B 3.5 EMERGENCY CORE COOLING SYSTEM (ECCS)

B 3.5.1 Safety Injection Tanks (SITs)

BASES

BACKGROUND

The function of the four SITs is to inject large quantities of borated water to the reactor vessel following the blowdown phase of a large break loss of coolant accident (LOCA) and to provide inventory to help accomplish the refill phase that follows thereafter.

The blowdown phase of a large break LOCA is the initial period of the transient during which the Reactor Coolant System (RCS) departs from equilibrium conditions, and heat from fission product decay, hot internals, and the vessel continues to be transferred to the reactor coolant. The blowdown phase of the transient ends when the RCS pressure falls to a value approaching that of the containment atmosphere.

The refill phase of a LOCA follows immediately where reactor coolant inventory has vacated the core through steam flashing and ejection out through the break. The core is essentially in adiabatic heatup. The rest of the SITs' inventory is then available to help fill voids in the lower plenum and reactor vessel downcomer to establish a recovery water level at the bottom of the core and continue reflood of the core with the addition of safety injection water.

The SITs are pressure vessels partially filled with borated water and pressurized with nitrogen gas. The SITs are passive components, since no operator or control action is required for them to perform their function. Internal tank pressure is sufficient to discharge the contents to the RCS, if RCS pressure decreases below the SIT pressure.

Each SIT is piped into an RCS cold leg via the injection lines utilized by the High Pressure Safety Injection and Low Pressure Safety Injection (HPSI and LPSI) systems. Each SIT is isolated from the RCS by a motor-operated isolation valve and two check valves in series. The motor-operated isolation valves are normally open, with power removed from the valve motor to prevent inadvertent closure prior to or during an accident.

B 3.5 EMERGENCY CORE COOLING SYSTEM (ECCS)

B 3.5.2 ECCS - Operating

BASES

BACKGROUND

The function of the ECCS is to provide core cooling and negative reactivity, to ensure that the reactor core is protected after any of the following accidents:

a. Loss of coolant accident;

b. Control element assembly ejection accident;

c. Secondary event, including uncontrolled steam release or excess feedwater heat removal event; and

d. Steam generator tube rupture.

The addition of negative reactivity by the ECCS during a secondary event where primary cooldown could add enough positive reactivity to achieve criticality and return to significant power was considered in design requirements for the ECCS.

There are two phases of ECCS operation: injection and recirculation. In the injection phase, all injection is initially added to the RCS via the cold legs. After the refueling water tank (RWT) has been depleted, the ECCS recirculation phase is entered as the ECCS suction is automatically transferred to the containment sump.

Two redundant, 100% capacity trains are provided. In MODEs 1 and 2, and MODE 3 with pressurizer pressure $\geq$ 1750 psia, each train consists of HPSI and LPSI charging subsystems. In MODEs 1 and 2, and MODE 3 with pressurizer pressure $\geq$ 1750 psia, both trains must be OPERABLE. This ensures that 100% of the core cooling requirements can be provided in the event of a single active failure.

A suction header supplies water from the RWT or the containment sump to the ECCS pumps. Separate piping supplies each train. The discharge headers from each HPSI pump divide into four supply lines. Both HPSI trains feed into each of the four injection lines. The discharge header which is fed from both LPSI pumps divides into four supply lines, each feeding the injection line to each RCS cold leg.

For LOCAs that are too small to initially depressurize the RCS below the shutoff head of the HPSI pumps, the steam generators must provide the core cooling function.

During low temperature conditions in the RCS, limitations are placed on the maximum number of HPSI pumps that may be OPERABLE. Refer to LCO 3.4.12 Bases, for the basis of these requirements.

During a large break LOCA, RCS pressure will decrease to < 200 psia in < 20 seconds. The safety injection systems are actuated upon receipt of a SIAS. If offsite power is available, the safeguard loads start immediately. If offsite power is not available, the engineered safety feature (ESF) buses shed normal operating loads and are connected to the diesel generators. Safeguard loads are then actuated in the programmed time sequence. The time delay associated with diesel starting, sequenced loading, and pump starting determines the time required before pumped flow is available to the core following a LOCA.

The active ECCS components, along with the passive SITs and RWT, covered in LCO 3.5.1 and LCO 3.5.4, provide the cooling water necessary to meet Reference 1, Appendix 1C, Criterion 44.

APPLICABLE SAFETY ANALYSES

The LCO helps to ensure that the following acceptance criteria, established by Reference 2 for ECCSs, will be met following a LOCA:

a. Maximum fuel element cladding temperature is ≤ 2200°F;

b. Maximum cladding oxidation is ≤ 0.17 times the total cladding thickness before oxidation;

c. Maximum hydrogen generation from a zirconium water reaction is ≤ 0.01 times the hypothetical amount generated if all of the metal in the cladding cylinders surrounding the fuel, excluding the cladding surrounding the plenum volume, were to react;

d. Core is maintained in a coolable geometry; and

e. Adequate long-term core cooling capability is maintained.

The LCO also limits the potential for a post-trip return to power, following a steam line break, and ensures that containment temperature limits are met.

Both HPSI and LPSI subsystems are assumed to be OPERABLE in the large break LOCA analysis at full power (Reference 1, Section 14.17). This analysis establishes a minimum required runout flow for the HPSI and LPSI pumps, as well as the maximum required response time for their actuation. The HPSI pumps are credited in the small break LOCA analysis. This analysis establishes the flow and discharge head requirements at the design point for the HPSI pump. The steam generator tube rupture and steam line break analyses also credit the HPSI pumps, but are not limiting in their design.

The large break LOCA event with a loss of offsite power and a single failure (disabling one ECCS train) establishes the OPERABILITY requirements for the ECCS. During the blowdown stage of a LOCA, the RCS depressurizes as primary coolant is ejected through the break into Containment. The nuclear reaction is terminated either by moderator voiding during large breaks or control element assembly insertion during small breaks. Following depressurization, emergency cooling water is injected into the cold legs, flows into the downcomer, fills the lower plenum, and refloods the core.

On smaller breaks, RCS pressure will stabilize at a value dependent upon break size, heat load, and injection flow. The smaller the break, the higher this equilibrium pressure. In all LOCA analyses, injection flow is not credited until RCS pressure drops below the shutoff head of the HPSI pumps.

The LCO ensures that an ECCS train will deliver sufficient water to match decay heat boiloff rates soon enough to minimize core uncovery for a large LOCA. It also ensures that the accident assumptions are met for the small break LOCA and steam line break. For smaller LOCAs the steam generators serve as the heat sink to provide core cooling.

Emergency Core Cooling System - Operating satisfies 10 CFR 50.36(c)(2)(ii), Criterion 3.

LCO

In MODEs 1, 2, and 3, with pressurizer pressure ≥ 1750 psia, two independent (and redundant) ECCS trains are required to ensure that sufficient ECCS flow is available, assuming there is a single failure affecting either train. Additionally, individual components within the ECCS trains may be called upon to mitigate the consequences of other transients and accidents.

In MODEs 1 and 2, and in MODE 3 with pressurizer pressure ≥ 1750 psia, an ECCS train consists of a HPSI subsystem, and a LPSI subsystem.

Each HPSI and LPSI train includes the piping, instruments, and controls to ensure the availability of an OPERABLE flow path capable of taking suction from the RWT on a SIAS and automatically transferring suction to the containment sump upon a recirculation actuation signal.

During an event requiring ECCS actuation, a flow path is provided to ensure an abundant supply of water from the RWT to the RCS, via the HPSI and LPSI pumps and their respective supply headers, to each of the four cold leg injection nozzles. In the long-term, this flow path may be switched to take its supply from the containment sump and to supply part of its flow to the RCS hot legs via the pressurizer or the shutdown cooling (SDC) suction nozzles.

The flow path for each train must maintain its designed independence to ensure that no single failure can disable both ECCS trains.

In addition for the HPSI pump system to be considered OPERABLE, each HPSI pump system (consisting of a HPSI pump and one of two safety injection headers) must have balanced flows, such that the sum of the flow rates of the three lowest flow legs is > 470 gpm.

APPLICABILITY

In MODEs 1 and 2, and in MODE 3 with RCS pressure ≥ 1750 psia, the ECCS OPERABILITY requirements for the limiting DBA large break LOCA are based on full power operation. Although reduced power would not require the same level of performance, the accident analysis does not provide for reduced cooling requirements in the lower MODEs.

The HPSI pump performance is based on the small break LOCA, which establishes the pump performance curve and has less dependence on power. The requirements of MODE 2, and MODE 3 with RCS pressure ≥ 1750 psia, are bounded by the MODE 1 analysis.

The ECCS functional requirements of MODE 3, with RCS pressure < 1750 psia, and MODE 4 are described in LCO 3.5.3.

In MODEs 5 and 6, unit conditions are such that the probability of an event requiring ECCS injection is extremely low. Core cooling requirements in MODE 5 are addressed by LCO 3.4.7 and LCO 3.4.8. MODE 6 core cooling requirements are addressed by LCO 3.9.4 and LCO 3.9.5.

ACTIONS

A.1

If one or more trains are inoperable and at least 100% of the ECCS flow equivalent to a single OPERABLE ECCS train is available, the inoperable components must be returned to OPERABLE status within 72 hours. The 72 hour Completion Time is based on an Nuclear Regulatory Commission study (Reference 3) using a reliability evaluation and is a reasonable amount of time to effect many repairs.

An ECCS train is inoperable if it is not capable of delivering the design flow to the RCS. The individual components are inoperable if they are not capable of performing their design function, or if supporting systems are not available.

The LCO requires the OPERABILITY of a number of independent subsystems. Due to the redundancy of trains and the diversity of subsystems, the inoperability of one component in a train does not render the ECCS incapable of performing its function. Neither does the inoperability of two different components, each in a different train, necessarily result in a loss of function for the ECCS. The intent of this Condition is to maintain a combination of OPERABLE equipment such that 100% of the ECCS flow equivalent to 100% of a single OPERABLE train remains available. This allows increased flexibility in plant operations when components in opposite trains are inoperable.

An event accompanied by a loss of offsite power and the failure of an emergency diesel generator can disable one ECCS train until power is restored. A reliability analysis (Reference 3) has shown that the impact with one full ECCS train inoperable is sufficiently small to justify continued operation for 72 hours.

Reference 4 describes situations in which one component, such as a SDC total flow control valve, can disable both ECCS trains. With one or more components inoperable, such that 100% of the equivalent flow to a single OPERABLE ECCS train is not available, the facility is in a condition outside the accident analyses. Therefore, LCO 3.0.3 must be immediately entered.

B.1 and B.2

If the inoperable train cannot be restored to OPERABLE status within the associated Completion Time, the plant must be brought to a MODE in which the LCO does not apply. To achieve this status, the plant must be brought to at least MODE 3 within 6 hours and pressurizer pressure reduced to $<$ 1750 psia within 12 hours. The allowed Completion Times are reasonable, based on operating experience, to reach the required unit conditions from full power in an orderly manner and without challenging unit systems.

SURVEILLANCE REQUIREMENTS

SR 3.5.2.1

Verification of proper valve position ensures that the flow path from the ECCS pumps to the RCS is maintained. Misalignment of these valves could render both ECCS trains inoperable. Securing these valves in position by interrupting the control signal to the valve operator, ensures that the valves cannot be inadvertently misaligned. These valves are of the type described in Reference 4, which can disable the function of both ECCS trains and invalidate the accident analysis. A 12 hour Frequency is considered reasonable in view of other administrative controls ensuring that a mispositioned valve is an unlikely possibility.

SR 3.5.2.2

Verifying the correct alignment for manual, power-operated, and automatic valves in the ECCS flow paths provides assurance that the proper flow paths will exist for ECCS operation. This SR does not apply to valves that are locked, sealed, or otherwise secured in position, since these valves were verified to be in the correct position prior to locking, sealing, or securing. A valve that receives an actuation signal is allowed to be in a non-accident position provided the valve automatically repositions within the proper stroke time. This SR does not require any testing or valve manipulation. Rather, it involves verification that those valves capable of being mispositioned are in the correct position.

The 31 day Frequency is appropriate because the valves are operated under procedural control and an improper valve position would only affect a single train. This Frequency has been shown to be acceptable through operating experience.

SR 3.5.2.3

Periodic surveillance testing of the HPSI and LPSI pumps to detect gross degradation caused by impeller structural damage or other hydraulic component problems is required by the American Society of Mechanical Engineers Code, Section XI. This type of testing may be accomplished by measuring the pump developed head at only one point of the pump characteristic curve. This verifies both that the measured performance is within an acceptable tolerance of the original pump baseline performance and that the performance at the test flow is greater than or equal to the performance assumed in the unit safety analysis. Surveillance Requirements are specified in the Inservice Testing Program, which encompasses American Society of Mechanical Engineers Code, Section XI. American Society of Mechanical Engineers Code, Section XI provides the activities and Frequencies necessary to satisfy the requirements.

SR 3.5.2.4

The Surveillance Requirement was deleted in Amendment Nos. 260/237.

SR 3.5.2.5, SR 3.5.2.6, and SR 3.5.2.7

These SRs demonstrate that each automatic ECCS valve actuates to the required position on an actual, or simulated SIAS, and on a recirculation actuation signal; that each ECCS pump starts on receipt of an actual or simulated SIAS; and that the LPSI pumps stop on receipt of an actual or simulated recirculation actuation signal. This Surveillance is not required for valves that are locked, sealed, or otherwise secured in the required position under administrative controls. In order to assure the results of the low temperature overpressure protection analysis remain bounding, whenever flow testing into the RCS is required at RCS temperatures ≤ 365°F (Unit 1), ≤ 301°F (Unit 2), the HPSI pump shall recirculate RCS water (suction from the RWT isolated) or the requirements of LCO 3.4.12, shall be satisfied. The 24 month Frequency is based on the need to perform these surveillance tests under the conditions that apply during a plant outage and the potential for unplanned transients if the surveillance tests were performed with the reactor at power. The 24 month Frequency is also acceptable based on consideration of the design reliability (and confirming operating experience) of the equipment. The actuation logic is tested as part of the Engineered Safety Feature Actuation System testing, and equipment performance is monitored as part of the Inservice Testing Program.

SR 3.5.2.8

Periodic inspection of the containment sump ensures that it is unrestricted and stays in proper operating condition. The 24 month Frequency is based on the need to perform this surveillance test under the conditions that apply during an outage, on the need to have access to the location, and on the potential for unplanned transients if the surveillance test were performed with the reactor at power. This Frequency is sufficient to detect abnormal degradation and is confirmed by operating experience.

During the 2007 refueling outage for Unit 2, the sump trash racks and screens will be replaced with a strainer as part of the resolution of NRC Generic Safety Issue 191. The new strainer provides at least equivalent protection for the containment sump to ensure that it is unrestricted and stays in proper operating condition. The Surveillance requires inspection of the components that protect the sump from debris. During the 2007 refueling outage for Unit 2, the Unit 2 sump suction inlet will be visually inspected to ensure that it is not restricted by debris. In addition, the new strainers will be visually inspected to ensure that they show no evidence of structural distress or abnormal corrosion. These inspections meet the requirements for SR 3.5.2.8.

SR 3.5.2.9

Verifying that the SDC System open-permissive interlock is OPERABLE ensures that the SDC suction isolation valves are prevented from being remotely opened when RCS pressure, is at or above, the SDC System design suction pressure of 350 psia. The suction piping of the LPSI pumps, is the SDC component with the limiting design pressure rating. The interlock provides assurance that double isolation of the SDC System from the RCS is preserved whenever RCS pressure, is at or above, the design pressure. The 309 psia value specified in the Surveillance is the actual pressurizer pressure at the instrument tap elevation for PT-103 and PT-103-1 when the SDC System suction pressure is 350 psia. The procedure for this surveillance test contains the required compensation to be applied to this value to account for instrument uncertainties. This surveillance test is normally performed using a simulated RCS pressure input signal. The 24 month Frequency is based on the need to perform this surveillance test under conditions that apply during an outage. The 24 month Frequency is also acceptable based on consideration of the design reliability (and confirming operating experience) for the equipment.

REFERENCES

1. UFSAR
2. 10 CFR 50.46, "Acceptance Criteria for Emergency Core Cooling Systems for Light Water Nuclear Power Plants"

3. Nuclear Regulatory Commission Memorandum to V. Stello, Jr., from R. L. Baer, "Recommended Interim Revisions to LCOs for ECCS Components," December 1, 1975

4. Inspection and Enforcement Information Notice No. 87-01, "RHR Valve Misalignment Causes Degradation of ECCS in PWRs," January 6, 1987

B 3.5 EMERGENCY CORE COOLING SYSTEM (ECCS)

B 3.5.3 ECCS - Shutdown

BASES

BACKGROUND

The Background Section for B 3.5.2, is applicable to these Bases, with the following modification.

In MODE 3 with pressurizer pressure < 1750 psia and in MODE 4, an ECCS train is defined as one HPSI subsystem. The HPSI flow path consists of piping, valves, and pumps that enable water from the RWT to be injected into the RCS following the accidents described in B 3.5.2.

APPLICABLE SAFETY ANALYSES

The Applicable Safety Analyses section of B 3.5.2 is applicable to these Bases.

Due to the stable conditions associated with operation in MODE 3 with RCS pressure < 1750 psia and MODE 4, and the reduced probability of a DBA, the ECCS operational requirements are reduced. Included in these reductions is that certain automatic SIASs are not available. In this MODE, sufficient time exists for manual actuation of the required ECCS to mitigate the consequences of a DBA.

Only one train of ECCS is required for MODE 3 with RCS pressure < 1750 psia and MODE 4. Protection against single failures is not relied on for this MODE of operation.

Emergency Core Cooling System - Shutdown satisfies 10 CFR 50.36(c)(2)(ii), Criterion 3.

LCO

In MODE 3 with pressurizer pressure < 1750 psia and MODE 4, an ECCS subsystem is composed of a single HPSI subsystem. Each HPSI subsystem includes the piping, instruments, and controls to ensure an OPERABLE flow path capable of taking suction from the RWT and transferring suction to the containment sump.

During an event requiring ECCS actuation, a flow path is required to supply water from the RWT to the RCS via the HPSI pumps and their respective supply headers to each of the four cold leg injection nozzles. In the long-term, this flow path may be switched to take its supply from the containment sump and to deliver its flow to the RCS hot and cold legs.

