7.3 Engineered Safety Features

AP1000 provides instrumentation and controls to sense accident situations and initiate engineered safety features (ESF). The occurrence of a limiting fault, such as a loss of coolant accident or a secondary system break, requires a reactor trip plus actuation of one or more of the engineered safety features. This combination of events prevents or mitigates damage to the core and reactor coolant system components, and provides containment integrity.

7.3.1 Description

The protection and safety monitoring system is actuated when safety system setpoints are reached for selected plant parameters. The selected combination of process parameter setpoint violations is indicative of primary or secondary system boundary ruptures. Once the required logic combination is generated, the protection and safety monitoring system equipment sends the signals to actuate appropriate engineered safety features components. A block diagram of the protection and safety monitoring system is provided in Figure 7.1-2.

The following paragraphs summarize the major functional elements of the protection and safety monitoring system that are involved in generating an actuation signal to an engineered safety features component.

Four sensors normally monitor each variable used for an engineered safety feature actuation. (These sensors may monitor the same variable for a reactor trip function.) Analog measurements are converted to digital form by analog-to-digital converters within each of the four divisions of the protection and safety monitoring system. Following required signal conditioning or processing, the measurements are compared against the setpoints for the engineered safety feature to be generated. When the measurement exceeds the setpoint, the output of the comparison results in a channel partial trip condition. The partial trip information is transmitted to the ESF coincidence logic to form the signals that result in an engineered safety features actuation. The voting logic is performed twice within each division. Each voting logic element generates an actuation signal if the required coincidence of partial trips exists at its inputs.

The signals are combined within each division of ESF coincidence logic to generate a system-level signal. System-level manual actions are also processed by the logic in each division.

The system-level signals are then broken down to the individual actuation signals to actuate each component associated with a system-level engineered safety feature. For example, a single safeguards actuation signal must trip the reactor and the reactor coolant pumps, align core makeup tank and in-containment refueling water storage tank valves, and initiate containment isolation. The interposing logic accomplishes this function and also performs necessary interlocking so that components are properly aligned for safety. Component-level manual actions are also processed by this interposing logic. The power interface transforms the low level signals to voltages and currents commensurate with the actuation devices they operate. The actuation devices, in turn, control motive power to the final engineered safety feature component.

Subsection 7.3.1.2 provides a functional description of the signals and initiating logic for each of the engineered safety features. Figure 7.2-1 presents the functional diagrams for engineered safety features actuation.

Table 7.3-1 summarizes the signals and initiating logic for each of the engineered safety features initiated by the protection and safety monitoring system. Most of the functions provide protection against design basis events which are analyzed in Chapter 15. However, not all the functions listed in Table 7.3-1 are necessary to meet the assumptions used in performing the safety analysis. For example, the design provides features which provide automatic actuations which are not required for performing the safety analysis. In addition, some functions are provided to support assumptions used in the probabilistic risk assessment, but are not used to mitigate a design basis accident. Only those functions which meet the 10 CFR 50.36(c)(2)(ii) criteria are included in the AP1000 DCD, Section 16.1, Technical Specifications. This accounts for any difference between functions listed in Table 7.3-1 and functions which are included in the Technical Specifications.

7.3.1.1 Safeguards Actuation (S) Signal

A safeguards actuation (S) signal is used in the initiation logic of many of the engineered safety features discussed in subsection 7.3.1.2. In addition, as described in Section 7.2, the safeguards actuation signal also initiates a reactor trip. The variables that are monitored and used to generate a safeguards actuation signal are typically those that provide indication of a significant plant transient that requires a response by several engineered safety features.

The safeguards actuation signal is generated from any of the following initiating conditions:

1. Low pressurizer pressure
2. Low lead-lag compensated steam line pressure
3. Low cold leg temperature
4. High-2 containment pressure
5. Manual initiation

Condition 1 results from the coincidence of pressurizer pressure below the Low setpoint in any two of the four divisions.

Condition 2 results from the coincidence of two of the four divisions of compensated steam line pressure below the Low setpoint in either of the two steam lines. The steam line pressure signal is lead-lag compensated to improve system response.

Condition 3 results from the coincidence of two of the four divisions of reactor coolant system cold leg temperature below the Low setpoint in any loop.

Condition 4 results from the coincidence of two of the four divisions of containment pressure above the High-2 setpoint.

Condition 5 consists of two momentary controls. Manual actuation of either of the two controls will trip the reactor and generate a safeguards actuation signal.

To permit startup and cooldown, the safeguards actuation signals generated from low pressurizer pressure, low steam line pressure, or low reactor coolant inlet temperature can be manually blocked when pressurizer pressure is below the P-11 setpoint. The signal is automatically unblocked when the pressurizer pressure is above the P-11 setpoint.

Separate momentary controls are provided, each of which will manually reset the safeguards actuation signal in a single division. Manual reset of a safeguards actuation signal in coincidence with reactor trip breaker open (P-3) blocks the safeguards actuation signal. Absence of P-3 automatically resets the blocking function. The safeguards actuation signal is manually reset based on a preset delay following initiation. Resetting the signal does not reposition any safeguards actuated equipment, since individual components are required to latch in and seal on the safeguards actuation signal.

The logic relating to the development of the safeguards actuation signal is illustrated in Figure 7.2-1, sheets 9 and 11.

7.3.1.2 Engineered Safety Feature Descriptions

The following subsections provide a functional description of the signals and initiating logic for each engineered safety feature. Table 7.3-1 lists the signals and summarizes the coincidence logic used to generate the safeguards actuation signal or initiate each engineered safety feature. Table 7.3-2 describes the permissives and interlocks relating to the engineered safety features. Table 7.3-3 lists the system-level manual input to the engineered safety features.

7.3.1.2.1 Containment Isolation

A signal to actuate containment isolation is generated from any of the following conditions:

1. Automatic or manual safeguards actuation signal (subsection 7.3.1.1)
2. Manual initiation
3. Manual actuation of passive containment cooling (subsection 7.3.1.2.12)

Conditions 1 and 3 are discussed in other subsections as noted.

Condition 2 consists of the manual actuation of either of two momentary controls in the main control room. Either control actuates all divisions and closes the nonessential fluid system paths from the containment.

Manual reset is provided to block the automatic actuation signal for containment isolation. Separate momentary controls are provided for resetting each division.

No other interlocks or permissive signals apply directly to the containment isolation function. Automatic actuation originates from a safeguards actuation (S) signal that does contain interlock and permissive inputs.

The functional logic that actuates containment isolation is illustrated in Figure 7.2-1, sheets 11 and 13.

7.3.1.2.2 In-Containment Refueling Water Storage Tank Injection

Signals to align the in-containment refueling water storage tank for injection are generated from the following conditions:

1. Actuation of the fourth stage of the automatic depressurization system (subsection 7.3.1.2.4)

2. Coincidence loop 1 and loop 2 hot leg levels below Low-2 setpoint for a duration exceeding an adjustable time delay

3. Manual initiation

Each of the above conditions opens the in-containment refueling water storage tank injection valves, thereby providing a flow path to the reactor coolant system.

In addition to initiating in-containment refueling water storage tank injection, condition 2 also initiates the opening sequence of the fourth stage of the automatic depressurization system. This is discussed in subsection 7.3.1.2.4.

Condition 3 consists of two sets of two momentary controls. Manual actuation of both controls of either of the two control sets generates signals that open the in-containment refueling water storage tank injection valves. A two-control simultaneous actuation prevents inadvertent actuation.

In-containment refueling water storage tank injection on Low-2 hot leg level is automatically blocked when the pressurizer water level is above the P-12 setpoint. This reduces the probability of a spurious injection. This block is removed when the core makeup tank actuation on low pressurizer level function is manually blocked to allow mid-loop operation. As described in subsection 7.3.1.2.3, this core makeup tank actuation function can be manually blocked when the pressurizer water level is below the P-12 setpoint.

The functional logic relating to in-containment refueling water storage tank injection is illustrated in Figure 7.2-1, sheets 12 and 16.

7.3.1.2.3 Core Makeup Tank Injection

Signals to align the core makeup tanks for injection are generated from the following conditions:

1. Automatic or manual safeguards actuation (subsection 7.3.1.1)

2. Automatic or manual actuation of the first stage of the automatic depressurization system (subsection 7.3.1.2.4)

3. Low-2 pressurizer level

4. Low wide range steam generator level coincident with High hot leg temperature

5. Manual initiation

Conditions 1 through 5 initiate a block of the pressurizer heaters; trip the reactor and reactor coolant pumps; initiate alignment of the core makeup tank isolation valves for passive injection to the reactor coolant system; and provide a confirmatory open signal to the cold leg balance line isolation valves. The balance line isolation valves are normally open but can be closed by the operator. The confirmatory open signal automatically overrides any bypass features that are provided to allow the cold leg balance line isolation valves to be closed for short periods of time. The motive force for core makeup tank injection is provided by density differences between the fluids in the cold leg balance line and the core makeup tank water.

Condition 3 results from the coincidence of pressurizer level below the Low-2 setpoint in any two of the four divisions. This function can be manually blocked when the pressurizer water level is below the P-12 setpoint. This function is automatically unblocked when the pressurizer water level is above the P-12 setpoint.

Condition 4 is derived from a coincidence of:

- Both steam generator 1 and steam generator 2 wide range level below the Low setpoint (derived from two of the four wide range level measurement divisions for each steam generator), and
- Two of the four divisions of hot leg temperature above the High (T_{hot}) setpoint

Condition 5 consists of two momentary controls. Manual actuation of either of the two controls will align the core makeup tanks for injection.

The functional logic relating to core makeup tank injection is illustrated in Figure 7.2-1, sheets 7, 12 and 15.

