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B 3.4 REACTOR COOLANT SYSTEM (RCS)

B 3.4.10 RCS Pressure and Temperature (P/T) Limits

BASES

BACKGROUND

All components of the RCS are designed to withstand effects of cyclic loads due to system pressure and temperature changes. These loads are introduced by startup (heatup) and shutdown (cooldown) operations, power transients, and reactor trips. This LCO limits the pressure and temperature changes during RCS heatup and cooldown, within the design assumptions and the stress limits for cyclic operation.

This Specification contains P/T limit curves for heatup, cooldown, and inservice leakage and hydrostatic testing, and limits for the maximum rate of change of reactor coolant temperature. The heatup curve provides limits for both heatup and criticality.

Each P/T limit curve defines an acceptable region for normal operation. The usual use of the curves is operational guidance during heatup or cooldown maneuvering, when pressure and temperature indications are monitored and compared to the applicable curve to determine that operation is within the allowable region.

The LCO establishes operating limits that provide a margin to brittle failure of the reactor vessel and piping of the reactor coolant pressure boundary (RCPB). The vessel is the component most subject to brittle failure. Therefore, the LCO limits apply mainly to the vessel.

10 CFR 50, Appendix G (Ref. 1), requires the establishment of P/T limits for material fracture toughness requirements of the RCPB materials. Reference 1 requires an adequate margin to brittle failure during normal operation, anticipated operational occurrences, and system hydrostatic tests. It mandates the use of the ASME Code, Section XI, Appendix G (Ref. 2).

The actual shift in the RT_{NDT} of the vessel material will be established periodically by removing and evaluating the irradiated reactor vessel material specimens, in accordance with ASTM E 185 (Ref. 3) and Appendix H of 10 CFR 50 (Ref. 4). The operating P/T limit curves will be adjusted, as necessary, based on the evaluation findings and the recommendations of RG 1.99, "Radiation Embrittlement of Reactor Vessel Materials (Ref. 5). The calculations to determine neutron fluence will be developed using the BWRVIP RAMA code methodology, which is NRC approved and meets the intent of RG 1.190, "Calculational and Dosimetry Methods for Determining Pressure Vessel Neutron Fluence" (Ref. 11). See FSAR Section 4.1.4.5 for determining fluence (Ref. 12).

(continued)

BASES

BACKGROUND (continued)

The P/T limit curves are composite curves established by superimposing limits derived from stress analyses of those portions of the reactor vessel and head that are the most restrictive. At any specific pressure, temperature, and temperature rate of change, one location within the reactor vessel will dictate the most restrictive limit. Across the span of the P/T limit curves, different locations are more restrictive, and, thus, the curves are composites of the most restrictive regions.

The heatup curve used to develop the P/T limit curve composite represents a different set of restrictions than the cooldown curve used to develop the P/T limit curve composite because the directions of the thermal gradients through the vessel wall are reversed. The thermal gradient reversal alters the location of the tensile stress between the outer and inner walls.

The criticality limits include the Reference 1 requirement that they be at least 40°F above the heatup curve or the cooldown curve and not lower than the minimum permissible temperature for the inservice leakage and hydrostatic testing.

The consequence of violating the LCO limits is that the RCS has been operated under conditions that can result in brittle failure of the RCPB, possibly leading to a nonisolable leak or loss of coolant accident. In the event these limits are exceeded, an evaluation must be performed to determine the effect on the structural integrity of the RCPB components. ASME Code, Section XI, Appendix E (Ref. 6), provides a recommended methodology for evaluating an operating event that causes an excursion outside the limits.

APPLICABLE SAFETY ANALYSES

The P/T limits are not derived from Design Basis Accident (DBA) analyses. They are prescribed during normal operation to avoid encountering pressure, temperature, and temperature rate of change conditions that might cause undetected flaws to propagate and cause nonductile failure of the RCPB, a condition that is unanalyzed. Reference 7 establishes the methodology for determining the P/T limits. Since the P/T limits are not derived from any DBA, there are no acceptance limits related to the P/T limits. Rather, the P/T limits are acceptance limits themselves since they preclude operation in an unanalyzed condition.

RCS P/T limits satisfy Criterion 2 of the NRC Policy Statement (Ref. 8).

(continued)

BASES

LCO

The elements of this LCO are:

a. RCS pressure and temperature are to the right of the applicable curves specified in Figures 3.4.10-1 through 3.4.10-3 and within the applicable heat-up or cool down rate specified in SR 3.4.10.1 during RCS heatup, cooldown, and inservice leak and hydrostatic testing;

b. The temperature difference between the reactor vessel bottom head coolant and the reactor pressure vessel (RPV) coolant is ≤ 145°F during recirculation pump startup, and during increases in THERMAL POWER or loop flow while operating at low THERMAL POWER or loop flow;

c. The temperature difference between the reactor coolant in the respective recirculation loop and in the reactor vessel is ≤ 50°F during recirculation pump startup, and during increases in THERMAL POWER or loop flow while operating at low THERMAL POWER or loop flow;

d. RCS pressure and temperature are to the right of the criticality limits specified in Figure 3.4.10-3 prior to achieving criticality; and

e. The reactor vessel flange and the head flange temperatures are ≥ 70°F when tensioning the reactor vessel head bolting studs.

These limits define allowable operating regions and permit a large number of operating cycles while also providing a wide margin to nonductile failure.

The P/T limit composite curves are calculated using the worst case of material properties, stresses, and temperature change rates anticipated under all heatup and cooldown conditions. The design calculations account for the reactor coolant fluid temperature impact on the inner wall of the vessel and the temperature gradients through the vessel wall. Because these fluid temperatures drive the vessel wall temperature gradient, monitoring reactor coolant temperature provides a conservative method of ensuring the P/T limits are not exceeded. Proper monitoring of vessel temperatures to assure compliance with brittle fracture temperature limits and vessel thermal stress limits during normal heatup and cooldown, and during inservice leakage and hydrostatic testing, is established in PPL Calculation EC 062-0573 (Ref. 9). For P/T curves A, B, and C, the bottom head drain line coolant temperature should be monitored and maintained to the right of the most limiting curve.

(continued)

BASES

LCO (continued)

Curve A must be used for any ASME Section III Design Hydrostatic Tests performed at unsaturated reactor conditions. Curve A may also be used for ASME Section XI inservice leakage and hydrostatic testing when heatup and cooldown rates can be limited to 20°F in a one-hour period. Curve A is based on pressure stresses only. Thermal stresses are assumed to be insignificant. Therefore, heatup and cooldown rates are limited to 20°F in a one-hour period when using Curve A to ensure minimal thermal stresses. The recirculation loop suction line temperatures should be monitored to determine the temperature change rate.

Curves B and C are to be used for non-nuclear and nuclear heatup and cooldown, respectively. In addition, Curve B may be used for ASME Section XI inservice leakage and hydrostatic testing, but not for ASME Section III Design Hydrostatic Tests performed at unsaturated reactor conditions. Heatup and cooldown rates are limited to 100°F in a one-hour period when using Curves B and C. This limits the thermal gradient through the vessel wall, which is used to calculate the thermal stresses in the vessel wall. Thus, the LCO for the rate of coolant temperature change limits the thermal stresses and ensures the validity of the P/T curves. The vessel belt-line fracture analysis assumes a 100°F/hr coolant heatup or cooldown rate in the beltline area. The 100°F limit in a one-hour period applies to the coolant in the beltline region, and takes into account the thermal inertia of the vessel wall. Steam dome saturation temperature (T_{SAT}), as derived from steam dome pressure, should be monitored to determine the beltline temperature change rate at temperatures above 212°F. At temperatures below 212°F, the recirculation loop suction line temperatures should be monitored.

During heatups and cooldowns, the reactor vessel could experience a vacuum (negative pressure) at low temperatures (unsaturated conditions) and low rates of temperature change. Under a vacuum, the vessel wall would experience a uniform compressive loading, which would counteract the tensile stress due to any thermal gradients through the vessel wall. To ensure the margin to brittle fracture is no less than at any other pressure, Curves A, B, and C require a minimum vessel metal temperature of 70°F when the reactor vessel is at a negative pressure.

(continued)

BASES

LCO (continued)

Violation of the limits places the reactor vessel outside of the bounds of the stress analyses and can increase stresses in other RCS components. The consequences depend on several factors, as follows:

a. The severity of the departure from the allowable operating pressure temperature regime or the severity of the rate of change of temperature;

b. The length of time the limits were violated (longer violations allow the temperature gradient in the thick vessel walls to become more pronounced); and

c. The existences, sizes, and orientations of flaws in the vessel material.