With RCS pressure < 1750 psia, one HPSI pump is acceptable without single failure consideration, based on the stable reactivity condition of the reactor, and the limited core cooling requirements. The LPSI pumps may therefore be released from the ECCS train for use in SDC. In MODE 3 with RCS cold leg temperature ≤ 365°F (Unit 1), ≤ 301°F (Unit 2), a maximum of one HPSI pump is allowed to be OPERABLE in accordance with LCO 3.4.12.

The LCO is modified by a Note which allows the HPSI train to not be capable of automatically starting on an actuation signal when RCS cold leg temperature is < 385°F (Unit 1), < 325°F (Unit 2), during heatup and cooldown and when < 365°F (Unit 1), < 301°F (Unit 2), during other conditions. This allowance is necessary to ensure low temperature overpressure protection analysis assumptions are maintained. The LCO Note provides a transition period [between 385°F and 365°F (Unit 1), between 325°F and 301°F (Unit 2)] where the OPERABLE HPSI pump will be placed in pull-to-lock on a cooldown and restored to automatic status on heatup (see LCO 3.4.12). At 365°F and less (Unit 1), 301°F and less (Unit 2), the required HPSI pump shall be placed in pull-to-lock and will not start automatically. The HPSI pumps and HPSI header isolation valves are required to be out of automatic when operating within the MODEs of Applicability for the Low Temperature Overpressure Protection System (LCO 3.4.12).

APPLICABILITY

In MODEs 1, 2, and 3 with RCS pressure ≥ 1750 psia, the OPERABILITY requirements for ECCS are covered by LCO 3.5.2.

In MODE 3 with RCS pressure < 1750 psia and in MODE 4, one OPERABLE ECCS train is acceptable without single failure consideration, based on the stable reactivity condition of the reactor, and the limited core cooling requirements.

In MODEs 5 and 6, unit conditions are such that the probability of an event requiring ECCS injection is extremely low. Core cooling requirements in MODE 5 are addressed by LCO 3.4.7 and LCO 3.4.8. MODE 6 core cooling requirements are addressed by LCO 3.9.4 and LCO 3.9.5.

ACTIONS

A Note prohibits the application of LCO 3.0.4.b to an inoperable ECCS HPSI subsystem. There is an increased risk associated with entering MODE 4 from MODE 5 with an inoperable ECCS HPSI subsystem and the provisions of LCO 3.0.4.b, which allow entry into a MODE or other specified condition in the Applicability with the LCO not met after performance of a risk assessment addressing inoperable systems and components, should not be applied in this circumstance.

A.1

With no HPSI pump OPERABLE, the unit is not prepared to respond to a LOCA. The one hour Completion Time to restore at least one HPSI train to OPERABLE status, ensures that prompt action is taken to restore the required cooling capacity or to initiate actions to place the unit in MODE 5, where an ECCS train is not required.

B.1

When the Required Action cannot be completed within the required Completion Time, a controlled shutdown should be initiated. Twenty-four hours is reasonable, based on operating experience, to reach MODE 5 in an orderly manner and without challenging plant systems.

SURVEILLANCE REQUIREMENTS

SR 3.5.3.1

The applicable SR descriptions from B 3.5.2 apply.

REFERENCES

The applicable references from B 3.5.2 apply.

Additionally, the isolation valves are interlocked with the pressurizer pressure instrumentation channels, to ensure that the valves will automatically open as RCS pressure increases above SIT pressure, and to prevent inadvertent closure prior to an accident. The valves also receive a safety injection actuation signal (SIAS) to open. These features ensure that the valves meet the requirements of Reference 1 for "operating bypasses" and that the SITs will be available for injection without reliance on operator action.

The SIT gas and water volumes, gas pressure, and outlet pipe size are selected to allow three of the four SITs to partially recover the core before significant clad melting or zirconium water reaction can occur following a LOCA. The need to ensure that three SITs are adequate for this function is consistent with the LOCA assumption that the entire contents of one SIT will be lost via the break during the blowdown phase of a LOCA.

APPLICABLE SAFETY ANALYSES

The large break LOCA analyses at full power (Reference 2, Section 6.3) credits the SITs. This is the Design Basis Accident (DBA) that establishes the acceptance limits for the SITs. Reference to the analysis for this DBA is used to assess changes to the SITs as they relate to the acceptance limits.

In performing the large break LOCA calculations, conservative assumptions are made concerning the availability of safety injection flow. These assumptions include signal generation time, equipment starting times, and delivery time due to system piping. In the early stages of a large break LOCA with a loss of offsite power, the SITs provide the sole source of makeup water to the RCS. (The assumption of a loss of offsite power is required by regulations.) This is because the LPSI pumps, HPSI pumps, and charging pumps cannot deliver flow until the diesel generators start, come to rated speed, and go through their timed loading sequence. In cold leg breaks, the entire contents of one SIT are assumed to be lost through the break during the blowdown and reflood phases.

The limiting large break LOCA is a double ended guillotine cold leg break at the discharge of the reactor coolant pump. During this event, the SITs discharge to the RCS as soon as RCS pressure decreases to below SIT pressure. As a conservative estimate, no credit is taken for safety injection pump flow until the SITs are empty. This results in a minimum effective delay of over 60 seconds, during which the SITs must provide the core cooling function. The actual delay time is less. No operator action is assumed during the blowdown stage of a large break LOCA.

This Limiting Condition for Operation (LCO) helps to ensure that the following acceptance criteria, established by Reference 3 for the Emergency Core Cooling System (ECCS), will be met following a LOCA:

a. Maximum fuel element cladding temperature is ≤ 2200°F;

b. Maximum cladding oxidation is ≤ 0.17 times the total cladding thickness before oxidation;

c. Maximum hydrogen generation from a zirconium water reaction is ≤ 0.01 times the hypothetical amount that would be generated if all of the metal in the cladding cylinders surrounding the fuel, excluding the cladding surrounding the plenum volume, were to react; and

d. The core is maintained in a coolable geometry.

Since the SITs discharge during the blowdown phase of a LOCA, they do not contribute to the long-term cooling requirements of 10 CFR 50.46.

Since the SITs are passive components, single active failures are not applicable to their operation. The SIT isolation valves, however, are not single failure proof; therefore, whenever the valves are open, power is removed from their operators and the switch is key locked open.