7.3.1.2.4 Automatic Depressurization System Actuation

A signal to actuate the first stage of the automatic depressurization system is generated from any of the following conditions:

1. Core makeup tank injection alignment signal (subsection 7.3.1.2.3) coincident with core makeup tank level less than the Low-1 setpoint in either core makeup tank in two of the four divisions
2. Extended loss of ac power sources (low Class 1E battery charger input voltage)
3. Manual initiation

Any actuation of the first stage of the automatic depressurization system also trips the reactor and reactor coolant pumps, align the core makeup tanks for injection, and actuates the passive residual heat removal heat exchanger.

The automatic depressurization system is arranged to sequentially open four parallel stages of valves. Each of the first three stages consists of two parallel paths with each path containing an isolation valve and a depressurization valve. The first three stages are connected to the pressurizer and discharge into the in-containment refueling water storage tank. The fourth stage paths are connected to the hot legs of the reactor coolant system and discharge to containment.

The first stage isolation valves open on any actuation of the first stage of the automatic depressurization system. The first stage depressurization valves are opened following a preset time delay after the opening of the isolation valves. No interlocks or permissive signals apply directly to the first stage depressurization. However, some safeguards actuation signals, from which the core makeup tank injection actuation signal is derived, do contain interlock and permissive inputs.

The second stage isolation valves are opened following a preset time delay after the first stage depressurization valves open. The second stage depressurization valves are opened following a preset time delay after the second stage isolation valves are opened, similar to stage one. Actuation of the second stage depressurization valves is interlocked with the first stage depressurization actuation signal so that the second stage is not actuated until after the first stage actuation signal has been generated.

Similar to the second stage, the third stage isolation valves are opened following a preset time delay after the opening of the second stage depressurization valves. The third stage depressurization valves are opened following a preset time delay after the third stage isolation valves are opened. Actuation of the third stage depressurization valves is interlocked with the second stage depressurization actuation signal such that the third stage is not actuated until after the second stage actuation signal has been generated.

The fourth stage of the automatic depressurization system consists of four parallel paths. Each of these paths consists of a normally open isolation valve and a depressurization valve. The four paths are divided into two redundant groups with two paths in each group. Within each group, one path is designated to be substage A and the second path is designated to be substage B.

The fourth stage is actuated upon the coincidence of a Low-2 core makeup tank level and Low reactor coolant system pressure following a preset time delay after the third stage depressurization valves are opened. The Low-2 core makeup tank level input is based on the core makeup tank level being less than the Low-2 setpoint in two of the four divisions in either core makeup tank. Upon a fourth stage actuation signal, a confirmatory open signal is immediately provided to the substage-A isolation valves. The substage-A depressurization valves are opened following a preset time delay after the substage-A isolation valve confirmatory open signal. The sequence is continued with substage-B. A confirmatory open signal is provided to the substage-B isolation valves following a preset time delay after the substage-A depressurization valve has been opened. The signal to open the substage-B depressurization valve is provided following a preset time delay after the substage-B isolation valves confirmatory open signal. The net effect is to provide a controlled depressurization of the reactor coolant system. In addition to initiating this controlled depressurization sequence, the fourth stage actuation signal also provides a signal that aligns the in-containment refueling water storage tank for injection, as discussed in subsection 7.3.1.2.2.

A signal to initiate the opening sequence of the fourth stage is also generated upon the occurrence of coincidence loop 1 and loop 2 hot leg levels below the Low-2 setpoint for a duration exceeding an adjustable time delay. This signal also initiates in-containment refueling water storage tank injection. As discussed in subsection 7.3.1.2.2, this signal is automatically blocked when the pressurizer water level is above the P-12 setpoint. This reduces the probability of a spurious signal. The block is removed when the core makeup tanks actuation on low pressurizer level function is manually blocked to allow mid-loop operation.

The fourth stage can also be manually initiated. In this case the manual initiation signal is interlocked to prevent actuation until either the reactor coolant system pressure has decreased below a preset setpoint, or until the signals which control the opening sequence of the first, second, and third stage valves have been generated. As discussed above, the signals to the first, second, and third stage valves are generated based on preset time delays.

The core makeup tank injection alignment signal, which is part of condition 1, is latched-in upon its occurrence. A deliberate operator action is required to reset this latch. This feature is provided so that an automatic depressurization system actuation signal is not cleared by the reset of the safeguards actuation signal as discussed in subsection 7.3.1.1.

Condition 2 results from the loss of all ac power for a period of time that approaches the 24-hour Class 1E dc battery capability to activate the automatic depressurization system valves. The timed output holds upon restoration of ac power and is manually reset after the batteries are recharged. The loss of all ac power is detected by undervoltage sensors that are connected to the input of each of the four Class 1E battery chargers. Two sensors are connected to each of the four battery charger inputs. The loss of ac power signal is based on the detection of an undervoltage condition by either of the two sensors connected to two of the four battery chargers.

Condition 3 is achieved via either of two sets of two momentary controls. If both controls of either set are operated simultaneously, actuation of the automatic depressurization system occurs. A two-control simultaneous actuation prevents inadvertent actuation.

The functional logic relating to automatic depressurization operation is illustrated in Figure 7.2-1, sheet 15.

7.3.1.2.5 Reactor Coolant Pump Trip

A signal to trip reactor coolant pumps is generated from any one of the following conditions:

1. Automatic or manual safeguards actuation signal (subsection 7.3.1.1)

2. Automatic or manual actuation of the first stage of the automatic depressurization system (subsection 7.3.1.2.4)

3. Low-2 pressurizer level

4. Low wide range steam generator level coincident with High hot leg temperature

5. Manual initiation of core makeup tank injection (subsection 7.3.1.2.3)

6. High reactor coolant pump bearing water temperature (trips only affected reactor coolant pump)

Once a signal to trip a reactor coolant pump is generated, the actual tripping of the pump is delayed by a preset time delay. While conditions 1 through 5 trip all four reactor coolant pumps, condition 6 trips only the reactor coolant pump with the high bearing water temperature condition.

Condition 3 results from the coincidence of pressurizer level below the Low-2 setpoint in any two of the four divisions. This function can be manually blocked when the pressurizer water level is below the P-12 setpoint. This function is automatically unblocked when the pressurizer water level is above the P-12 setpoint.

Condition 4 is derived from a coincidence of:

- Both steam generator 1 and steam generator 2 wide range level below the Low setpoint (derived from two of the four wide range level measurement divisions for each steam generator), and

- Two of the four divisions of hot leg temperature above the High (T_{hot}) setpoint

Condition 6 is derived from a coincidence of two of the four divisions of high reactor coolant pump bearing water temperature for a single reactor coolant pump. Each reactor coolant pump is tripped independently if Condition 6 is met for its own bearing water temperature. This function is included for equipment protection. The high temperature setpoint and dynamic compensation are the same as used in the high reactor coolant pump bearing water temperature reactor trip (subsection 7.2.1.1.3) but with the inclusion of preset time delay.

The functional logic relating to the tripping of the reactor coolant pumps is illustrated in Figure 7.2-1, sheets 5, 7, 12, and 15.

7.3.1.2.6 Main Feedwater Isolation

Signals to isolate the main feedwater supply to the steam generators are generated from any of the following conditions:

1. Automatic or manual safeguards actuation (subsection 7.3.1.1)
2. Manual initiation
3. High-2 steam generator narrow range water level
4. Low-1 reactor coolant system average temperature coincident with P-4 permissive
5. Low-2 reactor coolant system average temperature coincident with P-4 permissive

Conditions 1, 2, and 3 isolate the main feedwater supply by tripping the main feedwater pumps and closing the main feedwater control, isolation and crossover valves. These conditions also initiate a turbine trip.

Condition 2 consists of two momentary controls. Manual actuation of either of the two controls will trip the turbine and isolate the main feedwater supply. This action also initiates isolation of startup feedwater (subsection 7.3.1.2.13).

Condition 3 is derived from a coincidence of two of the four divisions of narrow range steam generator water level above the High-2 setpoint for either steam generator. In addition to tripping the turbine and isolating the main feedwater supply, condition 3 also initiates a reactor trip, isolates the startup feedwater supply (subsection 7.3.1.2.13), and isolates the chemical volume control system.

Condition 4 results from a coincidence of two of the four divisions of reactor loop average temperature (T_{avg}) below the Low-1 setpoint coincident with the P-4 permissive (reactor trip). This condition results in the closure of the main feedwater control valves. The feedwater isolation resulting from this condition may be manually blocked when the pressurizer pressure is below the P-11 setpoint. The block is automatically removed when the pressurizer pressure is above the P-11 setpoint.

Condition 5 results from a coincidence of two of the four divisions of reactor loop average temperature (T_{avg}) below the Low-2 setpoint coincident with the P-4 permissive (reactor trip). This condition results in the tripping of the main feedwater pumps and closure of the main feedwater isolation and crossover valves. The feedwater isolation resulting from this condition may be manually blocked when the pressurizer pressure is below the P-11 setpoint. The block is automatically removed when the pressurizer pressure is above the P-11 setpoint.

Condition 5 also blocks the steam dump valves and becomes an interlock to the steam dump interlock selector switch. This is discussed in subsection 7.3.1.2.16.

The functional logic relating to the isolation of the main feedwater is illustrated in Figure 7.2-1, sheet 10.