APPLICABILITY

The potential for violating a P/T limit exists at all times. For example, P/T limit violations could result from ambient temperature conditions that result in the reactor vessel metal temperature being less than the minimum allowed temperature for boltup. Therefore, this LCO is applicable even when fuel is not loaded in the core.

ACTIONS

A.1 and A.2

Operation outside the P/T limits while in MODES 1, 2, and 3 must be corrected so that the RCPB is returned to a condition that has been verified by stress analyses.

The 30 minute Completion Time reflects the urgency of restoring the parameters to within the analyzed range. Most violations will not be severe, and the activity can be accomplished in this time in a controlled manner.

Besides restoring operation within limits, an evaluation is required to determine if RCS operation can continue. The evaluation must verify the RCPB integrity remains acceptable and must be completed if continued operation is desired. Several methods may be used, including comparison with pre-analyzed transients in the stress analyses, new analyses, or inspection of the components.

ASME Code, Section XI, Appendix E (Ref. 6), may be used to support the evaluation. However, its use is restricted to evaluation of the vessel beltline.

(continued)

BASES

ACTIONS (continued)

A.1 and A.2 (continued)

The 72 hour Completion Time is reasonable to accomplish the evaluation of a mild violation. More severe violations may require special, event specific stress analyses or inspections. A favorable evaluation must be completed if continued operation is desired.

Condition A is modified by a Note requiring Required Action A.2 be completed whenever the Condition is entered. The Note emphasizes the need to perform the evaluation of the effects of the excursion outside the allowable limits. Restoration alone per Required Action A.1 is insufficient because higher than analyzed stresses may have occurred and may have affected the RCPB integrity.

B.1 and B.2

If a Required Action and associated Completion Time of Condition A are not met, the plant must be placed in a lower MODE because either the RCS remained in an unacceptable P/T region for an extended period of increased stress, or a sufficiently severe event caused entry into an unacceptable region. Either possibility indicates a need for more careful examination of the event, best accomplished with the RCS at reduced pressure and temperature. With the reduced pressure and temperature conditions, the possibility of propagation of undetected flaws is decreased.

Pressure and temperature are reduced by placing the plant in at least MODE 3 within 12 hours and in MODE 4 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.

C.1 and C.2

Operation outside the P/T limits in other than MODES 1, 2, and 3 (including defueled conditions) must be corrected so that the RCPB is returned to a condition that has been verified by stress analyses. The Required Action must be initiated without delay and continued until the limits are restored.

(continued)

BASES

ACTIONS (continued)

C.1 and C.2 (continued)

Besides restoring the P/T limit parameters to within limits, an evaluation is required to determine if RCS operation is allowed. This evaluation must verify that the RCPB integrity is acceptable and must be completed before approaching criticality or heating up to > 200°F. Several methods may be used, including comparison with pre-analyzed transients, new analyses, or inspection of the components. ASME Code, Section XI, Appendix E (Ref. 6), may be used to support the evaluation; however, its use is restricted to evaluation of the beltline.

SURVEILLANCE REQUIREMENTS

SR 3.4.10.1

Verification that operation is within limits (i.e., to the right of the applicable curves in Figures 3.4.10-1 through 3.4.10-3) is required when RCS pressure and temperature conditions are undergoing planned changes. The Surveillance Frequency is controlled under the Surveillance Frequency Control Program.

Surveillance for heatup, cooldown, or inservice leakage and hydrostatic testing may be discontinued when the criteria given in the relevant plant procedure for ending the activity are satisfied.

This SR has been modified with a Note that requires this Surveillance to be performed only during system heatup and cooldown operations and inservice leakage and hydrostatic testing.

Notes to the acceptance criteria for heatup and cooldown rates ensure that more restrictive limits are applicable when the P/T limits associated with hydrostatic and inservice testing are being applied.

SR 3.4.10.2

A separate limit is used when the reactor is approaching criticality. Consequently, the RCS pressure and temperature must be verified within the appropriate limits (i.e., to the right of the criticality curve in Figure 3.4.10-3) before withdrawing control rods that will make the reactor critical.

(continued)

BASES

SURVEILLANCE REQUIREMENTS (continued)

SR 3.4.10.2 (continued)

Performing the Surveillance within 15 minutes before control rod withdrawal for the purpose of achieving criticality provides adequate assurance that the limits will not be exceeded between the time of the Surveillance and the time of reactor criticality. Although no Surveillance Frequency is specified, the requirements of SR 3.4.10.2 must be met at all times when the reactor is critical.