These precautions ensure that the SITs are available during an accident (Reference 2, Section 14.17). With power supplied to the valves, a single active failure could result in a valve closure, which would render one SIT unavailable for injection. If a second SIT is lost through the break, only two SITs would reach the core. Since the only active failure that could affect the SITs would be the closure of a motor-operated outlet valve, the requirement to remove power from these eliminates this failure mode.

The minimum volume requirement for the SITs ensures that three SITs can provide adequate inventory to reflood the core and downcomer following a LOCA. The downcomer then remains flooded until the HPSI and LPSI systems start to deliver flow.

The maximum volume limit is based on maintaining an adequate gas volume to ensure proper injection and the ability of the SITs to fully discharge, as well as limiting the maximum amount of boron inventory in the SITs.

A minimum level, corresponding to 1090 cubic feet of borated water is used in the safety analysis as the volume in the SITs. To provide margin, the low level alarms are set at 187 inches (corresponding to 1113 cubic feet) and 199 inches (corresponding to 1179 cubic feet). The analyses are based upon the cubic feet requirements; the level (inches) figures are provided for operator use because the level indicator provided in the Control Room is marked in inches, not in cubic feet.

The minimum nitrogen cover pressure requirement ensures that the contained gas volume will generate discharge flow rates during injection that are consistent with those assumed in the safety analyses.

The maximum nitrogen cover pressure limit ensures that excessive amounts of gas will not be injected into the RCS after the SITs have emptied.

A minimum pressure of 195 psia is used in the analyses. To allow for instrument accuracy, a 200 psig minimum and 250 psig maximum are specified. The maximum allowable boron concentration of 2700 ppm is based upon boron precipitation limits in the core following a LOCA. Establishing a maximum limit for boron is necessary since the time at which boron precipitation would occur in the core following a LOCA is a function of break location, break size, the amount of boron injected into the core, and the point of ECCS injection.

Post-LOCA emergency procedures directing the operator to establish simultaneous hot and cold leg injection are based on the worst case minimum boron precipitation time. Maintaining the maximum SIT boron concentration within the upper limit ensures that the SITs do not invalidate this calculation. An excessive boron concentration in any of the borated water sources used for injection during a LOCA could result in boron precipitation earlier than predicted.

The minimum boron requirements of 2300 ppm are based on beginning-of-life reactivity values and are selected to ensure that the reactor will remain subcritical during the reflood stage of a large break LOCA. During a large break LOCA, all control element assemblies are assumed not to insert into the core, and the initial reactor shutdown is accomplished by void formation during blowdown. Sufficient boron concentration must be maintained in the SITs to prevent a return to criticality during reflood.

The SITs satisfy 10 CFR 50.36(c)(2)(ii), Criterion 3.

LCO

The LCO establishes the minimum conditions required to ensure that the SITs are available to accomplish their core cooling safety function following a LOCA. Four SITs are required to be OPERABLE to ensure that 100% of the contents, for three of the SITs, will reach the core during a LOCA.

This is consistent with the assumption that the contents of one tank spill through the break. If the contents of fewer than three tanks are injected during the blowdown phase of a LOCA, the ECCS acceptance criteria of Reference 3 could be violated.

For an SIT to be considered OPERABLE, the isolation valve must be fully open, power removed above 2000 psig, and the limits established in the Surveillance Requirement (SR) for contained volume, boron concentration, and nitrogen cover pressure must be met.

APPLICABILITY

In MODEs 1, 2, and 3 the SIT OPERABILITY requirements are based on an assumption of full power operation. Although cooling requirements decrease as power decreases, the SITs are still required to provide core cooling as long as elevated RCS pressures and temperatures exist.

In MODEs 4, 5, and 6, the SIT motor-operated isolation valves are closed to isolate the SITs from the RCS. This allows RCS cooldown and depressurization without discharging the SITs into the RCS or requiring depressurization of the SITs.

ACTIONS

A.1

If the boron concentration of one SIT is not within limits it must be returned to within the limits within 72 hours. In this condition, ability to maintain subcriticality or minimum boron precipitation time may be reduced, but the reduced concentration effects on core subcriticality during reflood are minor. Boiling of the ECCS water in the core during reflood concentrates the boron in the saturated liquid that remains in the core. In addition, the volume of the SIT is still available for injection. Since the boron requirements are based on the average boron concentration of the total volume of three SITs, the consequences are less severe than they would be if an SIT were not available for injection. Thus, 72 hours is allowed to return the boron concentration to within limits.

B.1

If one SIT is inoperable, for reasons other than boron concentration, the SIT must be returned to OPERABLE status within one hour. In this Condition, the required contents of three SITs cannot be assumed to reach the core during a LOCA. Due to the severity of the consequences should a LOCA occur in these conditions, the one hour Completion Time to open the valve, remove power from the valve, or restore proper water volume or nitrogen cover pressure, ensures that prompt action will be taken to return the inoperable accumulator to OPERABLE status. The Completion Time minimizes the exposure of the plant to a LOCA in these conditions.

C.1 and C.2

If the SIT cannot be restored to OPERABLE status within the associated Completion Time, the plant must be brought to a MODE in which the LCO does not apply. To achieve this status, the plant must be brought to at least MODE 3 within 6 hours and MODE 4 within 12 hours. The allowed Completion Times are reasonable, based on operating experience, to reach the required plant conditions from full power conditions in an orderly manner and without challenging plant systems.

D.1

If more than one SIT is inoperable, the unit is in a condition outside the accident analyses. Therefore, LCO 3.0.3 must be entered immediately.

SURVEILLANCE REQUIREMENTS

SR 3.5.1.1

Verification every 12 hours that each SIT isolation valve is fully open, as indicated in the Control Room, ensures that SITs are available for injection and ensures timely discovery if a valve should be partially closed. If an isolation valve is not fully open, the rate of injection to the RCS would be reduced. Although a motor-operated valve should not change position with power removed, a closed valve could result in not meeting accident analysis assumptions. A 12 hour Frequency is considered reasonable in view of other administrative controls that ensure the unlikelihood of a mispositioned isolation valve.

SR 3.5.1.2 and SR 3.5.1.3

Safety injection tank borated water volume and nitrogen cover pressure should be verified to be within specified limits every 12 hours in order to ensure adequate injection during a LOCA. Due to the static design of the SITs, a 12 hour Frequency usually allows the operator sufficient time to identify changes before the limits are reached. Operating experience has shown this Frequency to be appropriate for early detection and correction of off normal trends.