7.3.1.2.7 Passive Residual Heat Removal Heat Exchanger Alignment

A signal to align the passive heat removal heat exchanger to passively remove core heat is generated from any of the following conditions:

1. Core makeup tank injection alignment signal (subsection 7.3.1.2.3)
2. First stage automatic depressurization system actuation (subsection 7.3.1.2.4)
3. Low wide range steam generator level
4. Low narrow range steam generator level coincident with Low startup feedwater flow
5. High-3 pressurizer water level
6. Manual initiation

Each of these conditions opens the passive residual heat removal discharge isolation valves, closes the in-containment refueling water storage tank gutter isolation valves, and provides a confirmatory open signal to the inlet isolation valve. The inlet isolation valve is normally open but can be closed by the operator. These conditions override any closure signal to this valve and also close the blowdown isolation valves in both steam generators.

Condition 3 results from the coincidence of two of the four divisions of wide range steam generator level below the Low setpoint in either of the two steam generators.

Condition 4 results from the coincidence of two of the four divisions of narrow range steam generator level below the Low setpoint, after a preset time delay, coincident with a Low startup feedwater flow in a particular steam generator. This function is provided for each of the two steam generators. The low narrow range steam generator level also isolates blowdown in the affected steam generator.

Condition 5 results from the coincidence of pressurizer level above the High-3 setpoint in any two of four divisions. This function can be manually blocked when the reactor coolant system pressure is below the P-19 permissive setpoint to permit pressurizer water solid conditions with the plant cold. This function is automatically unblocked when reactor coolant system pressure is above the P-19 setpoint. In addition to actuating the passive residual heat removal heat exchanger, condition 5 initiates a block of the pressurizer heaters.

Condition 6 consists of two momentary controls. Manual actuation of either of the two controls will align the passive residual heat removal heat exchanger initiating heat removal by this path.

The functional logic relating to alignment of the passive residual heat removal heat exchanger is illustrated in Figure 7.2-1, sheet 8.

7.3.1.2.8 Turbine Trip

A signal to initiate turbine trip is generated from any of the following conditions:

1. Reactor trip (Table 7.3-2, interlock P-4)
2. High-2 steam generator narrow-range water level
3. Manual feedwater isolation (subsection 7.3.1.2.6)

Each of these conditions initiates a turbine trip to prevent or terminate an excessive cooldown of the reactor or minimizes the potential for equipment damage caused by loss of steam supply to the turbine.

Condition 2 results from a coincidence of two of the four divisions of narrow range steam generator water level above the High-2 setpoint for either steam generator.

The functional logic relating to the tripping of the turbine is illustrated in Figure 7.2-1, sheet 14.

7.3.1.2.9 Containment Recirculation

Signals to align the containment recirculation isolation valves are generated from the following conditions:

1. Low-3 in-containment refueling water storage tank water level in coincidence with fourth stage automatic depressurization system actuation (subsection 7.3.1.2.4)

2. Manual initiation

3. Extended loss of ac power sources

There are four parallel containment recirculation paths provided to permit the recirculation of the water provided by the in-containment refueling water storage tank. Two of these paths are provided with two isolation valves in series while the remaining two paths are provided with a single isolation valve in series with a check valve.

Conditions 1 and 2 result in the opening of all isolation valves in all four parallel paths. Condition 3 results in the opening of the two isolation valves that are in series with the check valves.

Condition 1 results from the coincidence of two of the four divisions of in-containment refueling water storage tank water level below the Low-3 setpoint, coincident with an automatic fourth stage automatic depressurization system signal.

Condition 2 consists of two sets of two momentary controls. Manual actuation of both controls of either of the two control sets initiates recirculation in all four parallel paths. A two-control simultaneous actuation prevents inadvertent actuation.

Condition 3 results from the loss of all ac power for a period of time that approaches the 24-hour Class 1E dc battery capability to activate the in-containment refueling water storage tank containment recirculation isolation valves. The timed output holds on restoration of ac power and is manually reset after the batteries are recharged. The loss of all ac power is detected by undervoltage sensors that are connected to the input of each of the four Class 1E battery chargers. Two sensors are connected to each of the four battery charger inputs. The loss of ac power signal is based on the detection of an undervoltage condition by either of the two sensors connected to two of the four battery chargers.

The functional logic relating to activation of the containment recirculation isolation valves is illustrated in Figure 7.2-1, sheets 15 and 16.

7.3.1.2.10 Steam Line Isolation

A signal to isolate the steam line is generated from any one of the following conditions:

1. Manual initiation
2. High-2 containment pressure
3. Low lead-lag compensated steam line pressure
4. High steam line pressure negative rate
5. Low cold leg temperature

The steam line isolation signal closes the main steam line isolation valves and the stop and bypass valves. In addition to manual system-level steam line isolation, steam line isolation valves can be closed individually via the non-safety plant control system.

Condition 1 consists of two momentary controls. Manual actuation of either of the two controls initiates steam line isolation for both steam generators.

Condition 2 results from the coincidence of two of the four divisions of containment pressure above the High-2 setpoint.

Condition 3 results from the coincidence of two of the four divisions of compensated steam line pressure below the Low setpoint. The steam line pressure signal is lead-lag compensated to improve system response. If the pressure is below this setpoint, in either steam line, both main steam lines are isolated.

Condition 4 results from the coincidence in either steam line of two of the four divisions of rate-lag compensated steam line pressure exceeding the High negative rate setpoint.

Condition 5 results from the coincidence of reactor coolant system cold leg temperature below the Low T_{cold} setpoint in any loop.

Steam line isolation for conditions 3 and 5 may be manually blocked when pressurizer pressure is below the P-11 setpoint and is automatically unblocked when pressurizer pressure is above P-11. Steam line isolation on condition 4 is automatically blocked when pressurizer pressure is above P-11 and is automatically unblocked on the manual blocking of the steam line isolation for conditions 3 and 5. Under all plant conditions, steam line isolation is automatically provided on either Condition 3 or 5, or Condition 4.

The functional logic relating to main steam isolation is illustrated in Figure 7.2-1, sheet 9.

7.3.1.2.11 Steam Generator Blowdown System Isolation

Signals to close the isolation valves of the steam generator blowdown system in both steam generators are generated from the following conditions:

1. Passive residual heat removal heat exchanger alignment signal (subsection 7.3.1.2.7)
2. Low narrow range steam generator level

Condition 2 results from the coincidence of two of the four divisions of narrow range steam generator level below the Low setpoint. This condition only closes the blowdown system isolation valves of the affected steam generator.

The functional logic relating to steam generator blowdown isolation is illustrated in Figure 7.2-1, sheets 7 and 8.

7.3.1.2.12 Passive Containment Cooling Actuation

A signal to actuate the passive containment cooling system is generated from either of the following conditions:

1. Manual initiation
2. High-2 containment pressure

The passive containment cooling actuation signal opens valves that initiate gravity flow of cooling water from the passive containment cooling system water storage tank to the top of the containment shell. The evaporation of the water on the containment shell provides the passive cooling.

Condition 1 consists of two momentary controls. Manual actuation of either of the two controls results in manual actuation of the passive containment cooling system. This action also initiates containment isolation (subsection 7.3.1.2.1) and isolation of the containment air filtration system (subsection 7.3.1.2.19).

Condition 2 results from a coincidence of two of the four divisions of containment pressure above the High-2 setpoint. Manual reset is provided to block this actuation signal for passive containment cooling. Separate momentary controls are provided for resetting each division.

The functional logic relating to actuation of the passive containment cooling system is illustrated in Figure 7.2-1, sheet 13.

7.3.1.2.13 Startup Feedwater Isolation

Signals to isolate the startup feedwater supply to the steam generators are generated from either of the following conditions:

1. Low cold leg temperature
2. High-2 steam generator narrow range water level
3. Manual actuation of main feedwater isolation (subsection 7.3.1.2.6)

Any of these conditions isolates the startup feedwater supply by tripping the startup feedwater pumps and closing the startup feedwater isolation and control valves.

Condition 1 results from the coincidence of reactor coolant system cold leg temperature below the Low T_{cold} setpoint in any loop. Startup feedwater isolation on this condition may be manually blocked when the pressurizer pressure is below the P-11 setpoint. This function is automatically unblocked when the pressurizer pressure is above the P-11 setpoint.

Condition 2 results from a coincidence of two of the four divisions of narrow range steam generator water level above the High-2 setpoint for either steam generator.

Condition 3 is discussed in other subsections as noted.

The functional logic relating to the isolation of the startup feedwater is illustrated in Figure 7.2-1, sheets 9 and 10.

7.3.1.2.14 Boron Dilution Block

Signals to block boron dilution are generated from any of the following conditions:

1. Excessive increasing rate of source range flux doubling signal
2. Loss of ac power sources (low Class 1E battery charger input voltage)

3. Reactor trip (Table 7.3-2, interlock P-4)

In the event of an excessive increasing rate of source range flux doubling signal, the block of boron dilution is accomplished by closing the chemical and volume control system makeup isolation valves and closing the makeup pump suction valves to the demineralized water storage tanks. This signal also provides a non-safety trip of the makeup pumps. These actions terminate the supply of potentially unborated water to the reactor coolant system as quickly as possible.

In the event of a loss of ac power sources or a reactor trip (as indicated by P-4), the block of boron dilution is accomplished by closing the makeup pump suction valves to the demineralized water storage tanks and aligning the boric acid tank to the suction of the makeup pumps. This permits makeup as needed but ensures that it will be from a borated source that will not reduce the available shutdown margin in the reactor core.

Condition 1 is an average of the source range count rate, sampled at least N times over the most recent time period T_1, compared to a similar average taken at time period T_2 earlier. If the ratio of the current average count rate to the earlier average count rate is greater than a preset value, a partial trip is generated in the division. On a coincidence of excessively increasing source range neutron flux in two of the four divisions, boron dilution is blocked. The Flux Doubling function is also delayed from actuating each time the source range detector’s high voltage power is energized to prevent a spurious dilution block due to the short term instability of the processed source range values. This source range flux doubling signal may be manually blocked to permit plant startup and normal power operation. It is automatically reinstated when reactor power is decreased below the P-6 power level during shutdown.