SR 3.4.10.3 and SR 3.4.10.4

Differential temperatures within the applicable limits ensure that thermal stresses resulting from the startup of an idle recirculation pump will not exceed design allowances. In addition, compliance with these limits ensures that the assumptions of the analysis for the startup of an idle recirculation loop (Ref. 10) are satisfied.

Performing the Surveillance within 15 minutes before starting the idle recirculation pump provides adequate assurance that the limits will not be exceeded between the time of the Surveillance and the time of the idle pump start.

An acceptable means of demonstrating compliance with the temperature differential requirement in SR 3.4.10.4 is to compare the temperatures of the operating recirculation loop and the idle loop. If both loops are idle, compare the temperature difference between the reactor coolant within the idle loop to be started and coolant in the reactor vessel.

SR 3.4.10.3 has been modified by a Note that requires the Surveillance to be performed only in MODES 1, 2, 3, and 4. In MODE 5, the overall stress on limiting components is lower. Therefore, ΔT limits are not required. The Note also states the SR is only required to be met during a recirculation pump start-up, because this is when the stresses occur.

SR 3.4.10.5 and SR 3.4.10.6

Differential temperatures within the applicable limits ensure that thermal stresses resulting from increases in THERMAL POWER or recirculation loop flow during single recirculation loop operation will not exceed design allowances. Performing the Surveillance within 15 minutes before beginning such an increase in power or flow rate provides adequate assurance that the limits will not be exceeded between the time of the Surveillance and the time of the change in operation.

(continued)

BASES

SURVEILLANCE REQUIREMENTS (continued)

SR 3.4.10.5 and SR 3.4.10.6 (continued)

An acceptable means of demonstrating compliance with the temperature differential requirement in SR 3.4.10.6 is to compare the temperatures of the operating recirculation loop and the idle loop.

Plant specific startup test data has determined that the bottom head is not subject to temperature stratification at power levels > 27% of RTP and with single loop flow rate ≥ 21,320 gpm (50% of rated loop flow). Therefore, SR 3.4.10.5 and SR 3.4.10.6 have been modified by a Note that requires the Surveillance to be met only under these conditions. The Note for SR 3.4.10.6 further limits the requirement for this Surveillance to exclude comparison of the idle loop temperature if the idle loop is isolated from the RPV since the water in the loop can not be introduced into the remainder of the Reactor Coolant System.

SR 3.4.10.7, SR 3.4.10.8, and SR 3.4.10.9

Limits on the reactor vessel flange and head flange temperatures are generally bounded by the other P/T limits during system heatup and cooldown. However, operations approaching MODE 4 from MODE 5 and in MODE 4 with RCS temperature less than or equal to certain specified values require assurance that these temperatures meet the LCO limits.

The flange temperatures must be verified to be above the limits before and while tensioning the vessel head bolting studs to ensure that once the head is tensioned the limits are satisfied. When in MODE 4 with RCS temperature ≤ 80°F, checks of the flange temperatures are required because of the reduced margin to the limits. When in MODE 4 with RCS temperature ≤ 100°F, monitoring of the flange temperature is required to ensure the temperature is within the specified limits.

The Surveillance Frequency is controlled under the Surveillance Frequency Control Program.

(continued)

BASES

REFERENCES

1. 10 CFR 50, Appendix G.

2. ASME, Boiler and Pressure Vessel Code, Section XI, Appendix G.

3. ASTM E 185-73

4. 10 CFR 50, Appendix H.

5. Regulatory Guide 1.99, Revision 2, May 1988.

6. ASME, Boiler and Pressure Vessel Code, Section XI, Appendix E.

7. Licensed Topical Reports:

   a. Structural Integrity Associates Report No. SIR-05-044, Revision 1-A, "Pressure-Temperature Limits Report Methodology for Boiling Water Reactors," June 2013.

   b. Structural Integrity Associates Report No. 0900876.401, Revision 0-A, "Linear Elastic Fracture Mechanics Evaluation of GE BWR Water Level Instrument Nozzles for Pressure-Temperature Curve Evaluations," May 2013.

8. Final Policy Statement on Technical Specifications Improvements, July 22, 1993 (58 FR 39132).

9. PPL Calculation EC-062-0573, "Study to Support the Bases Section of Technical Specification 3.4.10."

10. FSAR, Section 15.4.4.

11. Regulatory Guide 1.190, March 2001.

12 FSAR, Section 4.1.4.5.