SR 3.5.1.4

Six months is reasonable for verification by sampling to determine that each SIT's boron concentration is within the required limits, because the static design of the SITs limits the ways in which the concentration can be changed. This Frequency is adequate to identify changes that could occur from mechanisms, such as stratification or inleakage.

Verification consists of monitoring inleakage or sampling. The inleakage is monitored every 12 hours by monitoring tank level. Sampling of each tank is done every six months. All intentional sources of level increase are maintained administratively to ensure SIT boron concentrations are within technical specification limits. The boron concentration of each tank is verified prior to startup from outages. A sample of the SIT is required, to verify boron concentration, if 10 inches or greater of inleakage has occurred since last sampled.

Sampling the affected SIT (by taking the sample at the discharge of the operating HPSI pump) within one hour prior to a 1% volume increase of normal tank volume, will ensure the boron concentration of the fluid to be added to the SIT is within the required limit prior to adding inventory to the SIT(s).

SR 3.5.1.5

Verification every 31 days that power is removed from each SIT isolation valve operator, by maintaining the feeder breaker open under administrative control, when the pressurizer pressure is ≥ 2000 psig ensures that an active failure could not result in the undetected closure of an SIT motor-operated isolation valve. If this were to occur, only two SITs would be available for injection, given a single failure coincident with a LOCA. Since installation and removal of power to the SIT isolation valve operators is conducted under administrative control, the 31 day Frequency was chosen to provide additional assurance that power is removed.

This SR allows power to be supplied to the motor-operated isolation valves when RCS pressure is < 2000 psig, thus allowing operational flexibility by avoiding unnecessary delays to manipulate the breakers during unit startups or shutdowns. Even with power supplied to the valves, inadvertent closure is prevented by the RCS pressure interlock associated with the valves. Should closure of a valve occur in spite of the interlock, the safety injection signal provided to the valves would open a closed valve in the event of a LOCA.

REFERENCES

1. Institute of Electrical and Electronic Engineers Standard 279-1971, "IEEE Standard: Criteria for Protection Systems for Nuclear Power Generating Stations"
2. Updated Final Safety Analysis Report (UFSAR)
3. 10 CFR 50.46, "Acceptance Criteria for Emergency Core Cooling Systems for Light Water Nuclear Power Plants"

B 3.5 EMERGENCY CORE COOLING SYSTEM (ECCS)

B 3.5.4 Refueling Water Tank (RWT)

BASES

BACKGROUND

The RWT supports the ECCS and the Containment Spray System by providing a source of borated water for ESF pump operation.

The RWT supplies two ECCS trains by separate, redundant supply headers. Each header also supplies one train of the Containment Spray System. A motor-operated isolation valve is provided in each header, to allow the operator to isolate the usable volume of the RWT from the ECCS after the ESF pump suction has been transferred to the containment sump, following depletion of the RWT during a LOCA. A separate header is used to supply the Chemical and Volume Control System from the RWT. Use of a single RWT to supply both trains of the ECCS is acceptable, since the RWT is a passive component, and passive failures are not assumed to occur coincidentally with the Design Basis Event during the injection phase of an accident. Not all the water stored in the RWT is available for injection following a LOCA; the location of the ECCS suction piping in the RWT will result in some portion of the stored volume being unavailable.

The HPSI, LPSI, and containment spray pumps are provided with recirculation lines that ensure each pump can maintain minimum flow requirements when operating at shutoff head conditions. These lines discharge back to the RWT, which vents to the atmosphere. When the suction for the HPSI and containment spray pumps is transferred to the containment sump, this flow path must be isolated to prevent a release of the containment sump contents to the RWT. If not isolated, this flow path could result in a release of contaminants to the atmosphere and the eventual loss of suction head for the ESF pumps.

This LCO ensures that:

a. The RWT contains sufficient borated water to support the ECCS during the injection phase;

b. Sufficient water volume exists in the containment sump to support continued operation of the ESF pumps at the time of transfer to the recirculation mode of cooling; and

c. The reactor remains subcritical following a LOCA.

Insufficient water inventory in the RWT could result in insufficient cooling capacity of the ECCS when the transfer to the recirculation mode occurs. Improper boron concentrations could result in a reduction of SDM or excessive boric acid precipitation in the core following a LOCA, as well as excessive caustic stress corrosion of mechanical components and systems inside Containment.

APPLICABLE SAFETY ANALYSES

During accident conditions, the RWT provides a source of borated water to the HPSI, LPSI, containment spray, and charging pumps when level is low in the boric acid tanks. As such, it provides containment cooling and depressurization, core cooling, and replacement inventory, and is a source of negative reactivity for reactor shutdown (Reference 1). The design basis transients and applicable safety analyses concerning each of these systems are discussed in the Applicable Safety Analyses Section of B 3.5.2 and B 3.6.6. These analyses are used to assess changes to the RWT in order to evaluate their effects in relation to the acceptance limits.

The volume limit of 400,000 gallons is based on two factors:

a. Sufficient deliverable volume must be available to provide at least 32 minutes (plus a 10% margin) of full flow from all ESF pumps prior to reaching a low level switchover to the containment sump for recirculation; and

b. The containment sump water volume must be sufficient to support continued ESF pump operation after the switchover to recirculation occurs. This sump volume water inventory is supplied by the RWT borated water inventory.

When ESF pump suction is transferred to the sump, there must be sufficient water in the sump to ensure adequate net positive suction head for the HPSI and containment spray pumps. The RWT capacity must be sufficient to supply this amount of water without considering the inventory added from the SITs or RCS, but accounting for loss of inventory to containment subcompartments and reservoirs due to containment spray operation and to areas outside containment due to leakage from ECCS injection and recirculation equipment.

The 2300 ppm limit for minimum boron concentration was established to ensure that, following a LOCA with a minimum level in the RWT, the reactor will remain subcritical in the cold condition following mixing of the RWT and RCS water volumes with all control rods inserted, except for the control element assembly of highest worth, which is withdrawn from the core. The most limiting case occurs at beginning of core life.