Condition 2 results from the loss of ac power. A short, preset time delay is provided to prevent actuation upon momentary power fluctuations; however, actuation occurs before ac power is restored by the onsite diesel generators. The loss of all ac power is detected by undervoltage sensors that are connected to the input of each of the four Class 1E battery chargers. Two sensors are connected to each of the four battery charger inputs. The loss of ac power signal is based on the detection of an undervoltage condition by each of the two sensors connected to two of the four battery chargers. The two-out-of-four logic is based on an undervoltage to the battery chargers for divisions A or C coincident with an undervoltage to the battery chargers for divisions B or D.

Condition 3 results from a reactor trip as indicated by the P-4 interlock.

The functional logic relating to the boron dilution block is illustrated in Figure 7.2-1, sheets 3 and 15.

7.3.1.2.15 Chemical and Volume Control System Isolation

A signal to close the isolation valves of the chemical and volume control system is generated from any of the following conditions:

1. High-2 pressurizer level

2. High-2 steam generator narrow range water level

3. Automatic or manual safeguards actuation signal (subsection 7.3.1.1) coincident with High-1 pressurizer level

4. High-2 containment radioactivity

5. Manual initiation

6. Excessive increasing rate of source range flux doubling signal

Condition 1 results from the coincidence of pressurizer level above the High-2 setpoint in any two of the four divisions. This function can be manually blocked when the reactor coolant system pressure is below the P-19 permissive setpoint to permit pressurizer water solid conditions with the plant cold and to permit pressurizer level makeup during plant cooldowns. This function is automatically unblocked when reactor coolant system pressure is above the P-19 setpoint.

Condition 2 results from a coincidence of two of the four divisions of narrow range steam generator water level above the High-2 setpoint for either steam generator.

Condition 3 results from the coincidence of two of the four divisions of pressurizer level above the High-1 setpoint, coincident with an automatic or manual safeguards actuation.

Condition 4 results from the coincidence of containment radioactivity above the High-2 setpoint in any two of the four divisions.

Condition 5 consists of two momentary controls. This action also initiates auxiliary spray and letdown purification line isolation (subsection 7.3.1.2.18).

Condition 6 is an average of the source range count rate, sampled at least N times over the most recent time period T1, compared to a similar average taken at time period T2 earlier. If the ratio of the current average count rate to the earlier average count rate is greater than a preset value, a partial trip is generated in the division. On a coincidence of excessively increasing source range neutron flux in two of the four divisions, boron dilution is blocked. The Flux Doubling function is also delayed from actuating each time the source range detector’s high voltage power is energized to prevent a spurious isolation due to the short term instability of the processed source range values. This source range flux doubling signal may be manually blocked to permit plant startup and normal power operation. It is automatically reinstated when reactor power is decreased below the P-6 power level during shutdown.

The functional logic relating to chemical and volume control system isolation is illustrated in Figure 7.2-1, sheets 3, 6 and 11.

7.3.1.2.16 Steam Dump Block

Signals to block steam dump (turbine bypass) are generated from either of the following conditions:

1. Low-2 reactor coolant system average temperature
2. Manual initiation

Condition 1 results from a coincidence of two of the four divisions of reactor loop average temperature (T_{avg}) below the Low-2 setpoint. This blocks the opening of the steam dump valves. This signal also becomes an input to the steam dump interlock selector switch for unblocking the steam dump valves used for plant cooldown.

Condition 2 consists of three sets of controls. The first set of two controls selects whether the steam dump system has its normal manual and automatic operating modes available or is turned off. The second set of two controls enables or disables the operations of the Stage 1 cooldown steam dump valves if the reactor coolant average temperature (T_{avg}) is below the Low-2 setpoint. The third set of two controls enables or disables the operation of the Stage 2 cooldown steam dump valves.

The functional logic relating to the steam dump block is illustrated in Figure 7.2-1, sheet 10.

7.3.1.2.17 Control Room Isolation and Air Supply Initiation

Signals to initiate isolation of the main control room, to initiate the air supply, and to open the control room pressure relief isolation valves are generated from either of the following conditions:

1. High-2 control room air supply radioactivity level
2. Loss of ac power sources
3. Manual initiation

Condition 1 is the occurrence one of two control room air supply radioactivity monitors detecting a radioactivity level above the High-2 setpoint.

Condition 2 results from the loss of all ac power sources. A preset time delay is provided to permit the restoration of ac power from the offsite sources or from the onsite diesel generators before initiation. The loss of all ac power is detected by undervoltage sensors that are connected to the input of each of the four Class 1E battery chargers. Two sensors are connected to each of the four battery charger inputs. The loss of ac power signal is based on the detection of an undervoltage condition by each of the two sensors connected to two of the four battery chargers. The two-out-of-four logic is based on an undervoltage to the battery chargers for divisions A or C coincident with an undervoltage to the battery chargers for divisions B or D.

Condition 3 consists of two momentary controls. Manual actuation of either of the two controls will result in control room isolation and air supply initiation.

The functional logic relating to control room isolation and air supply initiation is illustrated in Figure 7.2-1, sheet 13.

7.3.1.2.18 Auxiliary Spray and Letdown Purification Line Isolation

A signal to isolate the auxiliary spray and letdown purification lines is generated upon the coincidence of pressurizer level below the Low-1 setpoint in any two of four divisions. This helps to maintain reactor coolant system inventory. This function can be manually blocked when the pressurizer water level is below the P-12 setpoint. This function is automatically unblocked when the pressurizer water level is above the P-12 setpoint. The auxiliary spray isolation function can be manually blocked anytime to allow the operators to use the auxiliary spray to rapidly depressurize the reactor coolant system. The functional logic relating to this is illustrated in Figure 7.2-1, sheet 12.

The auxiliary spray and letdown purification line isolation signal is also generated upon manual actuation of chemical and volume control system isolation (subsection 7.3.1.2.15).

7.3.1.2.19 Containment Air Filtration System Isolation

A signal to isolate the containment air filtration system is generated from any of the following conditions:

1. Automatic or manual safeguards actuation signal (subsection 7.3.1.1)
2. Manual actuation of containment isolation (subsection 7.3.1.2.1)
3. Manual actuation of passive containment cooling (subsection 7.3.1.2.12)
4. High-1 containment radioactivity

Conditions 1, 2, and 3 are discussed in other subsections as noted.

Condition 4 results from the coincidence of containment radioactivity above the High-1 setpoint in any two of the four divisions.

The manual reset which is provided to block the automatic actuation signal for containment isolation (subsection 7.3.1.2.1) also resets the containment air filtration system isolation signal generated as a result of condition 1.

No other interlocks or permissive signals apply directly to the containment air filtration system isolation function. Automatic actuation originates from a safeguards actuation (S) signal that does contain interlock and permissive inputs.

The functional logic relating to air filtration system isolation is illustrated in Figure 7.2-1, sheets 11 and 13.

7.3.1.2.20 Normal Residual Heat Removal System Isolation

Signals for isolating the normal residual heat removal system lines are generated from any of the following conditions:

1. Automatic or manual safeguards actuation signal (subsection 7.3.1.1)
2. High-2 containment radioactivity
3. Manual initiation

The isolation signal generated as a result of Condition 1 can be manually reset to block the isolation of the normal heat removal system lines. This is done to permit the normal residual heat removal system to operate after the occurrence of a safeguards actuation signal. Separate momentary controls are provided for resetting each division.

Condition 2 results from the coincidence of containment radioactivity above the High-2 setpoint in any two of the four divisions.

These actuation signals can be manually blocked when pressurizer pressure is below the P-11 permissive setpoint and are automatically unblocked when pressurizer pressure is above the P-11 setpoint.

Condition 3 consists of two sets of two momentary controls. Manual actuation of both controls of either of two control sets initiates closure of RNS isolation valves. A two-control simultaneous actuation prevents inadvertent actuation.

The functional logic relating to normal residual heat removal system isolation is illustrated in Figure 7.2-1, sheets 13 and 18.

7.3.1.2.21 Refueling Cavity Isolation

A signal for isolating the spent fuel pool cooling system lines is generated upon the coincidence of spent fuel pool level below the Low setpoint in two of three divisions. This helps to maintain the water inventory in the refueling cavity due to line leakage. The functional logic relating to this is illustrated in Figure 7.2-1, sheet 13.

7.3.1.2.22 Chemical and Volume Control System Letdown Isolation

A signal to isolate the letdown valves of the chemical and volume control system is generated upon the occurrence of a Low-1 hot leg level in either of the two hot leg loops. This helps to maintain reactor coolant system inventory during mid-loop operation. The signal may be manually blocked by the operator when pressurizer level is above the P-12 setpoint. The functional logic relating to this is illustrated in Figure 7.2-1, sheet 16. These letdown valves are also closed by the containment isolation function as described in subsection 7.3.1.2.1.

7.3.1.2.23 Pressurizer Heater Trip

Signals for disabling the operation of the pressurizer heaters are generated from any of the following conditions:

1. Core makeup tank injection alignment signal (subsection 7.3.1.2.3)
2. High-3 pressurizer water level

Division A of the protection and safety monitoring system provides actuation signals to five load center circuit breakers which provide the power feed to five pressurizer heater electrical control centers. When these five power feed breakers are opened, the electrical power is removed from the pressurizer heaters. In addition, Division C of the protection and safety monitoring system provides a separate signal to the plant control system. This separate signal is used to command the plant control system to open the molded-case circuit breakers which provide a power feed to each individual pressurizer heater. This arrangement provides for complete disabling of the pressurizer heaters, even if a single component failure occurs.

