6.8 Extra Borating System

The extra borating system (EBS) injects borated water into the reactor coolant system (RCS) to maintain the core subcritical for safe shutdown.

6.8.1 Design Bases

The EBS is designed to inject concentrated boron solution into the RCS against any credible RCS pressure. The EBS injects borated water into the RCS at a rate sufficient to maintain subcriticality during the cool down from any operational or anticipated transient, and is required to maintain subcriticality for the steam generator tube rupture (SGTR) event described in Section 15.6.3. The EBS also provides reactivity control to support the capability to take the reactor from normal operating conditions to cold shutdown using only safety-related systems, in accordance with Branch Technical Position 5-4.

- A portion of the EBS is part of the reactor coolant pressure boundary (RCPB). The system is normally isolated from the RCS to maintain the integrity of the RCPB in the event of a leak in the EBS piping (GDC 14).
- The EBS provides containment isolation for EBS piping that penetrates containment (GDC 54).
- EBS components are designed to quality standards commensurate with their importance to safety (GDC 1). As such, the EBS is protected from the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, and external missiles, and is designed to function following such events (GDC 2). It is designed to remain functional following the postulated hazards of fire and explosion (GDC 3), is designed to withstand internal missiles, pipe whipping, and discharging fluids (GDC 4), and is not shared among nuclear power units (GDC 5).
- The EBS has both an onsite and an offsite electric power system, each of which can alone power it to its full capacity (GDC 17).
- The EBS is capable of adding sufficient neutron poison to reliably control reactivity changes and maintain the capability to cool the core under postulated conditions for the SGTR event (GDC 27).

6.8.2 System Description

The EBS is composed of two trains, designated Trains 1 and 4 to reflect their divisional separation. Each train consists of a borated water storage tank, a full-capacity positive displacement pump, and a test line (all of which are located in the Fuel Building), and an injection line into the RCS via the safety injection nozzles. Key design and operating parameters for the EBS are listed in Table 6.8-1—Extra Borating System Design and Operating Parameters and the general configuration of the EBS is shown schematically in Figure 6.8-1—Extra Borating System. The materials of construction for the EBS are described in Section 6.1.1. Refer to Section 3.2 for the seismic and system quality group classifications for the EBS.

The EBS pumps are air cooled, positive-displacement piston pumps. Power is supplied to the pumps from the 480 Vac electrical distribution buses and emergency diesel generators provide backup power.

The EBS tanks are located above the pumps to maintain adequate net positive suction head. The two EBS tanks are interconnected through a normally open flow path that allows either EBS pump to draw from both tanks.

A test line with a multi-stage flow restrictor in each EBS train allows it to be tested at its required injection pressure by recirculating the borated water in the EBS tank. This feature also allows mixing and heating of the EBS inventory using pump energy, thereby eliminating any requirement for heaters or mixers in the tanks. Flow and pressure indications confirm proper pump operation. If EBS injection is required during the periodic test, the test line motor-operated valves (MOVs) are closed and the outboard containment isolation MOVs are opened.

Each EBS train's injection line branches into two lines just downstream of its Containment Building penetration. Each branch line connects to a safety injection system (SIS) line upstream of the SIS check valve, which in turn connects to an RCS cold leg. Each line is isolated with its normally closed MOV. The EBS piping between the containment isolation valves and the outboard RCS isolation valves is protected by relief valves against over pressure due to thermal expansion.

The EBS is designed to prevent boric acid crystallization during standby without heat tracing. The temperature inside the Fuel Building where the tanks and main lines are located is maintained above 68°F by the fuel building ventilation system. For piping outside the temperature controlled rooms, a normally closed suction connection from the in-containment refueling water storage tank (IRWST), described in Section 6.3, allows those pipes to be filled with lower boron concentration water to prevent crystallization.

The EBS lines outside the temperature controlled rooms are also thermally insulated. After an initiation of the EBS, the insulation delays crystallization of the boric acid remaining in the lines to allow time for the lines to be purged with IRWST water, or to take other measures to prevent crystallization.

A normally closed suction connection from the volume control tank allows the EBS to be used for hydrostatic testing of the RCS. A normally closed connection from the Train 1 EBS pump discharge line to seal #1 of the reactor coolant pumps—via the chemical and volume control system (CVCS) seal injection header—provides the injection path for these tests.

6.8.2.1 System Operation

In the event of an SGTR, or for any instance where shutdown is required and boration from other sources is not available (such as from the IRWST, CVCS, or the reactor boron and water makeup system), EBS injection is required and is manually initiated by the operator in the Main Control Room (MCR). Manual operation is not required to mitigate a design basis event for the first 30 minutes after event initiation. If a containment isolation signal that automatically closes the EBS containment isolation valves occurs, the signal immediately resets to allow the valves to be reopened so that EBS injection may proceed. Once injection begins, the EBS operates until the operator manually stops the EBS injection based on EBS level for minimum required injected volume. Level indications and alarms alert the operator if the EBS tank inventory is nearing depletion so that the pumps are stopped prior to loss of suction. The SGTR response sequence is described in Section 15.6.3.

During normal operations, the EBS is in standby and has no function other than periodic mixing of the borated water in the EBS tanks and periodic system testing. The concentrated boric acid solution in the tanks is initially prepared in the mixing tank of the reactor boron and water makeup system (RBWMS) and transferred to the EBS tanks. The EBS tanks' levels and temperatures are continuously monitored to verify system readiness.

