# B 3.5 EMERGENCY CORE COOLING SYSTEMS (ECCS)

## B 3.5.1 Accumulators

BASES

BACKGROUND

The functions of the ECCS accumulators are to supply water to the reactor vessel during the blowdown phase of a loss of coolant accident (LOCA), to provide inventory to help accomplish the refill phase that follows thereafter, and to provide Reactor Coolant System (RCS) makeup for a small break LOCA.

The blowdown phase of a large break LOCA is the initial period of the transient during which the 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 flow from the accumulators or safety injection (SI) begins (Ref. 1).

In the refill phase of a LOCA, which immediately follows the blowdown phase, reactor coolant inventory has vacated the core through steam flashing and ejection out through the break. The core is essentially in adiabatic heatup. The balance of accumulator inventory is then available to help fill voids in the lower plenum and reactor vessel downcomer so as to establish a recovery level at the bottom of the core and ongoing reflood of the core with the addition of SI water.

The accumulators are pressure vessels partially filled with borated water and pressurized with nitrogen gas. Boric acid used in the accumulators is enriched in $B^{10}$ to allow for a reduction in the boric acid concentration. The accumulators are passive components, since no operator or control actions are required in order for them to perform their function. Internal accumulator tank pressure is sufficient to discharge the accumulator contents to the RCS, if RCS pressure decreases below the accumulator pressure.

Each accumulator is piped into an RCS cold leg via an accumulator line and is isolated from the RCS by a motor operated isolation valve and two check valves in series.

The accumulator size, water volume, and nitrogen cover pressure are selected so that three of the four accumulators are sufficient to partially cover the core before significant clad melting or zirconium water reaction can occur following a LOCA. The need to ensure that three accumulators are adequate for this function is consistent with the LOCA assumption that the entire contents of one accumulator will be lost via the RCS pipe break during the blowdown phase of the LOCA.

BASES

APPLICABLE SAFETY ANALYSES

The accumulators are assumed OPERABLE in both the large and small break LOCA analyses at full power (Ref. 1). These are the Design Basis Accidents (DBAs) that establish the acceptance limits for the accumulators. Reference to the analyses for these DBAs is used to assess changes in the accumulators as they relate to the acceptance limits.

In performing the LOCA calculations, conservative assumptions are made concerning the availability of ECCS flow. In the early stages of a LOCA, with or without a loss of offsite power, the accumulators provide the sole source of makeup water to the RCS. The assumption of loss of offsite power is required by regulations and conservatively imposes a delay wherein the ECCS pumps cannot deliver flow until the emergency diesel generators start, come to rated speed, and go through their timed loading sequence. In cold leg break scenarios, the entire contents of one accumulator are assumed to be lost through the break.

The limiting large break LOCA is a double ended guillotine break in the cold leg piping between the reactor coolant pump and the reactor vessel for the RCS loop containing the pressurizer. During this event, the accumulators discharge to the RCS as soon as RCS pressure decreases to below accumulator pressure.

As a conservative estimate, no credit is taken for ECCS pump flow until an effective delay has elapsed. This delay accounts for the diesels starting and the pumps being loaded and delivering full flow. During this time, the accumulators are analyzed as providing the sole source of emergency core cooling. No operator action is assumed during the blowdown stage of a large break LOCA.

The worst case small break LOCA analyses also assume a time delay before pumped flow reaches the core. The Protection System automatically starts the Medium Head Safety Injection (MHSI) and Low Head Safety Injection (LHSI) pumps and initiates a partial cooldown of the secondary system. The degree of accumulator discharge into the RCS depends on RCS pressure.

This LCO helps to ensure that the following acceptance criteria established for the ECCS by 10 CFR 50.46 (Ref. 2) 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;

BASES

APPLICABLE SAFETY ANALYSES (continued)

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. Core is maintained in a coolable geometry.

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

For both the large and small break LOCA analyses, a nominal contained accumulator water volume is used. The contained water volume is the same as the deliverable volume for the accumulators, since the accumulators are emptied, once discharged. For small breaks, an increase in water volume is a peak clad temperature penalty. For large breaks, an increase in water volume can be either a peak clad temperature penalty or benefit, depending on downcomer filling and subsequent spill through the break during the core reflooding portion of the transient. The analysis makes a conservative assumption with respect to ignoring or taking credit for line water volume from the accumulator to the check valve. The safety analysis assumes values of 1236 $ft^3$ and 1412.6 $ft^3$.

The minimum boron concentration setpoint is used in the post LOCA boron concentration calculation. The calculation is performed to assure reactor subcriticality in a post LOCA environment. Of particular interest is the large break LOCA, since no credit is taken for control rod assembly insertion. A reduction in the accumulator minimum boron concentration would produce a subsequent reduction in the available containment sump concentration for post LOCA shutdown and an increase in the maximum sump pH. The maximum boron concentration is used in determining the cold leg to hot leg recirculation injection switchover time and minimum sump pH.

The large and small break LOCA analyses are performed at the minimum nitrogen cover pressure, since sensitivity analyses have demonstrated that higher nitrogen cover pressure results in a computed peak clad temperature benefit. The maximum nitrogen cover pressure limit prevents accumulator relief valve actuation, and ultimately preserves accumulator integrity.

BASES

APPLICABLE SAFETY ANALYSES (continued)

The effects on containment mass and energy releases from the accumulators are accounted for in the appropriate analyses (Refs. 1 and 3).