The functional logic relating to the pressurizer heater block is illustrated in Figure 7.2-1, sheets 6 and 12.

7.3.1.2.24 Steam Generator Relief Isolation

A signal for closing the steam generator power operated relief valves and their block valves is generated from any of the following conditions:

1. Manual initiation
2. Low lead-lag compensated steam line pressure

Condition 2 results from the coincidence of two of the four divisions of compensated steam line pressure below the Low setpoint. The steam line pressure signal is lead-lag compensated to improve system response. The signal closes the steam generator power-operated relief valve and the associated block valve for the affected steam generator. Steam generator relief isolation for condition 2 may be manually blocked when pressurizer pressure is below the P-11 setpoint and is automatically unblocked when pressurizer pressure is above P-11.

The functional logic relating to steam generator relief isolation is illustrated in Figure 7.2-1, sheet 9.

7.3.1.3 Blocks, Permissives, and Interlocks for Engineered Safety Features Actuation

The interlocks used for engineered safety features actuation are designated as "P-xx" permissives and are listed in Table 7.3-2.

7.3.1.4 Bypasses of Engineered Safety Features Actuation

The channels used in engineered safety features actuation that can be manually bypassed are indicated in Table 7.3-1. A description of this bypass capability is provided in subsection 7.1.2.9. The actuation logic is not bypassed for test. During tests, the actuation logic is fully tested by blocking the actuation logic output before it results in component actuation.

7.3.1.5 Design Basis for Engineered Safety Features Actuation

The following subsections provide the design bases information for engineered safety features actuation, including the information required by Section 4 of IEEE 603-1991. Engineered safety features are initiated by the protection and safety monitoring system. Those design bases relating to the equipment that initiates and accomplishes engineered safety features are given in WCAP-15776 (Reference 1). The design bases presented here concern the variables monitored for engineered safety features actuation and the minimum performance requirements in generating the actuation signals.

7.3.1.5.1 Design Basis: Generating Station Conditions Requiring Engineered Safety Features Actuation (Paragraph 4.1 of IEEE 603-1991)

The generating station conditions requiring protective action are identified in Table 15.0-6, which summarizes the engineered safety features as they relate to the Condition II, III, or IV events analyzed in Chapter 15.

7.3.1.5.2 Design Basis: Variables, Ranges, Accuracies, and Typical Response Times Used in Engineered Safety Features Actuation (Paragraphs 4.1, 4.2, and 4.4 of IEEE 603-1991)

The variables monitored for engineered safety features actuation are:

- Pressurizer pressure
- Pressurizer water level
- Reactor coolant temperature (T_{hot} and T_{cold}) in each loop
- Containment pressure
- Containment radioactivity level
- Steam line pressure in each steam line
- Water level in each steam generator (narrow and wide ranges)
- Source range neutron flux
- Core makeup tank level
- Reactor coolant level in each of the two hot legs
- Loss of ac power sources (low Class 1E battery charger input voltage)
- In-containment refueling water storage tank level
- Main control room supply air radioactivity level
- Reactor coolant pump bearing water temperature
- Startup feedwater flow
- Spent fuel pool level
- Reactor coolant pressure in each of the two hot legs

Subsections 7.3.1.1 and 7.3.1.2 discuss levels that result in engineered safety features actuation. The allowable values for the limiting conditions for operation and the trip setpoints for engineered safety features actuation are given in the technical specifications (Chapter 16).

Ranges, typical accuracies, and typical response times for the variables used in engineered safety features actuation are listed in Table 7.3-4. The time response is the maximum allowable time period for an actuation signal to reach the necessary components. It is based on following a step change in the applicable process parameter from 5 percent below to 5 percent above (or vice versa) the actuation setpoint with externally adjustable time delays set to OFF.

7.3.1.5.3 Design Basis: Spatially Dependent Variables Used for Engineered Safety Features Actuation (Paragraph 4.6 of IEEE 603-1991)

Spatially dependent variables are discussed in subsection 7.2.1.2.3.

7.3.1.5.4 Design Basis: Limits for Engineered Safety Features Parameters in Various Reactor Operating Modes (Paragraph 4.3 of IEEE 603-1991)

During startup or shutdown, various engineered safety features actuation can be manually blocked. These functions are listed in Table 7.3-1.

During testing or maintenance of the protection and safety monitoring system, certain channels used for engineered safety features may be bypassed. Although no setpoints are changed for bypassing, the logic is automatically adjusted, as described in subsection 7.3.1.4. The safeguards channels that can be bypassed in the protection and safety monitoring system are listed in Table 7.3-1.

7.3.1.5.5 Design Basis: Engineered Safety Features for Malfunctions, Accidents, Natural Phenomena, or Credible Events (Paragraph 4.7 and 4.8 of IEEE 603-1991)

The accidents that the various engineered safety features are designed to mitigate are detailed in Chapter 15. Table 15.0-6 contains a summary listing of the engineered safety features actuated for various Condition II, III, or IV events. It relies on provisions made to protect equipment against damage from natural phenomena and credible internal events. Consequently, there are no engineered safety features actuated by the protection and safety monitoring system to mitigate the consequences of events such as fires.

Functional diversity is used in determining the actuation signals for engineered safety features. For example, a safeguards actuation signal is generated from high containment pressure, low pressurizer pressure, and low compensated steam line pressure. Engineered safety features are not normally actuated by a single signal. The extent of this diversity is seen from the initiating signals presented in subsections 7.3.1.1 and 7.3.1.2. Table 7.3-1 also lists the engineered safety features signals and the conditions that result from their actuation.

Redundancy provides confidence that engineered safety features are actuated on demand, even when the protection and safety monitoring system is degraded by a single random failure. The single-failure criterion is met even when engineered safety features channels are bypassed.

7.3.1.6 System Drawings

Functional diagrams are provided in Figure 7.2-1.

7.3.2 Analysis for Engineered Safety Features Actuation

7.3.2.1 Failure Modes and Effects Analyses

The AP1000 failure modes and effects analysis (Reference 1 of Section 7.2) examines failures of the protection and safety monitoring system. This analysis concludes that the protection system maintains safety functions during single point failures.

7.3.2.2 Conformance of Engineered Safety Features to the Requirements of IEEE 603-1991

The discussions presented in this subsection address only the functional aspects of actuating engineered safety features. Requirements addressing equipment in the protection and safety monitoring system are presented in WCAP-15776 (Reference 1).

7.3.2.2.1 Conformance to the General Functional Requirements for Engineered Safety Features Actuation (Section 5 of IEEE 603-1991)

The protection and safety monitoring system automatically generates an actuation signal for an engineered safety feature whenever a monitored condition reaches a preset value. The specific engineered safety features actuation functions are listed in Table 7.3-1 and are discussed in subsection 7.3.1.2.

Table 7.3-4 lists the ranges, accuracies, and response times of the parameters monitored. The engineered safety features, in conjunction with a reactor trip, protect against damage to the core and reactor coolant system components, as well as maintain containment integrity following a Condition II, III, or IV event. Table 15.0-6 summarizes the events that normally result in the initiation of engineered safety features. The setpoints that actuate engineered safety features are listed in the technical specifications (Chapter 16).

7.3.2.2.2 Conformance to the Single Failure Criterion for Engineered Safety Features Actuation (Paragraph 5.1 of IEEE 603-1991)

A single failure in the protection and safety monitoring system does not prevent an actuation of the engineered safety features when the monitored condition reaches the preset value that requires the initiation of an actuation signal. The single failure criterion is met even when one division of the ESF coincidence logic is being tested, as discussed in subsection 7.1.2.9, or when there is a bypass condition in connection with test or maintenance of the protection and safety monitoring system.

7.3.2.2.3 Conformance to the Requirements for Channel Independence of the Engineered Safety Features Actuation (Paragraph 5.6.1 of IEEE 603-1991)

A discussion of channel independence is presented in WCAP-15776 (Reference 1). The signals to initiate division A of the engineered safety features are electrically isolated from the signals to initiate the redundant divisions (B, C, and D). Divisions of the safeguards actuation system are electrically independent and redundant, as are the power supplies for the divisions up to and including the final actuated equipment.

7.3.2.2.4 Conformance to the Requirements Governing Control and Protection System Interaction of the Engineered Safety Features Actuation (Paragraphs 5.6.3.1, 5.6.3.3, and 6.3.1 of IEEE 603-1991)

Discussions on this subject are presented in WCAP-15776 (Reference 1).

7.3.2.2.5 Derivation of System Input for Engineered Safety Features Actuation (Paragraph 6.4 of IEEE 603-1991)

To the extent feasible and practical, the protection and safety monitoring system inputs used to actuate engineered safety features are derived from signals that are direct measures of the desired parameters. The parameters are listed in Table 7.3-4.

7.3.2.2.6 Capability for Sensor Checks and Equipment Test and Calibration of the Engineered Safety Features Actuation (Paragraphs 5.7 and 6.5 of IEEE 603-1991)

The discussion of system testability provided in Section 7.1 is applicable to the sensors, signal processing, and actuation logic that initiate engineered safety features actuation.

The testing program meets Regulatory Guide 1.22 as discussed in WCAP-15776 (Reference 1). The program is as follows:

- Prior to initial plant operations, engineered safety features tests are conducted.
- Subsequent to initial startup, engineered safety features tests are conducted during each regularly scheduled refueling outage.
- During operation of the reactor, the protection and safety monitoring system is tested as described in subsection 7.1.2.11. In addition, the engineered safety features final actuators, whose operation is compatible with continued plant operation, are tested periodically at power.
- Continuity of the wiring is verified for devices that cannot be tested at power without damaging or upsetting the plant. Operability of the final actuated equipment is demonstrated at shutdown.

