

The blowdown isolation valves isolate on a containment isolation signal or emergency feedwater (EFW) actuation signal, or mainsteam isolation signal with low SG pressure or high SG pressure drop. For steam generator tube rupture, radiation monitors are designed to isolate SGBS on main steam high activity coupled with a partial cooldown signal or high steam generator water level above the narrow range with a partial cooldown; only the SGBS of the affected steam generator will be automatically isolated (See Section 11.5.4.1 and Table 11.5-1).

10.4.8.4 Safety Evaluation

The design of the SGBS satisfies GDC 1 as it relates to system components being designed, fabricated, erected, and tested for quality standards.

- The safety-related portion of the SGBS is designed and fabricated to codes consistent with the quality group classification in accordance with RG 1.26 and the seismic category in accordance with RG 1.29. The design of the SGBS is Seismic Category I and Quality Group B from its connection to the SG inside primary containment up to and including the isolation valves outside containment. Table 3.2.2-1 provides the seismic design and other design classifications for components in the SGBS.

- The power supplies and control function necessary for the safety functions of the system are Class IE, as described in Chapter 7 and Chapter 8.
- The non-safety-related portion of the SGBS, downstream of the outer containment isolation valves (CIV), meets the quality standards of RG 1.143, regulatory position C.1.1.

The SGBS design satisfies RG 1.143, Regulatory Position C.5, as it relates to radwaste classifications so that the radiological release/quantity is met.

The design of the SGBS satisfies GDC 2 regarding protection from the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods and external missiles per general design criterion.

- The safety-related portions of the SGBS are located in the Reactor Building and the Safeguard Buildings. These buildings are designed to withstand the effects of earthquakes, tornadoes, hurricanes, floods, external missiles and other similar natural phenomena. Sections 3.3, 3.4, 3.5, 3.7, and 3.8 provide the bases for the adequacy of the structural design of these buildings.
- The safety-related portions of the SGBS are designed to remain functional after an SSE. Sections 3.7 and 3.9 discuss the design loading conditions considered.
- The foundations and walls of structures that house the SGBS, downstream of the outer CIV, are consistent with the natural phenomena and internal and external man-induced hazards criteria in RG 1.143, positions 1.1.3 and 6.

The SGBS design satisfies GDC 13 as it relates to monitoring system variables that can affect the reactor coolant pressure boundary and maintaining them within prescribed operating ranges.

- The SGBS maintains secondary chemistry within allowable limits. The blowdown system is sampled continuously to monitor its demineralization and clean up performance. The sampling system is further described in Section 9.3.2.

The SGBS design satisfies GDC 14 as it relates to secondary water chemistry control so that SG tube material integrity is maintained. Section 5.4.2 provides information concerning SG internal design related to blowdown.

- The SGBS maintains contaminants and minerals produced by phase separation in the steam generators within predetermined limits by a continuous blowdown of a portion of the total SG hot leg flow. Section 10.3.5 provides the description of the secondary water chemistry program and associated limits.
- Controls are provided to protect the SGBS demineralizers from high temperatures.

The single failure criterion is applied to the CIVs, SGBS isolation valves, SGBS 1&2 transfer valves, and SGBS 3&4 transfer valves. Section 6.2.4 and Section 6.2.6 discuss the system containment isolation arrangement and containment leakage testing. Section 8.3.1.2.11 discusses the application of Branch Technical Position (BTP) 8-4 to the SGBS 1&2 and 3&4 transfer valves as a means of designing against a single failure.

10.4.8.5 Inspection and Testing Requirements

The SGBS components are inspected and tested during plant startup. Refer to Section 14.2 (test abstracts #067, #072, #185 and #204) for initial plant startup test program.

The design of the SGBS includes the capability for inservice testing. This includes operation of applicable portions of the protection system. Refer to Section 3.9.6 for a description of the inservice testing program.

The SGBS components are designed and located to permit preservice and inservice inspections to the extent practical. The SGBS lines within the containment and Safeguard Buildings up to and including the isolation valves outside containment are inspected at installation as required by ASME Code, Section XI (Reference 2) preservice inspection requirements. Refer to Section 6.6 for a description of the inservice inspection program.

10.4.8.6 Instrumentation Requirements

The SGBS instrumentation is provided to facilitate automatic operation, remote control and continuous indication of system parameters.

Process radiation monitors are provided in the SG blowdown sampling system. These monitors are discussed in Section 11.5.4.3.

Safety-related isolation functions of the SGBS are performed by the protection system as described above in Section 10.4.8.3.3.

Non-safety related instrumentation and control (I&C) functions are performed by the process automation system.

10.4.8.7 References

1. ASME Boiler and Pressure Vessel Code, Section III, Division 1, Class 2 Components, Subsection NC: Article 7000 "Overpressure Protection," The American Society of Mechanical Engineers, 2004.

2. ASME Boiler and Pressure Vessel Code, Section XI: "Rules for Inservice Inspection of Nuclear Power Plant Components," The American Society of Mechanical Engineers, 2004.

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