The accumulators satisfy Criterion 3 of 10 CFR 50.36(d)(2)(ii).

LCO

The LCO establishes the minimum conditions required to ensure that the accumulators are available to accomplish their core cooling safety function following a LOCA. Four accumulators are required to ensure that 100% of the contents of three of the accumulators will reach the core during a LOCA. This is consistent with the assumption that the contents of one accumulator spill through the break. If less than three accumulators are injected during the blowdown phase of a LOCA, the ECCS acceptance criteria of 10 CFR 50.46 (Ref. 2) could be violated.

For an accumulator to be considered OPERABLE, the isolation valve must be fully open, power removed above 2000 psig, and the limits established in the SRs for contained volume, boron concentration, boron isotopic inventory, and nitrogen cover pressure must be met.

APPLICABILITY

In MODES 1 and 2, and in MODE 3 with RCS pressure > 1000 psig, the accumulator OPERABILITY requirements are based on full power operation. Although cooling requirements decrease as power decreases, the accumulators are still required to provide core cooling as long as elevated RCS pressures and temperatures exist.

This LCO is only applicable at pressures > 1000 psig. At pressures ≤ 1000 psig, the rate of RCS blowdown is such that the ECCS pumps can provide adequate injection to ensure that peak clad temperature remains below the 10 CFR 50.46 (Ref. 2) limit of 2200°F.

In MODE 3, with RCS pressure ≤ 1000 psig, and in MODES 4, 5, and 6, the accumulator motor operated isolation valves are closed to isolate the accumulators from the RCS. During RCS cooldown, two accumulators (Trains 3 and 4) are depressurized to approximately 304 psig and reconnected to the RCS to prevent Reactor Coolant Pump (RCP) seal injection damage in the event of an inadvertent RCS depressurization when the pressurizer is in a water solid state. Once all RCPs are stopped, the Train 3 and 4 accumulators are again isolated.

BASES

ACTIONS

A.1

If the boron concentration or boron enrichment of one accumulator 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. The boron in the accumulators contributes to the assumption that the combined ECCS water in the partially recovered core during the early reflooding phase of a large break LOCA is sufficient to keep that portion of the core subcritical. One accumulator below the minimum boron concentration or enrichment limit, however, will have no effect on available ECCS water and an insignificant effect on core subcriticality during reflood. Boiling of ECCS water in the core during reflood concentrates boron in the saturated liquid that remains in the core. In addition, the main steam line break analysis demonstrates that the accumulators do not discharge following a large main steam line break. Even if they do discharge, their impact is minor and not a design limiting event. Thus, 72 hours is allowed to return the boron concentration and enrichment to within limits.

B.1

If one accumulator is inoperable for a reason other than boron concentration or enrichment, the accumulator must be returned to OPERABLE status within 1 hour. In this Condition, the required contents of three accumulators 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 1 hour Completion Time to open the valve, remove power to the valve, or restore the 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 potential for exposure of the plant to a LOCA under these conditions.

C.1 and C.2

If the accumulator cannot be returned 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 MODE 3 within 6 hours and RCS pressure reduced to ≤ 1000 psig 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.

BASES

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ACTIONS (continued)

D.1

If more than one accumulator is inoperable, the plant is in a condition outside the accident analyses; therefore, LCO 3.0.3 must be entered immediately.

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SURVEILLANCE REQUIREMENTS

SR 3.5.1.1

Each accumulator valve should be verified to be fully open every 12 hours. This verification ensures that the accumulators are available for injection and ensures timely discovery if a valve should be less than fully open. If an isolation valve is not fully open, the rate of injection to the RCS would be reduced. Although a motor operated valve position should not change with power removed, a closed valve could result in not meeting accident analyses assumptions. This Frequency is considered reasonable in view of other administrative controls that ensure a mispositioned isolation valve is unlikely.

SR 3.5.1.2 and SR 3.5.1.3

Every 12 hours, borated water volume and nitrogen cover pressure are verified for each accumulator. This Frequency is sufficient to ensure adequate injection during a LOCA. Because of the static design of the accumulator, a 12 hour Frequency usually allows the operator to identify changes before 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

The boron concentration should be verified to be within required limits for each accumulator every 31 days since the static design of the accumulators limits the ways in which the concentration can be changed. The 31 day Frequency is adequate to identify changes that could occur from mechanisms such as stratification or inleakage. Sampling the affected accumulator within 6 hours after a 145 gallon (1%) volume increase will identify whether inleakage has caused a reduction in boron

BASES

SURVEILLANCE REQUIREMENTS (continued)

concentration to below the required limit. It is not necessary to verify boron concentration if the added water inventory is from the in-containment refueling water storage tank (IRWST), because the water contained in the IRWST is within the accumulator boron concentration requirements. This is consistent with the recommendation of NUREG-1366 (Ref. 4).

SR 3.5.1.5

Verification every 31 days that power is removed from each accumulator isolation valve operator when the RCS pressure is ≥ 2000 psig ensures that an active failure could not result in the undetected closure of an accumulator motor operated isolation valve. If this were to occur, only two accumulators would be available for injection given a single failure coincident with a LOCA. Since power is removed under administrative control, the 31 day Frequency will provide adequate 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 plant startups or shutdowns.