During reactor operation, the basis for acceptability of engineered safety features actuation is the successful completion of the overlapping tests performed on the protection and safety monitoring system. Process indications are used to verify operability of sensors.

7.3.2.2.7 Conformance to Requirements on Bypassing Engineered Safety Features Actuation Functions (Paragraph 5.8, 5.9, 6.6, and 6.7 of IEEE 603-1991)

Discussions on bypassing are provided in WCAP-15776 (Reference 1) and subsection 7.3.1.4.

7.3.2.2.8 Conformance to the Requirement for Completion of Engineered Safety Features Actuation Once Initiated (Paragraph 5.2 of IEEE 603-1991)

Once initiated, engineered safety features proceed to completion unless deliberate operator action is taken to terminate the function on a component-by-component basis.

Equipment actuated on a safeguards actuation signal cannot be returned to its previous position for a predetermined time period following initiation of the safeguards actuation signal. A block of the automatic safeguards signal is permitted at this time, if the reactor is tripped. This interlock is shown in Figure 7.2-1, sheet 11.

Resetting a system-level safeguards signal does not terminate any safeguards function. Rather, it permits the operator to individually reposition equipment. Equipment cannot be reset until the system-level signal is reset.

7.3.2.2.9 Conformance to the Requirement to Provide Manual Initiation at the System-Level for All Safeguards Actuation (Paragraph 6.2 of IEEE 603-1991)

Manual initiation at the system-level exists for the engineered safety features actuation. These system-level manual initiations are discussed in subsections 7.3.1.1 and 7.3.1.2.

As a minimum, two controls are provided for each system-level manual initiation so that the protective function can be manually initiated at the system-level, despite a single random failure in one control. In certain applications, such as automatic depressurization, two pairs of controls are provided. One pair must be actuated simultaneously. This reduces the likelihood of inadvertent actuation while providing a design that meets the single failure criterion.

7.3.3 Combined License Information

This section has no requirement for information to be provided in support of the Combined License application.

7.3.4 References

1. WCAP-15776, “Safety Criteria for the AP1000 Instrument and Control Systems,” April 2002.

Table 7.3-1 (Sheet 1 of 9)

ENGINEERED SAFETY FEATURES ACTUATION SIGNALS

Actuation Signal	No. of Divisions/ Controls	Actuation Logic	Permissives and Interlocks
1. Safeguards Actuation Signal (Figure 7.2-1, Sheets 9 and 11)			
a. Low pressurizer pressure	4	2/4-BYP[1]	Can be manually blocked on presence of P-3 Block automatically removed on absence of P-3
b. Low lead-lag compensated steam line pressure	4/steam line	2/4-BYP[1] in either steam line	Can be manually blocked on presence of P-3 Block automatically removed on absence of P-3
c. Low reactor cold leg (Low T_{cold})	4/loop	2/4-BYP[1] either loop[6]	Can be manually blocked on presence of P-3 Block automatically removed on absence of P-3
d. High-2 containment pressure	4	2/4-BYP[1]	Can be manually blocked on presence of P-3 Block automatically removed on absence of P-3
e. Manual safeguards initiation	2 controls	1/2 controls	None
2. Containment Isolation (Figure 7.2-1 Sheets 11 and 13)			
a. Automatic or manual safeguards actuation signal	(See items 1a through 1e)		
b. Manual initiation	2 controls	1/2 controls	None
c. Manual initiation of passive containment cooling	(See item 10a)		
3. Automatic Depressurization System (Figure 7.2-1, Sheet 15) **(Initiate Stages 1, 2, and 3)**			
a. Core makeup tank injection coincident with	(See items 6a through 6e)		
Core makeup tank level less than Low-1 setpoint	4/tank	2/4-BYP[1] either tank[2]	None
b. Extended undervoltage to Class 1E battery chargers[(8)]	2/charger	1/2 per charger and 2/4 chargers	None

Table 7.3-1 (Sheet 2 of 9)

ENGINEERED SAFETY FEATURES ACTUATION SIGNALS

Actuation Signal	No. of Divisions/ Controls	Actuation Logic	Permissives and Interlocks
(Initiate Stage 4)			
c. Stages 1, 2, and 3 manual initiation	4 controls	2/4 controls[3]	None
d. Stage 4 manual initiation coincident with one of the following two conditions:	4 controls	2/4 controls[3]	None
Low reactor coolant system pressure or	4	2/4 BYP[1]	None
Actuation of stages 1, 2, and 3	(See items 3a through 3c)		
e. Core makeup tank level less than Low-2 setpoint coincident with	4/tank	2/4 BYP[1] either tank[2]	None
Low reactor coolant system pressure and coincident with	4	2/4 BYP[1]	None
3rd stage depressurization			
f. Coincident loop 1 and loop 2 Low-2 hot leg level (after delay)	1 per loop	2/2	Manual unblock permitted below P-12 Automatically blocked above P-12
4. Main Feedwater Isolation (Figure 7.2-1, Sheet 10) **(Closure of Control Valves)**			
a. Safeguards actuation signal (automatic or manual)	(See items 1a through 1e)		
b. Manual initiation	2 controls	1/2 controls	None
c. High-2 steam generator narrow range level	4/steam generator	2/4-BYP[1] in either steam generator	None
d. Low reactor coolant temperature (Low-1 T_{avg}) coincident with	2/loop	2/4 -BYP[1]	Manual block permitted below P-11 Automatically unblocked above P-11
Reactor trip (P-4)	1/division	2/4	None

Table 7.3-1 (Sheet 3 of 9)

ENGINEERED SAFETY FEATURES ACTUATION SIGNALS

Actuation Signal	No. of Division/ Controls	Actuation Logic	Permissives and Interlocks
(Trip of Main Feedwater Pumps and Closure of Isolation and Crossover Valves)			
a. Safeguards actuation signal (automatic or manual)	(See items 1a through 1e)		
b. Manual initiation	2 controls	1/2 controls	None
c. High-2 steam generator narrow range level	4/steam generator	2/4-BYP[1] in either steam generator	None
d. Low reactor coolant temperature (Low-2 T_{avg}) coincident with	2/loop	2/4-BYP1	Manual block permitted below P-11 Automatically unblocked above P-11
Reactor trip (P-4)	1/division	2/4	None
5. Reactor Coolant Pump Trip (Figure 7.2-1, Sheets 5, 7, 12, and 15) **(Trips All Reactor Coolant Pumps)**			
a. Safeguards actuation signal (automatic or manual)	(See items 1a through 1e)		
b. Automatic reactor coolant system depressurization (first stage)	(See items 3a through 3c)		
c. Low-2 pressurizer level	4	2/4-BYP[1]	Manual block permitted below P-12 Automatically unblocked above P-12
d. Low wide range steam generator water level coincident with	4/steam generator	2/4-BYP[1] in both steam generators	None
High hot leg temperature (High T_{hot})[(8)]	2/loop	2/4-BYP[1]	None
e. Manual core makeup tank initiation	(See item 6e)		
(Trip Affected Pump)			
f. High reactor coolant pump water bearing temperature	4/pump	2/4-BYP[1] in affected pump	None

Table 7.3-1 (Sheet 4 of 9)

ENGINEERED SAFETY FEATURES ACTUATION SIGNALS

Actuation Signal	No. of Divisions/ Controls	Actuation Logic	Permissives and Interlocks
6. Core Makeup Tank Injection (Figure 7.2-1, Sheets 7, 12 and 15)			
a. Safeguards actuation signal (automatic or manual)	(See items 1a through 1e)		
b. Automatic reactor coolant system depressurization (first stage)	(See items 3a through 3c)		
c. Low-2 pressurizer level	4	2/4-BYP[1]	Manual block permitted below P-12 Automatically unblocked above P-12
d. Low wide range steam generator water level coincident with	4/steam generator	2/4-BYP[1] in both steam generators	None
High hot leg temperature (High T_{hot})[(8)]	2/loop	2/4-BYP[1]	None
e. Manual initiation	2 controls	1/2 controls	None
7. Turbine Trip (Figure 7.2-1, Sheet 14)			
a. Manual feedwater isolation	(See item 4b)		
b. Reactor trip (P-4)	1/division	2/4	None
c. High-2 steam generator narrow range level	4/steam generator	2/4-BYP[1] in either steam generator	None
8. Steam Line Isolation (Figure 7.2-1, Sheet 9)			
a. Manual initiation	2 controls	1/2 controls	None
b. High-2 containment pressure	4	2/4-BYP[1]	None
c. Low lead-lag compensated steam line pressure[4]	4/steam line	2/4-BYP[1] in either steam line	Manual block permitted below P-11 Automatically unblocked above P-11
d. High steam line negative pressure rate	4/steam line	2/4-BYP[1] in either steam line[7]	Manual unblock permitted below P-11 Automatically blocked above P-11
e. Low reactor coolant inlet temperature (Low T_{cold})	4/loop	2/4-BYP[1] either loop[6]	Manual block permitted below P-11 Automatically unblocked above P-11

Table 7.3-1 (Sheet 5 of 9)