6.8.3 Safety Evaluation

The EBS concentration of boric acid, enriched with B-10, provides the required negative reactivity insertion. The minimum volume of concentrated borated water for the EBS is conservatively established as that required to maintain subcriticality in the cold condition without control rods at the most limiting (reactive) stage of core life. The volume is divided between the two EBS tanks.

The minimum required EBS injection flow rate is sufficient to compensate for the positive reactivity addition due to RCS cooldown and xenon decay, and to maintain a sufficient shutdown margin. The maximum allowable EBS injection flow rate, which is less than the average rate of reactor coolant contraction that occurs during a postulated SGTR due to cooldown, prevents the pressure control instability that would result from overfilling the RCS.

Each train of the EBS is physically separated from the other by a wall in the Fuel Building that extends to the containment penetration. To avoid common mode failures, the common suction lines and outlet lines are separated from each other and from high energy pipes in other systems. Only one train of the EBS could be affected by internal missiles due to the system layout and train separations.

The separation of the trains by fire rated barriers protects the system's function from fire or explosion. The physical separation of the trains protects the system's function from an internal flood, which would be limited to a single division. The EBS equipment inside the Reactor Building is located above the flood level that would result from a piping failure.

The seismic Category I qualification of the Fuel Building, Reactor Building, and the EBS protect the system from earthquake damage. The Reactor Building and the Fuel Building are designed to protect against external hazards such as explosion, wind, missiles, or flooding.

The design pressure of those portions of the EBS downstream of the pumps is significantly higher than the design pressure of the RCS. In addition, the downstream components and piping are isolated from the RCS by multiple valves. These measures protect the EBS from unintentional exposure to pressurized reactor coolant.

The pump discharge relief valves protect the system from over-pressurization from pump dead-head operation due to system misalignment. In the event one of the pump discharge relief valves sticks open during required injection, the diverted inventory circulates back to the EBS tank and the unaffected train completes the injection.

The relief valves on the injection piping protect the containment penetration and injection piping against over pressurization due to thermal expansion. In the event one of the thermal relief valves inside containment sticks open during required injection, the relatively low capacity of the valve allows sufficient injection flow to the RCS to fulfill the system function.

As noted above, various systems prevent crystallization of boric acid within the EBS. The ventilation system in the Fuel Building rooms housing the EBS maintains the room temperature at a minimum of 68°F. The ventilation system is configured to receive power, if necessary, from the emergency diesel generators. In the unlikely event of a failure of the ventilation system, the EBS pumps on the test lines can be started to heat the boric acid solution. The EBS lines outside of the temperature-controlled area are normally filled with lower concentration borated water from the IRWST. These lines are also thermally insulated to delay boric acid crystallization of the high boron concentration water after an EBS actuation. The EBS injects into the safety injection lines downstream of the safety injection pumps. Thus, if boric acid crystallization were to occur in the SIS or RCS piping it would not block the safety injection pump suction.

Due to their physical and electrical separation, and the redundancy of two full-capacity pump trains, no single active failure will prevent the EBS from fulfilling its function. The most limiting single failure is determined to be the loss of one electrical division, in which case the remaining train is available to fulfill the EBS function.

Leakage from the EBS is detected, monitored, and controlled by plant operating procedures and programs.

6.8.4 Inspection and Testing Requirements

Refer to Sections 5.4.2 and 6.6 for inservice inspection of the EBS, and to Section 3.9.6 for inservice testing of EBS pumps and valves. Initial plant testing is addressed in Section 14.2 (Test #019), and Surveillance Requirement 3.5.5 in Chapter 16 describes the EBS surveillance requirements.

6.8.5 Instrumentation Requirements

System instrumentation is shown on Figure 6.8-1. The indicators and alarms for the EBS parameters, such as tank level and temperature, pump status, and valve alignment, are in the MCR and are used to confirm the system's standby readiness. Sampling of the tank inventory and downstream piping confirm the required boron concentrations.

In the event of an SGTR, or for any instance where shutdown is required and boration from other sources is not available (such as from the IRWST, CVCS, or RBWMS), EBS injection is required and is started manually.

MCR instruments, such as discharge pressure and flow rate, confirm the system operation, and alarms alert the operator to any abnormal system conditions. If a containment isolation signal that automatically closes the EBS containment isolation valves occurs, the signal immediately resets to allow the valves to be reopened so that EBS injection may proceed. The operator manually terminates EBS injection when the minimum EBS inventory as been injected based on tank level indication. EBS tank level alarms alert the operator to terminate injection prior to loss of pump suction.

Table 6.8-1—Extra Borating System Design and Operating Parameters

Parameter	Value
Pump design pressure	3770 psig
Pump design temperature	212°F
Nominal flow rate	52 gpm / pump
Minimum required flow rate	49 gpm
Maximum allowable flow rate	110.8 gpm
Tank design pressure	15 psig
Tank design temperature	140°F
Minimum boron enrichment	37% B-10
Boron concentration in tank	7000 to 7300 ppm
Tank gross volume (Tank 1 / Tank 4)	1274 ft^3 / 1253 ft^3
Tank minimum required volume (based on analysis)	1994 ft^3
Pump discharge relief valve setpoint / capacity	3625 psig / 52 gpm
Penetration and injection piping relief valve setpoint / capacity	3395 psig / 1 gpm

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