SR 3.5.1.6

The boron used in the accumulators is enriched to > 37% in the $B^{10}$ isotope. Verification every 24 months that the $B^{10}$ enrichment is > 37% ensures that the $B^{10}$ concentration assumed in the accident analysis is available. Since $B^{10}$ in the accumulators is not exposed to a significant neutron field, 24 months is considered conservative.

REFERENCES

1. FSAR Chapter 15.
2. 10 CFR 50.46.
3. FSAR Chapter 6.
4. NUREG-1366, February 1990.

# B 3.5 EMERGENCY CORE COOLING SYSTEMS (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 (LOCA), coolant leakage greater than the capability of the normal charging system;

b. Rod ejection accident;

c. Loss of secondary coolant accident, including uncontrolled steam release or loss of feedwater; and

d. Steam generator tube rupture (SGTR).

The addition of negative reactivity is designed primarily for the loss of secondary coolant accident where primary cooldown could add enough positive reactivity to achieve criticality and return to significant power.

There are two phases of ECCS operation: injection and hot leg recirculation. In the injection phase, water is taken from the in-containment refueling water storage tank (IRWST) and injected into the Reactor Coolant System (RCS) through the cold legs. After approximately 24 hours, the LHSI flow is shifted to the hot leg recirculation phase to provide a backflush, which would reduce the boiling in the top of the core and any resulting boron precipitation.

The ECCS consists of two separate subsystems: Medium Head Safety Injection (MHSI) and Low Head Safety Injection (LHSI). Each subsystem consists of four redundant, 100% capacity trains. The ECCS accumulators and the IRWST are also part of the ECCS, but are not considered part of an ECCS flow path as described by this LCO.

Each ECCS flow path consists of piping, valves, heat exchangers, and pumps such that water from the IRWST can be injected into the RCS following the accidents described in this LCO. The major components of each subsystem are the MHSI pumps, the LHSI pumps, and heat exchangers. Each of the two subsystems (MHSI and LHSI) consists of four 100% capacity trains that are independent and redundant such that each train is capable of supplying 100% of the flow required to mitigate the accident consequences.

BASES

BACKGROUND (continued)

Four separate suction supply lines supply water from the IRWST to the ECCS pumps. Each of the four trains is independent and injects into a single RCS cold leg. If it is necessary to remove one LHSI train from service, an isolatable ECCS cross-connect ensures LHSI delivery in the event of a cold-leg break. Whenever the cross-connects are opened, the isolation valve's electrical breakers are racked-out to avoid single failure. Otherwise, both ECCS cross-connects are isolated to maintain train separation.

For LOCAs that are too small to depressurize the RCS below the shutoff head of the MHSI pumps, the secondary side is cooled down to approximately 870 psia at a rate of approximately 180°F/hr by means of the relief valves to ensure adequate injection from the MHSI system.

Due to the large miniflow lines, it is not necessary to limit the number of MHSI or LHSI pumps in service during low temperature conditions in the RCS. Refer to the Bases for LCO 3.4.11, "Low Temperature Overpressure Protection (LTOP) System," for the basis of low RCS temperature operation.

The ECCS subsystems are actuated upon receipt of a Protection System (PS) signal. The actuation of safeguard loads is accomplished in a programmed time sequence. If offsite power is available, the safeguard loads start in the programmed sequence. If offsite power is not available, the Engineered Safety Feature (ESF) buses shed normal operating loads and are connected to the emergency diesel generators (EDGs). 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 accumulators and the IRWST covered in LCO 3.5.1, "Accumulators," and LCO 3.5.4, "In-Containment Refueling Water Storage Tank (IRWST)," provide the Cooling water necessary to meet GDC 35 (Ref. 1).

APPLICABLE SAFETY ANALYSES

The LCO helps to ensure that the following acceptance criteria for the ECCS, established by 10 CFR 50.46 (Ref. 2), 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;

BASES

APPLICABLE SAFETY ANALYSES (continued)

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 post trip return to power following an MSLB event and ensures that containment temperature limits are met.

Each ECCS subsystem is taken credit for in a large break LOCA event at full power (Refs. 3 and 4). This event establishes the requirement for runout flow for the ECCS pumps, as well as the maximum response time for their actuation. The MHSI and LHSI pumps are credited in a small break LOCA event. This event establishes the flow and discharge head at the design point for the MHSI pumps. The SGTR and MSLB events also credit the MHSI pumps. The OPERABILITY requirements for the ECCS are based on the following LOCA analysis assumptions:

a. A large break LOCA event, with loss of offsite power; and

b. A small break LOCA event, with a loss of offsite power.

In the event of a large break LOCA, when the only available LHSI connection is located adjacent to the broken cold leg, ECCS delivery to the reactor vessel downcomer may be affected by steam entrainment to the broken leg. This assumes that one train is out of service due to preventative maintenance, one train is assumed to have a single failure, and another train feeds the broken loop. In order to mitigate the effect of degraded ECCS delivery due to steam entrainment, isolable ECCS cross-connects are provided. This arrangement directs a portion of the LHSI flow to an adjacent train, thereby reducing flow lost to steam entrainment. The ECCS cross-connects between Trains 1 and 2 and Trains 3 and 4 are normally isolated by two motor-operated valves in series to maintain train separation. Both cross-connect isolation valves are opened when an ECCS train is taken out of service for maintenance and power removed from the motor operators.