ENGINEERED SAFETY FEATURES ACTUATION SIGNALS

Actuation Signal	No. of Divisions/ Controls	Actuation Logic	Permissives and Interlocks
9. Steam Generator Blowdown System Isolation (Figure 7.2-1 Sheets 7 and 8)			
a. Passive residual heat removal heat exchanger actuation	(See items 12a through 12f)		
b. Low narrow range steam generator water level	4/steam generator	2/4 BYP[1] in either steam generator	None
10. Passive Containment Cooling Actuation (Figure 7.2-1, Sheet 13)			
a. Manual initiation	2 controls	1/2 controls	None
b. High-2 containment pressure	4	2/4-BYP[1]	None
11. Startup Feedwater Isolation (Figure 7.2-1, Sheets 9 and 10)			
a. Low cold leg temperature (Low T_{cold})	4/loop	2/4-BYP[1] either loop[6]	Manual block permitted below P-11 Automatically unblocked above P-11
b. High-2 steam generator narrow range water level	4/steam generator	2/4-BYP[1] in either steam generator	None
c. Manual initiation of main feedwater isolation		(See item 4b)	
12. Passive Residual Heat Removal (Figure 7.2-1, Sheet 8)			
a. Manual initiation	2 controls	1/2 controls	None
b. Low narrow range steam generator water level coincident with	4/steam generator	2/4-BYP[1] in either steam generator	None
Low startup feedwater flow	2/feedwater line	1/2 in either feedwater line	None
c. Low steam generator wide range water level	4/steam generator	2/4-BYP[1] in either steam generator	None
d. Core makeup tank injection	(See Items 6a through 6e)		
e. Automatic reactor coolant system depressurization (first stage)	(See items 3a through 3c)		

Table 7.3-1 (Sheet 6 of 9)

ENGINEERED SAFETY FEATURES ACTUATION SIGNALS

Actuation Signal	No. of Division/ Controls	Actuation Logic	Permissives and Interlocks
f. High-3 pressurizer level	4	2/4-BYP[1]	Manual block permitted below P-19 Automatically unblocked above P-19
13. Block of Boron Dilution (Figure 7.2-1, Sheets 3 and 15)			
a. Flux doubling calculation	4	2/4-BYP[1]	Manual block permitted when critical or intentionally approaching criticality Automatically unblocked below P-6
b. Undervoltage to Class 1E battery chargers	2/charger	2/2 per charger and 2/4 chargers[5]	None
c. Reactor trip (P-4)	1/division	2/4	None
14. Chemical Volume Control System Isolation (See Figure 7.2-1, Sheets 6 and 11)			
a. High-2 pressurizer water level	4	2/4-BYP[1]	Automatically unblocked above P-19 Manual block permitted below P-19
b. High-2 steam generator narrow range level	4/steam generator	2/4-BYP[1] in either steam generator	None
c. Automatic or manual safeguards actuation signal coincident with	(See items 1a through 1e)		
High-1 pressurizer water level	4	2/4-BYP[1]	None
d. High-2 containment radioactivity	4	2/4-BYP[1]	None
e. Manual initiation	2 controls	1/2 controls	None
f. Flux doubling calculation	4	2/4-BYP[1]	Manual block permitted when critical or intentionally approaching criticality Automatically unblocked below P-6
15. Steam Dump Block (Figure 7.2-1, Sheet 10)[(8)]			
a. Low reactor coolant temperature (Low-2 T_{avg})	2/loop	2/4-BYP[1]	None
b. Mode control	2 controls	1/division	None

Table 7.3-1 (Sheet 7 of 9)

ENGINEERED SAFETY FEATURES ACTUATION SIGNALS

Actuation Signal	No. of Divisions/ Controls	Actuation Logic	Permissives and Interlocks
c. Manual stage 1 cooldown control	2 controls	1/division	None
d. Manual stage 2 cooldown control	2 controls	1/division	None
16. Main Control Room Isolation and Air Supply Initiation (Figure 7.2-1, Sheet 13)			
a. High-2 control room supply air radiation	2	1/2	None
b. Undervoltage to Class 1E battery chargers(8)	2/charger	2/2 per charger and 2/4 chargers[5]	None
c. Manual initiation(8)	2 controls	1/2 controls	None
17. Auxiliary Spray and Purification Line Isolation (Figure 7.2-1, Sheet 12)			
a. Low-1 pressurizer level	4	2/4-BYP[1]	Manual block permitted below P-12 Automatically unblocked above P-12
b. Manual initiation of chemical and volume control system isolation	(See item 14e)		
18. Containment Air Filtration System Isolation (Figure 7.2-1, Sheets 11 and 13)			
a. Containment isolation	(See items 2a through 2c)		
b.. High-1 containment radioactivity	4	2/4-BYP[1]	None
19. Normal Residual Heat Removal System Isolation (Figure 7.2-1, Sheets 13 and 18)			
a. Automatic or manual safeguards actuation signal	(See items 1a through 1e)		
b. High-2 containment radioactivity	4	2/4-BYP[1]	Manual block permitted below P-11 Automatically unblocked above P-11
c. Manual initiation	4 controls	2/4 controls[3]	None
20. Refueling Cavity Isolation (Figure 7.2-1, Sheet 13)			
a. Low spent fuel pool level	3	2/3	None

Table 7.3-1 (Sheet 8 of 9)

ENGINEERED SAFETY FEATURES ACTUATION SIGNALS

Actuation Signal	No. of Divisions/ Controls	Actuation Logic	Permissives and Interlocks
21. Open In-Containment Refueling Water Storage Tank (IRWST) Injection Line Valves (Figure 7.2-1, Sheets 12 and 16)			
a. Automatic reactor coolant system depressurization (fourth stage)	(See items 3d and 3e)		
b. Coincident loop 1 and loop 2 Low-2 hot leg level (after delay)	1 per loop	2/2	Manual unblock permitted below P-12 Automatically blocked above P-12
c. Manual initiation	4 controls	2/4 controls[3]	None
22. Open Containment Recirculation Valves In Series with Check Valves (Figure 7.2-1, Sheet 15 and 16)			
a. Extended undervoltage to Class 1E battery chargers[(8)]	2/charger	1/2 per charger and 2/4 chargers	None
23. Open All Containment Recirculation Valves (Figure 7.2-1, Sheet 16)			
a. Automatic reactor coolant system depressurization (fourth stage coincident with)		(See items 3d through 3f)	
Low IRWST level (Low-3 setpoint)	4	2/4 BYP[1]	None
b. Manual initiation	4 controls	2/4 controls[3]	None
24. Chemical and Volume Control System Letdown Isolation (Figure 7.2-1, Sheet 16)			
a. Low-1 hot leg level	1 per loop	1/2	Manual block permitted above P-12 Automatically unblocked below P-12
25. Pressurizer Heater Trip (Figure 7.2-1, Sheets 6 and 12)			
a. Core makeup tank injection	(See items 6a through 6e)		
b. High-3 pressurizer level	4	2/4 BYP[1]	Manual block permitted below P-19 Automatically unblocked above P-19

Table 7.3-1 (Sheet 9 of 9)

ENGINEERED SAFETY FEATURES ACTUATION SIGNALS

Actuation Signal	No. of Divisions/ Controls	Actuation Logic	Permissives and Interlocks
26. Steam Generator Relief Isolation (Figure 7.2-1, Sheet 9)			
a. Manual initiation	2 controls	1/2 controls	None
b. Low lead-lag compensated steam line pressure[4]	4/steam line	2/4-BYP[1] in either steam line	Manual block permitted below P-11 Automatically unblocked above P-11

Notes:

1. 2/4-BYP indicates bypass logic. The logic is 2 out of 4 with no bypasses and 2 out of 3 with one bypass.
2. Any two channels from either tank not in same division.
3. Two associated controls must be actuated simultaneously.
4. Also, closes power-operated relief block valve of respective steam generator.
5. The two-out-of-four logic is based on undervoltage to the battery chargers for divisions A or C coincident with an undervoltage to the battery chargers for divisions B or D.
6. Any two channels from either loop not in same division.
7. Any two channels from either line not in same division.
8. This function does not meet the 10 CFR 50.36(c)(2)(ii) criteria and is not included in the Technical Specifications.

Table 7.3-2 (Sheet 1 of 4)

INTERLOCKS FOR ENGINEERED SAFETY FEATURES ACTUATION SYSTEM

Designation	Derivation	Function
P-3	Reactor trip breaker open	Permits manual reset of safeguards actuation signal to block automatic safeguards actuation
$\overline{\text{P-3}}$	Reactor trip breakers closed	Automatically resets the manual block of automatic safeguards actuation
P-4	Reactor trip initiated or reactor trip breakers open	(a) Isolates main feedwater if coincident with low reactor coolant temperature (b) Trips turbine (c) Blocks boron dilution
$\overline{\text{P-4}}$	No reactor trip initiated and reactor trip breakers closed	Removes demand for isolation of main feedwater, turbine trip and boron dilution block
P-6	Intermediate range neutron flux channels above setpoint	Allows manual block of flux doubling actuation of the boron dilution block.
$\overline{\text{P-6}}$	Intermediate range neutron flux channels below setpoint	None
P-11	Pressurizer pressure below setpoint	(a) Permits manual block of safeguards actuation on low pressurizer pressure, low compensated steam line pressure, or low reactor coolant inlet temperature (b) Permits manual block of steam line isolation on low reactor coolant inlet temperature (c) Permits manual block of steam line isolation and steam generator power-operated relief valve block valve closure on low compensated steam line pressure (d) Coincident with manual actions of (b) or (c), automatically unblocks steam line isolation on high negative steam line pressure rate (e) Permits manual block of main feedwater isolation on low reactor coolant temperature

Table 7.3-2 (Sheet 2 of 4)