The maximum boron limit of 2700 ppm in the RWT is based on boron precipitation in the core following a LOCA. With the reactor vessel at saturated conditions, the core dissipates heat by pool nucleate boiling. Because of this boiling phenomenon in the core, the boric acid concentration will increase in this region. If allowed to proceed in this manner, a point will be reached where boron precipitation will occur in the core. Post-LOCA emergency procedures direct the operator to establish simultaneous hot and cold leg injection to prevent this condition by establishing a forced flow path through the core regardless of break location. These procedures are based on the minimum time in which precipitation could occur, assuming that maximum boron concentrations exist in the borated water sources used for injection following a LOCA. Boron concentrations in the RWT in excess of the limit could result in precipitation earlier than assumed in the analysis.

The upper limit of 100°F (only required for MODE 1 operation) and the lower limit of 40°F (RWT temperature), are the limits assumed in the accident analysis.

The RWT satisfies 10 CFR 50.36(c)(2)(ii), Criterion 3.

LCO

The RWT ensures that an adequate supply of borated water is available to: cool and depressurize the Containment in the event of a DBA, to cool and cover the core in the event of a

LOCA, ensure that the reactor remains subcritical following a DBA, and ensure that an adequate level exists in the containment sump to support ESF pump operation in the recirculation mode.

To be considered OPERABLE, the RWT must meet the limits established in the SRs for water volume, boron concentration, and temperature.

APPLICABILITY

In MODEs 1, 2, 3, and 4, the RWT OPERABILITY requirements are dictated by the ECCS and Containment Spray System OPERABILITY requirements. Since both the ECCS and the Containment Spray System must be OPERABLE in MODEs 1, 2, 3, and 4, the RWT must be OPERABLE to support their operation.

Core cooling requirements in MODE 5 are addressed by LCO 3.4.7 and LCO 3.4.8. MODE 6 core cooling requirements are addressed by LCO 3.9.4 and LCO 3.9.5.

ACTIONS

A.1

With RWT boron concentration or borated water temperature not within limits, it must be returned to within limits within eight hours. In this condition neither the ECCS nor the Containment Spray System can perform their design functions; therefore, prompt action must be taken to restore the tank to OPERABLE condition. The allowed Completion Time of eight hours to restore the RWT to within limits was developed considering the time required to change boron concentration or temperature, and that the contents of the tank are still available for injection.

Required Action A.1 only applies to the maximum borated water temperature in MODE 1.

B.1

With RWT borated water volume not within limits, it must be returned to within limits within one hour. In this condition, neither the ECCS nor Containment Spray System can perform their design functions; therefore, prompt action must be taken to restore the tank to OPERABLE status or to place the unit in a MODE in which these systems are not required. The allowed Completion Time of one hour to restore the RWT to OPERABLE status is based on this condition simultaneously affecting multiple redundant trains.

C.1 and C.2

If the RWT cannot be restored to OPERABLE status within the associated Completion Time, the plant must be brought to a MODE in which the LCO does not apply. To achieve this status, the plant must be brought to at least MODE 3 within 6 hours and to MODE 5 within 36 hours. The allowed Completion Times are reasonable, based on operating experience, to reach the required plant conditions from full power conditions in an orderly manner and without challenging plant systems.

SURVEILLANCE REQUIREMENTS

SR 3.5.4.1 and SR 3.5.4.2

Refueling water tank borated water temperature shall be verified every 24 hours to be within the limits assumed in the accident analysis. This Frequency has been shown to be sufficient to identify temperature changes that approach either acceptable limit.

The SRs are modified by a Note that eliminates the requirement to perform this surveillance test when ambient air temperatures are within the operating temperature limits of the RWT. With ambient temperatures within this range, the RWT temperature should not exceed the limits.

Surveillance Requirement 3.5.4.2 is modified by an additional Note which requires the SR to be met in MODE 1 only. A SR is "met" only when the acceptance criteria are satisfied. Known failure of the requirements of a SR, even without a surveillance test specifically being "performed," constitutes a SR not "met." This reflects the maximum coolant temperature assumptions in the LOCA analysis.

SR 3.5.4.3

Above minimum RWT water volume level shall be verified every seven days. This Frequency ensures that a sufficient initial water supply is available for injection and to support continued ESF pump operation on recirculation.

Since the RWT volume is normally stable and is provided with a Low Level Alarm, a seven day Frequency is appropriate and has been shown to be acceptable through operating experience.

SR 3.5.4.4

Boron concentration of the RWT shall be verified every seven days to be within the required range. This Frequency ensures that the reactor will remain subcritical following a LOCA. Further, it ensures that the resulting sump pH will be maintained in an acceptable range such that boron precipitation in the core will not occur earlier than predicted, and the effect of chloride and caustic stress corrosion on mechanical systems and components will be minimized. Since the RWT volume is normally stable, a seven day sampling Frequency is appropriate and has been shown through operating experience to be acceptable.

REFERENCES

1. UFSAR, Chapters 6, "Engineered Safety Features," and 14, "Safety Analysis"

B 3.5 EMERGENCY CORE COOLING SYSTEM (ECCS)

B 3.5.5 Trisodium Phosphate (TSP)

BASES

BACKGROUND

Trisodium phosphate dodecahydrate is placed in baskets on the floor of the Containment Building to ensure that iodine, which may be dissolved in the recirculated reactor cooling water following a LOCA, remains in solution. Trisodium phosphate also helps inhibit stress corrosion cracking (SCC) of austenitic stainless steel components in Containment during the recirculation phase following an accident.

Fuel that is damaged during a LOCA will release iodine in several chemical forms to the reactor coolant and to the containment atmosphere. A portion of the iodine in the containment atmosphere is washed to the sump by containment sprays. The emergency core cooling water is borated for reactivity control. This borated water causes the sump solution to be acidic. In a low pH (acidic) solution, dissolved iodine will be converted to a volatile form. The volatile iodine will evolve out of solution into the containment atmosphere, significantly increasing the levels of airborne iodine. The increased levels of airborne iodine in Containment contribute to the radiological releases and increase the consequences from the accident due to containment atmosphere leakage.

After a LOCA, the components of the core cooling and containment spray systems will be exposed to high temperature borated water. Prolonged exposure to the core cooling water combined with stresses imposed on the components can cause SCC. The SCC is a function of stress, oxygen and chloride concentrations, pH, temperature, and alloy composition of the components. High temperatures and low pH, which would be present after a LOCA, tend to promote SCC. This can lead to the failure of necessary safety systems or components.