During the blowdown stage of a LOCA, the RCS depressurizes as primary coolant is ejected through the break into the containment. The nuclear reaction is terminated either by moderator voiding during large breaks or control rod insertion for 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.

BASES

APPLICABLE SAFETY ANALYSES (continued)

The effects on containment mass and energy releases are accounted for in appropriate analyses (Refs. 3 and 4). The LCO ensures that an ECCS train will deliver sufficient water to match boil off rates soon enough to minimize the consequences of the core being uncovered following a large LOCA. It also ensures that the MHSI pumps will deliver sufficient water and boron during a small LOCA to maintain core subcriticality. For smaller LOCAs, the MHSI pump delivers sufficient fluid to maintain RCS inventory. For a small break LOCA, the steam generators continue to serve as the heat sink, providing part of the required core cooling. The cooling capability of the steam generators is enhanced by the operation of the secondary side main steam relief trains.

The ECCS trains satisfy Criterion 3 of 10 CFR 50.36(d)(2)(ii).

LCO

Four 100% capacity independent (cross-connect closed) ECCS trains are required to ensure that sufficient ECCS flow is available. Additionally, individual components within the ECCS trains may be called upon to mitigate the consequences of other transients and accidents.

An ECCS train consists of an MHSI subsystem, and an LHSI subsystem. Each train includes the piping, instruments, and controls to ensure an OPERABLE flow path capable of injecting upon an PS signal.

During an event requiring ECCS actuation, a flow path is required to provide an abundant supply of water from the IRWST to the RCS via the ECCS pumps to the individual cold leg injection nozzles. In the long term, this flow path may be switched to supply its flow to the RCS hot and cold legs.

The IRWST ensures that an adequate supply of borated water is available to cool and depressurize the containment in the event of a Design Basis Accident (DBA), to cool and cover the core in the event of a LOCA, to maintain the reactor subcritical following a DBA, and to ensure adequate level in the containment sump to support ECCS pump operation.

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

BASES

APPLICABILITY

In MODES 1, 2, and 3, the ECCS OPERABILITY requirements for the limiting Design Basis Accident, a 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 MHSI pump performance requirements are based on a small break LOCA. MODE 2, and 3 requirements are bounded by the MODE 1 analysis.

This LCO is only applicable in MODE 3 and above. Below 356°F, the PS signal setpoint is manually bypassed by operator control, and system functional requirements are relaxed as described in LCO 3.5.3, "ECCS - Shutdown."

In MODES 5 and 6, plant 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, "RCS Loops - MODE 5, Loops Filled," and LCO 3.4.8, "RCS Loops - MODE 5, Loops Not Filled." MODE 6 core cooling requirements are addressed by LCO 3.9.4, "LHSI / RHR and Coolant Circulation - High Water Level," and LCO 3.9.5, " LHSI / RHR and Coolant Circulation - Low Water Level."

ACTIONS

A.1

With one MHSI train inoperable, the inoperable components must be returned to OPERABLE status within 120 days. The 120 day Completion Time is based on the assumption in the FSAR Chapter 15 analysis that one ECCS train is assumed out of service for maintenance at the time of the accident.

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

B.1 and B.2

With one LHSI train inoperable, an acceptable ECCS configuration can be achieved by opening both ECCS cross connections. In the event of a cold leg break, one train is assumed lost due to steam entrainment to the broken loop, one train is assumed to mitigate the event, one train is assumed to spill out the break, and one train is assumed to have a single failure. A reliability analysis (Ref. 5) has shown that the impact of having one full ECCS train inoperable is sufficiently small to justify continued operation for 72 hours. The 120 day Completion Time is based on the assumption in the FSAR Chapter 15 analysis that one ECCS train is assumed out of service for maintenance at the time of the accident.

BASES

ACTIONS (continued)

C.1

With two MHSI trains inoperable, at least one train must be restored to OPERABLE status in 72 hours. This allowed completion time is reasonable since two trains are available and only one train is required to accomplish the safety function. With only two trains OPERABLE, the single failure criterion is not met.

D.1 and D.2

If the inoperable trains cannot be returned 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 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.

E.1

Condition E is applicable with three or more trains inoperable. With less than 100% of the ECCS flow equivalent to two OPERABLE ECCS trains available, the facility is in a condition outside of the accident analyses. Therefore, LCO 3.0.3 must be entered immediately.

SURVEILLANCE REQUIREMENTS

SR 3.5.2.1

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. The ECCS flow path verification includes verification that the cold leg cross-connect valves are in their required position. This SR does not apply to valves that are locked, sealed, or otherwise secured in position, since these 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 nonaccident position provided the valve will automatically reposition within the proper stroke time. This Surveillance 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 administrative control, and an improper valve position would only affect a single train. This Frequency has been shown to be acceptable through operating experience.

BASES

SURVEILLANCE REQUIREMENTS (continued)

SR 3.5.2.2

The ECCS pumps are normally in a standby, nonoperating mode. As such, flow path piping has the potential to develop voids and pockets of entrained gases. Maintaining the piping from the ECCS pumps to the RCS full of water ensures that the system will perform properly, injecting its full capacity into the RCS upon demand. This will also prevent water hammer, pump cavitation, and pumping of noncondensible gas (e.g., air, nitrogen, or hydrogen) into the reactor vessel following a PS signal or during shutdown cooling. The 31 day Frequency takes into consideration the gradual nature of gas accumulation in the ECCS piping and the procedural controls governing system operation.

