Long Term Cooling Requirements

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Scope

- Background
- Proposed Statements of Consideration (SOC)
- Potentially Impacted Language (Long Term Core Cooling, LTCC)
  - Unintended Consequences
- Implementation Schedule Impact
- Discussion

Background

- Draft 50.46c Rule issued for public comment in March 2014
- Industry provided comments on draft rule, including comments on the long-term core cooling (LTCC) language in August 2014
- After a March 17-18 public meeting, 3 workshops to discuss 50.46c compliance schedule and 1 workshop to discuss LTCC were scheduled
- NRC proposed revisions to LTCC language in draft 50.46c Rule in June 9th, 2015 meeting notice

Big Picture

- Industry Agrees with NRC Position
  - "…currently approved analytical models and methods continue to be acceptable…"
  - "…no further fuel testing and analysis required…"
- Final Rule Language and SOC Consistency
  - Major Challenge
- Industry Develop an LTCC Standard
  - Endorsable Guidance
  - Follow-up Presentation

Proposed Language for LTCC

- Proposed Rule Does Not Introduce New Requirements Regarding Long Term Core Cooling; Only Clarification of Existing Requirements
- Absent a Debris-Induced Post-Quench Reheat-Transient, Staff Has Determined:
  - (1) currently approved analytical models and methods continue to be acceptable and
  - (2) no further fuel testing and analysis is required to satisfy the more explicit performance requirement discussed below (i.e. Consideration of Debris).
- Existing Non-Debris Analysis Not Impacted
- Debris Addressed Under GSI-191

Existing Specific LTCC Language

- 50.46(b)
  - Sub-Paragraphs (4) & (5)
    - (4) Coolable geometry. Calculated changes in core geometry shall be such that the core remains amenable to cooling.
    - (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.
  - Color Coding ties with subsequent slides

§50.46c Specific LTCC Language

- Federal Register Notice Base Line
  - Paragraph (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-allow cladding material determined using an NRC-approved experimental technique. The analytical limit must be approved by the NRC.
  - Industry written comments on FRN could not foresee proposed change
- Proposed Base Line Delta: (ML15135A178)
    - (v) Long-term cooling. After any calculated successful initial operation of the emergency core cooling system, no further cladding damage occurs as indicated by the calculated core temperature for the extended period of time required by the long-lived radioactivity remaining in the core. As required by paragraph (d)(1)(ii) of this section, the ECCS must also provide sufficient coolant so that decay heat is removed for the extended period of time required by the long-lived radioactivity remaining in the core.

Statements of Consideration

Statements of Consideration

- Post Quench
  - Reheat Issue
    - Regarding Non-Debris Scenario
      - "In the absence of a debris-induced post-quench reheat transient, the staff has determined that (1) currently approved analytical models and methods continue to be acceptable and (2) no further fuel testing and analysis is required to satisfy the more explicit performance requirement discussed below"
    - Currently approved method for BWRs
      - NEDO-20566A (potential for reheat)
    - Some potentially impacted due to re-alignment
      - Cold leg switch-over

Statements of Consideration

- Changing Standard
  - Performance Base vs. Prescriptive
  - Acceptably Low vs. