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Long-Term Cooling (LTC) Issues

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USNRC Public Meeting
On Proposed 10 CFR 50.46c Rule

Agenda

- Purpose
- Current Regulatory Basis
- 10CFR50.46c Rule Package
- Evaluation Methods for LTC
- Analytical Limits for LTC
- Issues
- Compliance
- Proposals
- Summary

Purpose

The purpose of this presentation is to request clarity with regards to long-term cooling (LTC).

Current Regulatory Basis

- (a)(1)(i) Each boiling or pressurized light-water nuclear power reactor fueled with uranium oxide pellets within cylindrical zircaloy or ZIRLO cladding must be provided with an emergency core cooling system (ECCS) that must be designed so that its calculated cooling performance following postulated loss-of-coolant accidents conforms to the criteria set forth in paragraph (b) of this section. ECCS cooling performance must be calculated in accordance with **an acceptable evaluation model** and must be calculated for a number of postulated loss-of-coolant accidents of different sizes, locations, and other properties sufficient to provide assurance that the most severe postulated loss-of-coolant accidents are calculated.

Current Regulatory Basis

- (ii) Alternatively, an ECCS evaluation model may be developed in conformance with the required and acceptable features of **appendix K** ECCS Evaluation Models.
- (b)(5) Long-term cooling. After any calculated successful initial operation of the ECCS, the calculated **core temperature shall be maintained at an acceptably low value and decay heat shall be removed for the extended period of time required by the long-lived radioactivity remaining in the core**.

10CFR50.46c Rule Package

- V. Proposed Requirements for ECCS Performance During LOCAs

  In proposed § 50.46c, the specified performance objectives of the systems, structures, and components of the ECCS are to provide **residual heat removal** during and following a postulated LOCA. As with the current regulations, the ECCS performance is demonstrated by **NRC-approved ECCS evaluation models** in proposed § 50.46c.

10CFR50.46c Rule Package

- V. Proposed Requirements for ECCS Performance During LOCAs

  To achieve the NRC's goal of a more **performance-based rule**, significant changes in format and structure are being proposed relative to § 50.46. In place of the current prescriptive § 50.46(b) analytical limits, the proposed rule would define the following principal ECCS performance requirements:

  - **Core temperature during and following the LOCA event does not exceed the analytical limits for the fuel design used for ensuring acceptable performance.** This ensures that the fuel maintains a coolable geometry.
  - Sufficient cooling so that decay heat will be removed for **the extended period of time required by the long-lived radioactivity remaining in the core** so that long-term cooling is ensured.

10CFR50.46c Rule Package

- V.B. Performance-Based Aspects of the Proposed Rule 5. Long-Term Cooling

- The **current regulation** in § 50.46(b)(5) requires that for long-term cooling the **calculated core temperature** be maintained at an **acceptably low va**lue following any calculated successful initial operation of the ECCS. It also requires that decay heat be removed for the extended period of time required by the long-lived radioactivity remaining in the core.

- The **proposed rule** would define a performance-based requirement to ensure acceptable fuel performance during long-term cooling. Specifically, **the proposed rule would require that a specified and NRC-approved analytical limit on peak cladding temperature be established that corresponds to the measured ductile-to-brittle transition for the zirconium-based alloy cladding material based upon an NRC-approved experimental technique.** It would also require that the calculated maximum fuel element temperature should not exceed the established analytical limit.

10CFR50.46c Rule Package

- V.B. Performance-Based Aspects of the Proposed Rule

  E. Implementation

  2. Compliance With Long-Term Cooling Requirements Using Risk-Informed Approach To Address Debris Effects

- In this case, the licensee would have to **receive NRC approval** on both its risk informed submittal **and** the **analytical limit for long-term cooling** required under §50.46c(g)(1)(v) prior to using the risk-informed approach.

10CFR50.46c Rule Package

- VI. Section-by-Section Analysis
- E. Section 50.46c(d)—Emergency Core Cooling System Design

- Demonstration of ECCS performance in **the post-accident recovery period, or long-term cooling**, is expected to **consider inhibition of core flow** that can result from such factors as, but not limited to, **pump damage, piping damage, boron precipitation, and deposition of debris and/or chemicals** associated with the long-term cooling mode of recirculation coolant collection from the reactor building sump. Consideration of debris and/or chemical deposition is already required by the current rule, and the proposed rule does not alter the current efforts to address such factors under programs such as GSI–191. Demonstration of consideration of such factors may also be achieved through analytical models that adequately represent the empirical data obtained regarding debris deposition. The proposed rule would alternatively allow the use of risk informed approaches to evaluate the effects of debris on localized coolant flow and delivery of coolant to the core during the long-term cooling (post accident recovery) period.

10CFR50.46c Rule Package

- VI. Section-by-Section Analysis
- E. Section 50.46c(d)—Emergency Core Cooling System Design

- "In addition, paragraph (d)(2)(iv) of the proposed rule would specifically require that ECCS performance be demonstrated for both the **accident and the post-accident recovery and recirculation period**."
- "Paragraph (g)(1)(v) would be added to establish a performance-based requirement to ensure acceptable fuel performance during long-term cooling. This performance requirement is consistent with the current requirement to "maintain the calculated core temperature at an acceptably low value" located in § 50.46(b)(5)."

10CFR50.46c Rule Package

- VII. Specific Request for Comments on the Proposed Rule
- **NRC Question 3**. Analytical Long-Term Peak Cladding Temperature Limit.

- Section 50.46c(g)(1)(v) of the proposed rule would require that a specified and NRC-approved limit on long-term peak cladding temperature be established which preserves **a measure of cladding ductility throughout the period of long term demonstration** (e.g., 30 days). The current regulation at § 50.46(b)(5) stipulates that long-term temperature be maintained ‘‘at an acceptably low value.’’ The proposed rule would define the performance-based metric to judge an acceptably low temperature. The overall goal of preserving ductility would provide reasonable assurance that the fuel rods will maintain their coolable bundle array. The NRC is requesting input regarding this performance objective to determine if this is the most suitable performance based metric to demonstrate long-term cladding performance.

10CFR50.46c Rule Package

- VII. Specific Request for Comments on the Proposed Rule
- NRC Question 3. Analytical Long-Term Peak Cladding Temperature Limit.

- Alternatively, the proposed rule could establish an analytical limit of long-term fuel rod cladding temperature related to observed corrosion behavior. For example, the Pressurized Water Reactor Owners Group (PWROG) has applied as a long-term core cooling acceptance criterion that the cladding temperature be maintained below 800 °F (see Topical Report (TR) Westinghouse Commercial Atomic Power (WCAP)-16793–NP, Revision 2, ‘‘Evaluation of Long-Term Cooling Considering Particulate, Fibrous and Chemical Debris in the Recirculating Fluid,’’ Appendix A (ADAMS Accession No. ML11292A021)). Doing so will ensure that additional corrosion and hydrogen pickup over a 30-day period will not significantly affect cladding properties. The NRC seeks comment on the **acceptance criterion** for long-term cooling and **whether there is justification** for a different temperature limit (other than the 800 °F provided in the WCAP).

10CFR50.46c Rule Package
Rule Language

- (d)(2)(iii) *Core geometry and coolant flow.* The ECCS evaluation model must address calculated changes in core geometry and must consider those factors, **including debris**, that may alter localized coolant flow in the core or inhibit delivery of coolant to the core. A licensee may evaluate effects of debris using a risk-informed approach to demonstrate long-term ECCS performance, as specified in paragraph (e) of this section.

- (d)(2)(iv) *LOCA analytical requirements.* ECCS performance must be demonstrated for a range of postulated loss-of-coolant accidents of different sizes, locations, and other properties, sufficient to provide assurance that the most severe postulated loss-of-coolant accidents have been identified. ECCS performance must be demonstrated for the **accident, and the post-accident recovery and recirculation period.**

10CFR50.46c Rule Package
Rule Language

- (d)(3)(i)(A) **A description of each ECCS evaluation model must be furnished.** The description must be sufficiently complete to permit technical review of the analytical approach, including the equations used, their approximations in difference form, the assumptions made, and the values of all parameters or the procedure for their selection, as for example, in accordance with a specified physical law or empirical correlation.
- (g)(1)(v) *Long-term cooling. An analytical* limit on long-term peak cladding temperature shall be established that corresponds to the ductile-to-brittle transition for the zirconium-alloy cladding material determined using an **NRC-approved experimental technique**. The **analytical limit must be approved by the NRC**.

Evaluations for LTC

- David Fink, Fellow Engineer, Westinghouse Electric Company, “10 CFR 50.46c Proposed Rule Review of Current PWR Post-LOCA Long-Term Cooling Compliance Methods”
- A. Kurshad Muftuoglu, Principal Engineer, General Electric Hitachi (GEH), “BWR LOCA Long-Term Cooling Aspects”

Analytical Limits

- Analytical PCT Limits per (g)(1)(v)
  - Performance-Based versus Prescriptive Limit
  - What is the appropriate standard: (measure of ductility?)
  - Single vs. multiple temperature Limits
  - Ability to revise limit standard change with time
  - No Regulatory Guide on NRC-approved testing procedures for establishing an NRC-approved limit

Analytical Limits

- Possible Analytical Limits for Cladding Embrittlement, Breakaway Oxidation, Nodular Corroison
  - 2200°F (1200°C)
  - 1832°F (1000°C)
  - 1202°F (650°C)
  - 800°F (427°C)
  - Limit based on duration of time above limit
  - ECR Limit
  - Premature to do rulemaking before adequate research and Reg Guide

Required Calculations

- "Calculated changes in core geometry" "…to **consider inhibition of core flow…"**
  - SOC: "pump damage, piping damage, boron acid precipitation (BAP), and deposition of debris and/or chemicals"
  - Rule Language: "including debris"
- What is meant by "pump damage" and "piping damage"?
- Debris / Chemical Effects (i.e., GSI-191)
  - Deterministic, Risk informed perspectives
- BAP Analyses for PWRs

Issues

- Timing Issues
  - Undefined terms: **accident, the post-accident recovery, and recirculation period, and long-term and extended time**
  - When does short Term End?
  - When does long term begin?
  - When does long term end?
  - When does extended time begin?
  - When does extended time end?
- Is there an intermediate time?
- Are all times quantitative, qualitative, EOP symptomatic, or a combination?
- Operator Actions Timing assumptions
  - Non-symptomatic management

Modeling Issues

- Modeling Issues
  - Appendix K excessive conservatisms
    - Decay heat; Baker-Just
  - Realistic methods
    - Can we let Appendix K and Realistic live together
  - Graded Risk-Informed Approach
    - Transition Break Size
  - Do system code SERs need to be updated for use across the entire timeline?
- If short term end and long term begin are discontinuous, what is the appropriate initialization of the long term analysis.

Compliance Issues

- No Regulatory Guide
- Required calculations not well defined
  - What NRC-Approved Evaluation Models are required?
- What NRC-approved procedures are available to determine the NRC-approved limits?
- Schedule for resolution of GSI-191 and other issues may not dovetail with 10CFR50.46c implementation tracks
- Implementation impact of “new” methods on TS COLR generation
- Uncertainty could lead to exemption requests

Proposals

- Develop Regulatory Guidance for LTC
  - Graded Risk-Informed Methods
    - Transition Break Size
  - Test Procedures
- Move Appendix K to a Regulatory Guidance Document
  - Allow for a different Decay Heat Standard (consistent with SECY 01-0133 Rule Making Docket 2008-0332)
- Use of “acceptable” vs. “NRC-approved”
  - Sufficient for Adequate Protection

Proposals

- Regulatory Information Summary
  - Separate compliance dates for LTC
  - Provide Guidance on Expected Licensee Submittal
- Review Standard
  - Establishes standardized review guidance and acceptance criteria for the staff's reviews
  - Informs licensees of the guidance documents the staff will use when reviewing applications.

Summary

Industry considers the aspects discussed herein to be important for members in establishing actions to demonstrate compliance