SR 3.5.2.3

Periodic surveillance testing of ECCS pumps to detect gross degradation caused by impeller structural damage or other hydraulic component problems is required by the ASME Code. 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 plant safety analysis. SRs are specified in the Inservice Testing Program of the ASME Code. The ASME Code provides the activities and Frequencies necessary to satisfy the requirements.

SR 3.5.2.4 and SR 3.5.2.5

These Surveillances demonstrate that each automatic ECCS valve actuates to the required position on an actual or simulated PS signal and that each ECCS pump starts on receipt of an actual or simulated PS signal. This Surveillance is not required for valves that are locked, sealed, or otherwise secured in the required position under administrative controls. The 24 month Frequency is based on the need to perform these Surveillances under the conditions that apply during a plant outage and the potential for unplanned plant transients if the Surveillances 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 Protection System testing, and equipment performance is monitored as part of the Inservice Testing Program.

BASES

SURVEILLANCE REQUIREMENTS (continued)

SR 3.5.2.6

Periodic inspections of the suction inlet from the IRWST ensure that it is unrestricted and stays in proper operating condition. The 24 month Frequency is based on the need to perform this Surveillance under the conditions that apply during a plant outage, on the need to have access to the location, and because of the potential for an unplanned transient if the Surveillance were performed with the reactor at power. This Frequency has been found to be sufficient to detect abnormal degradation and is confirmed by operating experience.

REFERENCES

1. 10 CFR 50, Appendix A, GDC 35.
2. 10 CFR 50.46.
3. FSAR Section 6.2, "Containment Systems."
4. FSAR Chapter 15, "Accident Analysis."
5. NRC Memorandum to V. Stello, Jr., from R.L. Baer, "Recommended Interim Revisions to LCOs for ECCS Components," December 1, 1975.

# B 3.5 EMERGENCY CORE COOLING SYSTEMS (ECCS)

## B 3.5.3 ECCS - Shutdown

BASES

### BACKGROUND

The Background section for Bases 3.5.2, "ECCS - Operating," is applicable to these Bases, with the following modifications.

In MODE 4, a single ECCS train consisting of a Medium Head Safety Injection (MHSI) train is capable of providing the core cooling function. A second train is assumed to spill out of the break. Low head Safety Injection is not automatically actuated.

The ECCS flow paths consist of piping, valves, heat exchangers, and pumps such that water from the in-containment refueling water storage tank (IRWST) can be injected into the Reactor Coolant System (RCS) following the accidents described in Bases 3.5.2.

### APPLICABLE SAFETY ANALYSES

The Applicable Safety Analyses section of Bases 3.5.2 also applies to this Bases section.

Due to the stable conditions associated with operation in MODE 4 and the reduced probability of occurrence of a Design Basis Accident (DBA), the ECCS operational requirements are reduced. Below P14 and RHR connected, LHSI is not automatically actuated by the Protection System (PS). However, MHSI is automatically actuated by the PS.

Two trains of ECCS are required for MODE 4. Protection against single failures is not relied on for this MODE of operation.

The ECCS trains satisfy Criterion 3 of 10 CFR 50.36(d)(2)(ii).

### LCO

In MODE 4, two of the four independent (and redundant) ECCS MHSI trains are required to be OPERABLE to ensure that sufficient ECCS flow is available to the core following a DBA. One train is required to accomplish the safety function and one train is assumed to feed the break. The ECCS cross-connects are not needed for events postulated in MODE 4.

In MODE 4, an ECCS train consists of an MHSI subsystem. Each train includes the piping, instruments, and controls to ensure an OPERABLE flow path capable of taking suction from the IRWST.

BASES

LCO (continued)

During an event requiring ECCS MHSI actuation, a flow path is required to provide an abundant supply of water from the IRWST to the RCS via the ECCS pumps and to its associated four cold leg injection nozzles. In the long term, this flow path may be switched to deliver its flow to the RCS hot and cold legs.

APPLICABILITY

In MODES 1, 2, 3 and 4, the OPERABILITY requirements for ECCS are covered by LCO 3.5.2.

In MODE 4, two OPERABLE ECCS MHSI trains are acceptable without single failure consideration on the basis of the stable reactivity of the reactor and the limited core cooling requirements.

In MODES 5 and 6, plant 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, "RCS Loops - MODE 5, Loops Filled," and LCO 3.4.8, "RCS Loops - MODE 5, Loops Not Filled." MODE 6 core cooling requirements are addressed by LCO 3.9.4, "LHSI/RHR and Coolant Circulation - High Water Level," and LCO 3.9.5, "LHSI/RHR and Coolant Circulation - Low Water Level."

ACTIONS

A Note prohibits the application of LCO 3.0.4.b to an inoperable ECCS MHSI train. There is an increased risk associated with entering MODE 4 from MODE 5 with an inoperable ECCS MHSI train 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 one required MHSI train inoperable, the inoperable train must be returned to OPERABLE status within 72 hours. The 72 hour Completion Time is based on an NRC reliability evaluation (Ref. 5) and is a reasonable time for repair of many ECCS components.

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

BASES

ACTIONS (continued)

B.1

When Required Action A.1 cannot be completed within the required Completion Time; or if two required ECCS MHSI trains are inoperable, the unit must be placed in a MODE in which the LCO does not apply. To achieve this status, the unit must be placed in MODE 5 within 12 hours.