Adjusting the pH of the recirculation solution to levels ≥ 7.0 prevents a significant fraction of the dissolved iodine from converting to a volatile form. The higher pH thus decreases the level of airborne iodine in Containment and reduces the radiological consequences from containment atmosphere leakage following a LOCA. Maintaining the solution pH above 7.0 also reduces the occurrence of SCC of austenitic stainless steel components in Containment. Reducing SCC reduces the probability of failure of components.

Granular TSP dodecahydrate is employed as a passive form of pH control for post-LOCA containment spray and core cooling water. Baskets of TSP are placed on the floor in the Containment Building to dissolve from released reactor coolant water and containment sprays after a LOCA. Recirculation of the water for core cooling and containment sprays then provides mixing to achieve a uniform solution pH. The dodecahydrate form of TSP is used because of the high humidity in the Containment Building during normal operation. Since the TSP is hydrated, it is less likely to absorb large amounts of water from the humid atmosphere and will undergo less physical and chemical change than the anhydrous form of TSP.

APPLICABLE SAFETY ANALYSES

The LOCA radiological consequences analysis takes credit for iodine retention in the sump solution based on the recirculation water pH being ≥ 7.0. The radionuclide releases from the containment atmosphere and the consequences of a LOCA would be increased if the pH of the recirculation water were not adjusted to 7.0 or above.

Trisodium phosphate satisfies 10 CFR 50.36(c)(2)(ii), Criterion 3.

LCO

The TSP is required to adjust the pH of the recirculation water to ≥ 7.0 after a LOCA. A pH ≥ 7.0 is necessary to prevent significant amounts of iodine released from fuel failures and dissolved in the recirculation water from converting to a volatile form and evolving into the containment atmosphere. Higher levels of airborne iodine in Containment may increase the release of radionuclides and the consequences of the accident. A pH > 7.0 is also necessary to prevent SCC of austenitic stainless steel components in Containment. Stress corrosion cracking increases the probability of failure of components.

The required amount of TSP is based upon the extreme cases of water volume and pH possible in the containment sump after a large break LOCA. The minimum required volume is, the volume of TSP that will achieve a sump solution pH of ≥ 7.0 when taking into consideration the maximum possible sump water volume, and the minimum possible pH. The amount of TSP needed in the Containment Building is based on the mass of TSP required to achieve the desired pH. However, a required volume is specified, rather than mass, since it is not feasible to weigh the entire amount of TSP in Containment. The minimum required volume is based on the manufactured density of TSP dodecahydrate. Since TSP can have a tendency to agglomerate from high humidity in the Containment Building, the density may increase and the volume decrease during normal plant operation. Due to possible agglomeration and increase in density, estimating the minimum volume of TSP in Containment is conservative with respect to achieving a minimum required pH.

APPLICABILITY

In MODEs 1, 2, 3, and 4, the RCS is at elevated temperature and pressure, providing an energy potential for a LOCA. The potential for a LOCA results in a need for the ability to control the pH of the recirculated coolant.

In MODEs 5 and 6, the potential for a LOCA is reduced or non-existent due to the reduced pressure and temperature limitations of these MODEs, and TSP is not required.

ACTIONS

A.1

If it is discovered that the TSP in the Containment Building sump is not within limits, action must be taken to restore the TSP to within limits. During plant operation the containment sump is not accessible and corrections may not be possible.

The Completion Time of 72 hours is allowed for restoring the TSP within limits, where possible, because 72 hours is the same time allowed for restoration of other ECCS components.

B.1 and B.2

If the TSP cannot be restored within limits within the Completion Time of Required Action A.1, the plant must be brought to a MODE in which the LCO does not apply. To achieve this status, the plant must be brought to at least

MODE 3 within 6 hours and to MODE 5 within 36 hours. The allowed Completion Times are reasonable, based on operating experience, to reach the required plant conditions from full power in an orderly manner and without challenging plant systems.

SURVEILLANCE REQUIREMENTS

SR 3.5.5.1

Periodic determination of the volume of TSP in Containment must be performed due to the possibility of leaking valves and components in the Containment Building that could cause dissolution of the TSP during normal operation. A Frequency of 24 months is required to determine visually that a minimum of 289.3 cubic feet is contained in the TSP baskets. This requirement ensures that there is an adequate volume of TSP to adjust the pH of the post-LOCA sump solution to a value ≥ 7.0.

The periodic verification is required every 24 months, since access to the TSP baskets is only feasible during outages, and normal fuel cycles are scheduled for 24 months. Operating experience has shown this SR Frequency acceptable, due to the margin in the volume of TSP placed in the Containment Building.

SR 3.5.5.2

Testing must be performed to ensure the solubility and buffering ability of the TSP after exposure to the containment environment. A representative sample of 3.43 ± 0.05 grams of TSP, from one of the baskets in Containment is submerged in 1.0 ± 0.01 liters of water at a boron concentration of 3106 ± 50 ppm, and at the standard temperature of 120 ± 5°F. Within four hours without agitation, the solution is decanted and mixed, the temperature adjusted to 77 ± 2°F, and the pH measured. The solution pH should be ≥ 6.0. The representative sample weight is based on the minimum required TSP weight of 14,371 lbm, which at manufactured density corresponds to the minimum volume of 289.3 cubic feet, and maximum possible post-LOCA sump volume of 4,503,500 lbm, normalized to buffer a 1.0 ± 0.01 liter sample. The boron concentration of the test water is representative of the maximum possible boron concentration corresponding to the maximum possible post-LOCA sump volume. Agitation of the test solution is prohibited, since an adequate standard for the agitation intensity cannot be specified. A test time of four hours would allow time for the dissolved TSP to naturally diffuse through the sample solution. A test time of less than four hours is more conservative than a test time of longer than four hours because the longer time could permit additional TSP to dissolve, if excess TSP was available. In the post-LOCA containment sump, rapid mixing would occur, significantly decreasing the actual amount of time before the required pH is achieved. This would ensure compliance with the Standard Review Plan requirement of a pH $\geq$ 7.0 by the onset of recirculation after a LOCA.

REFERENCES None