INTERLOCKS FOR ENGINEERED SAFETY FEATURES ACTUATION SYSTEM

Designation	Derivation	Function
P-11 (continued)	Pressurizer pressure below setpoint	(f) Permits manual block of startup feedwater isolation on low reactor coolant inlet temperature (g) Permits manual block of steam dump block on low reactor coolant temperature (h) Permits manual block of normal residual heat removal system isolation on high containment radioactivity.
$\overline{\text{P-11}}$	Pressurizer pressure above setpoint	(a) Prevents manual block of safeguards actuation on low pressurizer pressure, low compensated steam line pressure, or low reactor coolant inlet temperature (b) Prevents manual block of steam line isolation on low reactor coolant inlet temperature (c) Prevents manual block of steam line isolation and steam generator power-operated relief valve block valve closure on low compensated steam line pressure (d) Automatic block of steam line isolation on high negative steam line pressure rate (e) Prevents manual block of feedwater isolation on low reactor coolant temperature (f) Prevents manual block of startup feedwater isolation on low reactor coolant inlet temperature (g) Prevents manual block of normal residual heat removal system isolation on high containment radioactivity

Table 7.3-2 (Sheet 3 of 4)

INTERLOCKS FOR ENGINEERED SAFETY FEATURES ACTUATION SYSTEM

Designation	Derivation	Function
P-12	Pressurizer level below setpoint	(a) Permits manual block of core makeup tank actuation on low pressurizer level to allow mid-loop operation (b) Permits manual block of reactor coolant pump trip on low pressurizer level to allow mid-loop operation (c) Permits manual block of auxiliary spray and purification line isolation on low pressurizer level to allow mid-loop operation (d) Coincident with manual action of (a), automatically unblocks in-containment refueling water storage tank injection and fourth stage automatic depressurization system initiation on low hot leg level to provide protection during mid-loop operation. (e) Automatically unblocks chemical and volume control system letdown isolation on Low-1 hot leg level
$\overline{\text{P-12}}$	Pressurizer level above setpoint	(a) Prevents manual block of core makeup tank actuation on low pressurizer level (b) Prevents manual block of reactor coolant pump trip on low pressurizer level (c) Prevents manual block of auxiliary spray and purification line isolation on low pressurizer level (d) Provides confirmatory open signal to the core makeup tank cold leg balance lines (e) Automatically blocks in-containment refueling water storage tank injection and fourth stage automatic depressurization system initiation on low hot leg level to reduce the probability of spurious actuation. (f) Permits manual block of chemical and volume control system letdown isolation on Low-1 hot leg level

Table 7.3-2 (Sheet 4 of 4)

INTERLOCKS FOR ENGINEERED SAFETY FEATURES ACTUATION SYSTEM

Designation	Derivation	Function
P-19	Reactor coolant system pressure below setpoint	(a) Permits manual block of chemical and volume control system isolation on high pressurizer water level (b) Permits manual block of passive residual heat removal heat exchanger alignment on high pressurizer water level (c) Permits manual block of the pressurizer heater trip on high pressurizer water level
$\overline{\text{P-19}}$	Reactor coolant system pressure above setpoint	(a) Prevents manual block of chemical and volume control system isolation on high pressurizer water level (b) Prevents manual block of passive residual heat removal heat exchanger alignment on high pressurizer water level (c) Prevents manual block of the pressurizer heater trip on high pressurizer water level

Table 7.3-3 (Sheet 1 of 2)

SYSTEM-LEVEL MANUAL INPUT TO THE ENGINEERED SAFETY FEATURES ACTUATION SYSTEM

Manual Control	To Divisions				Figure 7.2-1 Sheet
Manual safeguards actuation #1	A	B	C	D	11
Manual safeguards actuation #2	A	B	C	D	11
Manual chemical and volume control system isolation #1	A		C	D	6
Manual chemical and volume control system isolation #2	A		C	D	6
Manual passive residual heat removal heat exchanger alignment #1	A	B		D	8
Manual passive residual heat removal heat exchanger alignment #2	A	B		D	8
Manual steam line isolation #1		B		D	9
Manual steam line isolation #2		B		D	9
Manual steam generator relief isolation #1		B		D	9
Manual steam generator relief isolation #2		B		D	9
Steam/feedwater isolation and safeguards block control #1	A				9
Steam/feedwater isolation and safeguards block control #2		B			9
Steam/feedwater isolation and safeguards block control #3			C		9
Steam/feedwater isolation and safeguards block control #4				D	9
Manual feedwater isolation #1		B		D	10
Manual feedwater isolation #2		B		D	10
Manual steam dump mode control #1		B			10
Manual steam dump mode control #2				D	10
Manual Stage 1 steam dump cooldown control #1		B			10
Manual Stage 1 steam dump cooldown control #2				D	10
Manual Stage 2 steam dump cooldown control #1		B			10
Manual Stage 2 steam dump cooldown control #2				D	10
Pressurizer pressure safeguards block control #1	A				11
Pressurizer pressure safeguards block control #2		B			11
Pressurizer pressure safeguards block control #3			C		11
Pressurizer pressure safeguards block control #4				D	11
Auxiliary spray isolation block control			C		12
Manual core makeup tank injection actuation #1	A	B	C	D	12
Manual core makeup tank injection actuation #2	A	B	C	D	12
Core makeup tank injection actuation block control #1	A				12
Core makeup tank injection actuation block control #2		B			12
Core makeup tank injection actuation block control #3			C		12
Core makeup tank injection actuation block control #4				D	12

Table 7.3-3 (Sheet 2 of 2)

SYSTEM-LEVEL MANUAL INPUT TO THE ENGINEERED SAFETY FEATURES ACTUATION SYSTEM

Manual Control	To Divisions				Figure 7.2-1 Sheet
Manual passive containment cooling actuation #1	A	B	C	D	13
Manual passive containment cooling actuation #2	A	B	C	D	13
Manual passive containment isolation actuation #1	A	B	C	D	13
Manual passive containment isolation actuation #2	A	B	C	D	13
Manual depressurization system stages 1, 2, and 3 actuation #1 & #2	A	B	C	D	15
Manual depressurization system stages 1, 2, and 3 actuation #3 & #4	A	B	C	D	15
Manual depressurization system stage 4 actuation #1 & #2	A	B	C	D	15
Manual depressurization system stage 4 actuation #3 & #4	A	B	C	D	15
Manual IRWST injection actuation #1 & #2	A	B	C	D	16
Manual IRWST injection actuation #3 & #4	A	B	C	D	16
Manual containment recirculation actuation #1 & #2	A	B	C	D	16
Manual containment recirculation actuation #3 & #4	A	B	C	D	16
Manual control room isolation and air supply initiation #1	A	B	C	D	13
Manual control room isolation and air supply initiation #2	A	B	C	D	13
RCS pressure CVS/PRHR block control #1	A				6
RCS pressure CVS/PRHR block control #2		B			6
RCS pressure CVS/PRHR block control #3			C		6
RCS pressure CVS/PRHR block control #4				D	6
Normal residual heat removal system isolation safeguards block control #1	A				13
Normal residual heat removal system isolation safeguards block control #2		B			13
Boron dilution block control #1	A				3
Boron dilution block control #2		B			3
Boron dilution block control #3			C		3
Boron dilution block control #4				D	3
Manual RNS isolation #1 & #3	A	B		D	18
Manual RNS isolation #2 & #4	A	B		D	18
CVS letdown isolation block control #1	A				16
CVS letdown isolation block control #2				D	16

Table 7.3-4 (Sheet 1 of 2)

ENGINEERED SAFETY FEATURES ACTUATION, VARIABLES, LIMITS, RANGES, AND ACCURACIES (NOMINAL)

Variable	Range of Variable	Typical Accuracy[1]	Typical Response Time (Sec)[2]
Pressurizer pressure	1700 to 2500 psig	±14% of span	1.0
Steam line pressure	500 to 1300 psig	±3% of span (Normal environment) ±10% of span (Adverse environment)	1.0
Steam line negative pressure rate	0 to 250 psig/sec	±0.2% of span	1.0
Cold leg temperature (T_{cold})	490 to 610°F	±3% of span	5.5
Hot leg temperature (T_{hot})	530 to 650°F	±2% of span	5.5
Containment pressure	-5 to 10 psig	±3% of span	1.0
Reactor coolant system hot leg level	0 to 100% of span	±5% of span	1.0
In-containment refueling water storage tank level	0 to 100% of span	±6% of span	1.0
Undervoltage on input of Class 1E battery charger	0 to 500 V	±2% of setpoint	1.5
Steam generator narrow range water level	0 to 100% of span (narrow range taps)	±22% of span	1.0
Steam generator wide range water level	0 to 100% of span (wide range taps)	±32% of span	1.0
Core makeup tank narrow range upper water level	0 to 100% of span	±40% of span	1.0
Core makeup tank narrow range lower water level	0 to 100% of span	±40% of span	1.0
Reactor coolant pump bearing temperature	70 to 450°F	±2% of span	5.5
Spent fuel pool level	0 to 26 feet	±3% of span	1.0
Reactor coolant system wide range pressure	0 to 3300 psig	±3% of span	1.0

Table 7.3-4 (Sheet 2 of 2)

ENGINEERED SAFETY FEATURES ACTUATION, VARIABLES, LIMITS, RANGES, AND ACCURACIES (NOMINAL)

Variables	Range of Variables	Typical Accuracy[1]	Typical Response Time (Sec)[2]
Pressurizer water level	0 to 100% of cylindrical portion of pressurizer	± 10% of span	1.0
Startup feedwater flow	0 to 1000 gpm	±7% of span	1.0
Neutron flux (flux doubling calculation)	1 to 10^6 c/sec	± 30% of span	1.0[3]
Control room supply air radiation level	10^{-7} to 10^{-2} μ Ci/cc	± 50% of setpoint	20
Containment radioactivity	10^0 to 10^7 R/hr	± 50% of setpoint	20

Notes:

1. Measurement uncertainty typical of actual applications. Harsh environments allowance have been included where applicable.
2. Delay from the time that the process variable exceeds the setpoint until the time that an output is provided to the actuated device.
3. Response time depends on flux doubling calculation.