The allowed Completion Time is reasonable, based on operating experience, to reach the required unit conditions from MODE 4 in an orderly manner and without challenging unit systems.

SURVEILLANCE REQUIREMENTS

SR 3.5.3.1

The applicable Surveillance descriptions from Bases 3.5.2 apply.

REFERENCES

The applicable references from Bases 3.5.2 apply.

# B 3.5 EMERGENCY CORE COOLING SYSTEMS (ECCS)

## B 3.5.4 In-Containment Refueling Water Storage Tank (IRWST)

BASES

### BACKGROUND

The IRWST supplies borated water to the refueling pool during refueling, and to the ECCS during accident conditions.

The IRWST supplies all four trains of the ECCS through separate, independent supply headers during the injection phase of a loss of coolant accident (LOCA) recovery.

During normal operation in MODES 1, 2, and 3, Medium Head Safety Injection (MHSI) and Low Head Safety Injection (LHSI) pumps are aligned to take suction from the IRWST.

The ECCS pumps are provided with recirculation lines that ensure each pump can maintain minimum flow requirements when operating at or near shutoff head conditions.

This LCO ensures that:

a. The IRWST contains sufficient borated water to support the ECCS accident mitigation function; and

b. The reactor remains subcritical following a LOCA.

Insufficient water in the IRWST could result in insufficient cooling capacity and suction head for ECCS operation. Improper boron concentrations or enrichment could result in a reduction of SDM or excessive boric acid precipitation in the core following the LOCA, as well as excessive caustic stress corrosion of mechanical components and systems inside the containment.

### APPLICABLE SAFETY ANALYSES

During accident conditions, the IRWST provides a source of borated water to the ECCS pumps. As such, it provides containment energy removal, core cooling, and replacement inventory and is a source of negative reactivity for reactor shutdown (Ref. 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, "ECCS - Operating," and B 3.5.3, "ECCS – Shutdown." These analyses are used to assess changes to the IRWST in order to evaluate their effects in relation to the acceptance limits in the analyses.

The IRWST must also meet volume, boron concentration, boron isotopic inventory (i.e., enrichment), and temperature requirements for non-LOCA

BASES

APPLICABLE SAFETY ANALYSES (continued)

events. The volume is not an explicit assumption in non-LOCA events since the required volume is a small fraction of the available volume. The deliverable volume limit is set by the required volumes for an outage and is therefore not limiting. The minimum IRWST volume is determined by ECCS pump NPSH requirements. The minimum boron concentration and isotopic inventory are explicit assumptions in the main steam line break (MSLB) analysis to ensure the required shutdown capability. The importance of its value is small due to the Extra Boration System (EBS) with its high boron concentration.

The maximum boron concentration is an explicit assumption in the inadvertent ECCS actuation analysis, although it is typically a nonlimiting event and the results are very insensitive to boron concentrations. The maximum temperature ensures that the amount of cooling provided from the IRWST during the heatup phase of a feedline break is consistent with safety analysis assumptions; the minimum is an assumption in both the MSLB and inadvertent ECCS actuation analyses, although the inadvertent ECCS actuation event is typically nonlimiting.

For a large break LOCA analysis, the minimum water volume of 500,342 gallons and the lower boron concentration limit of 1700 ppm of > 37% enriched boron are used to compute the post LOCA sump boron concentration necessary to assure subcriticality. The large break LOCA is the limiting case since the safety analysis assumes that all control rods are out of the core. This minimum volume bounds the ECCS pump NPSH requirements.

The maximum water volume of 523,703 gallons and the upper limit on boron concentration of 1900 ppm are used to determine the maximum allowable time to switch to hot leg recirculation following a LOCA. The purpose of switching from cold leg to hot leg injection is to avoid boron precipitation in the core following the accident.

The upper temperature limit of 122°F is used in the small break LOCA analysis and containment OPERABILITY analysis. Exceeding this temperature will result in a higher peak clad temperature, because there is less heat transfer from the core to the injected water for the small break LOCA. For the containment response following an MSLB, the lower limit on boron concentration and the upper limit on IRWST water temperature are used to maximize the total energy release to containment.

The minimum temperature valve of 59°F is consistent with mechanical requirements, particularly reactor pressure vessel brittle fracture risk.

The IRWST satisfies Criterion 3 of 10 CFR 50.36(d)(2)(ii).

BASES

LCO

The IRWST ensures that an adequate supply of borated water is available to cool and depressurize the containment in the event of a Design Basis Accident (DBA), to cool and cover the core in the event of a LOCA, to maintain the reactor subcritical following a DBA, and to ensure adequate level in the containment sump to support ECCS pump operation.

To be considered OPERABLE, the IRWST must meet the water volume, and boron concentration and enrichment limits established in the SRs.

APPLICABILITY

In MODES 1, 2, 3, and 4, IRWST OPERABILITY requirements are dictated by ECCS OPERABILITY requirements. Since the ECCS must be OPERABLE in MODES 1, 2, 3, and 4, the IRWST must also be OPERABLE to support its operation. In MODES 5 and 6, the IRWST is in standby. Core cooling requirements in MODE 5 are addressed by LCO 3.4.7, "RCS Loops - MODE 5, Loops Filled," and LCO 3.4.8, "RCS Loops - MODE 5, Loops Not Filled." MODE 6 core cooling requirements are addressed by LCO 3.9.4, "LHSI/RHR and Coolant Circulation - High Water Level," and LCO 3.9.5, "LHSI/RHR and Coolant Circulation - Low Water Level."

ACTIONS

A.1

With IRWST boron concentration or enrichment not within limits, it must be returned to within limits within 8 hours. Under these conditions the ECCS cannot perform its design function. Therefore, prompt action must be taken to restore the tank to OPERABLE condition. The 8 hour limit to restore the IRWST boron concentration or enrichment to within limits was developed considering the time required to change the boron concentration/isotopic inventory and the fact that the contents of the tank are still available for injection.

B.1

With the IRWST inoperable for reasons other than Condition A (e.g., water volume), it must be restored to OPERABLE status within 1 hour.

In this Condition, the ECCS cannot perform its design function. Therefore, prompt action must be taken to restore the tank to OPERABLE status or to place the plant in a MODE in which the IRWST is not required. The short time limit of 1 hour to restore the IRWST to OPERABLE status is based on this condition simultaneously affecting redundant trains.

BASES

ACTIONS (continued)

C.1 and C.2

If the IRWST cannot be returned 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

The IRWST borated water temperature should be verified every 24 hours to be within the limits assumed in the accident analyses band. This Frequency is sufficient to identify a temperature change that would approach either limit and has been shown to be acceptable through operating experience.

SR 3.5.4.2

The IRWST water volume should be verified every 7 days to be within limits. The required minimum volume is verified in order to ensure that a sufficient NPSH is available for injection and to support continued ECCS pump operation. The maximum volume is verified in order to ensure the value assumed in the post-LOCA boron precipitation evaluation is not exceeded. Since the IRWST volume is normally stable and is protected by an alarm, a 7 day Frequency is appropriate and has been shown to be acceptable through operating experience.

SR 3.5.4.3

The boron concentration of the IRWST should be verified every 7 days to be within the required limits. This SR ensures that the reactor will remain subcritical following a LOCA. Further, it assures that the resulting sump pH will be maintained in an acceptable range so that boron precipitation in the core will not occur and the effect of chloride and caustic stress corrosion on mechanical systems and components will be minimized.

Since the IRWST inventory is normally stable, a 7 day sampling Frequency to verify boron concentration is appropriate and has been shown to be acceptable through operating experience.

BASES

SURVEILLANCE REQUIREMENTS (continued)

SR 3.5.4.4

The boron used in the IRWST is enriched to > 37% in the $B^{10}$ isotope. Verification every 24 months that the $B^{10}$ enrichment is > 37% ensures that the $B^{10}$ concentration assumed in the accident analysis is available. Since $B^{10}$ in the IRWST is not exposed to a significant neutron field, 24 months is considered conservative.

REFERENCES

1. FSAR Chapter 6 and Chapter 15.

# B 3.5 EMERGENCY CORE COOLING SYSTEMS (ECCS)

## B 3.5.5 Extra Boration System (EBS)

BASES

### BACKGROUND

The EBS is a manually actuated, safety-related system that is used in the mitigation of design basis accidents, including a steam generator tube rupture (SGTR). During this event, the EBS injects boron into the RCS to maintain the core subcritical while the RCS is being cooled to the point where the Low Heat Safety Injection System can be connected to remove core decay heat. The EBS also provides RCS makeup to balance a portion of the shrinkage during cooldown. The EBS can be used for hydrostatic testing of the RCS but otherwise does not perform any function supporting normal plant operation.

The EBS consists of two identical trains. Each train is composed of its own boron tank, a high pressure 100% capacity pump, a test line, and injection lines to the RCS. The volume of concentrated boric acid required to maintain subcriticality is divided between the two EBS tanks. A common suction header allows either EBS pump to take suction from both tanks. The boron tanks and the primary train lines are filled with borated water and are located in a temperature controlled room to prevent crystallization of the boron (Ref. 1 and 2). Outside of the temperature controlled rooms, the EBS piping is filled with lower concentration borated water from the In-Containment Refueling Water Storage Tank.

### APPLICABLE SAFETY ANALYSES

If needed, the EBS is manually initiated. A 30 minute operator action time is assumed in the analysis. Once started for safety reasons, the EBS will remain in operation until the boron concentration needed for cold shutdown is reached.

The EBS is initiated for an SGTR to ensure adequate boration to prevent criticality. The contents of the EBS are not credited for core cooling or immediate boration in the LOCA analysis. The EBS maximum boron concentration of 7300 ppm is used in the Boron Precipitation Assessment (Ref. 2). The minimum boron concentration of 7000 ppm is credited in the SGTR analysis and for cooldown from other design basis events. Boron used in the EBS is enriched to ≥ 37% in the $B^{10}$ isotope.

The EBS minimum water volume limit of 2345 $ft^3$ total between the two EBS tanks is used to ensure that the appropriate quantity of highly borated water with sufficient negative reactivity is injected into the RCS to maintain the core in a shutdown condition following an SGTR or during cooldown for other Design Basis Accidents (DBAs). This volume includes approximately 175 $ft^3$ of unusable volume in each tank.

BASES

APPLICABLE SAFETY ANALYSES (continued)

The minimum temperature limit of 68°F for the EBS borated water assures that the solution does not reach the point of boron crystallization.

The EBS satisfies Criteria 3 of 10 CFR 50.36(d)(2)(ii).

LCO

This LCO establishes the minimum requirements as well as requirements for contained volume, boron concentration, boron enrichment, and temperature of the EBS inventory (Ref. 3). This ensures that an adequate supply of borated water is available in the event of an SGTR or other design basis event to maintain the reactor subcritical following these accidents.

To be considered OPERABLE, the limits established in the SR for water volume, boron concentration, boron isotopic inventory, and temperature must be met.

APPLICABILITY

In MODES 1, 2, 3, and 4, the EBS is needed to maintain the core subcritical following an SGTR and during cooldown to MODE 5 for DBAs.

An SGTR and other DBAs that rely on the EBS for cooldown are not postulated in MODES 5, and 6 and EBS OPERABILITY is not required.

ACTIONS

A.1

If the boron concentration or boron enrichment of one or both EBS tanks is not within limits, it must be returned to within limits within 72 hours. Because of the low probability of an SGTR or other DBAs, the allowed Completion Time of 72 hours is acceptable and provides adequate time to restore concentration or enrichment to within limits.

B.1

If one EBS train is inoperable for reasons other than Condition A, the inoperable train must be restored to OPERABLE status within 7 days. In this condition, the remaining OPERABLE train is adequate to perform the shutdown function. However, the overall reliability is reduced because a single failure in the remaining OPERABLE train could result in reduced EBS shutdown capability. The 7 day Completion Time is based on the availability of an OPERABLE train capable of performing the intended EBS function and the low probability of a DBA occurring.

BASES

ACTIONS (continued)

C.1

If both EBS trains are inoperable for reasons other than Condition A, at least one subsystem must be restored to OPERABLE status within 8 hours. The allowed Completion Time of 8 hours is considered acceptable, given the low probability of a DBA occurring.

D.1 and D.2

If any Required Action and associated Completion Time is not met, the unit must be brought to a MODE in which the LCO does not apply. To achieve this status, the unit must be brought to MODE 3 within 12 hours and MODE 5 within 36 hours.

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

SURVEILLANCE REQUIREMENTS

SR 3.5.5.1

Verification every 24 hours that each EBS tank water temperature is at or above the specified minimum temperature is frequent enough to identify a temperature change that would approach the acceptable limit. The solution temperature is also monitored by an alarm that provides further assurance of protection against low temperature. This Frequency has been shown to be acceptable through operating experience.

SR 3.5.5.2

Verification every 7 days that the EBS contained volume is above the required limit is frequent enough to assure that this volume will be available for quick injection into the RCS. If the volume is too low, the EBS would not provide enough borated water to ensure subcriticality during recirculation. Since the EBS volume is normally stable, a 7 day Frequency is appropriate and has been shown to be acceptable through operating experience.

SURVEILLANCE REQUIREMENTS (continued)

SR 3.5.5.3

Verification every 31 days that the boron concentration of each EBS tank is within the required limits ensures that the reactor remains subcritical following an SGTR or other DBA event and maintains the resulting IRWST pH in an acceptable range so that boron precipitation will not occur in the core. In addition, the effect of chloride and caustic stress corrosion on mechanical systems and components will be minimized.

SR 3.5.5.4

Verifying the correct alignment for manual and power operated valves in the EBS flow paths provides assurance that the proper flow paths will exist for EBS operation. This SR does not apply to valves that are locked, sealed, or otherwise secured in position, since these were verified to be in the correct position prior to locking, sealing, or securing. This Surveillance 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 administrative control, and an improper valve position would only affect a single train. This Frequency has been shown to be acceptable through operating experience.

SR 3.5.5.5

Demonstrating each EBS pump develops a flow rate ≥ 49.0 gpm and ≤ 55.4 gpm ensures that pump performance has not degraded during the fuel cycle. This minimum pump flow rate requirement ensures that the core will remain subcritical during and after a cooldown following design basis accidents including an SGTR. The maximum flow rate to the RCS is needed so that the pressurizer is not filled which could actuate the pressurizer relief valves. This inservice test confirms EBS pump OPERABILITY, trends performance, and detects incipient failures by indicating abnormal performance. The Frequency of this Surveillance is in accordance with the Inservice Testing Program.

SR 3.5.5.6

The boron used in each EBS tank is enriched to ≥ 37% in the $B^{10}$ isotope. Verification every 24 months that the $B^{10}$ enrichment is ≥ 37% ensures that the $B^{10}$ concentration assumed in the accident analysis is available. Since $B^{10}$ in the EBS is not exposed to a significant neutron field, 24 months is considered conservative.

BASES

SURVEILLANCE REQUIREMENTS (continued)

SR 3.5.5.7

This Surveillance ensures that there is a functioning flow path from the EBS tank to the RCS. An acceptable method is to test the flow path in several separate tests. The 24 month Frequency is based on the need to perform this Surveillance under conditions that apply during a unit outage and the potential for an unplanned transient if the Surveillance were performed with the reactor at power. Operating experience has shown that these components usually pass the Surveillance test when performed at the 24 month Frequency; therefore, the Frequency was concluded to be acceptable from a reliability standpoint.

REFERENCES

1. FSAR Chapter 6

2. FSAR Chapter 15.

3. 10 CFR 50.46.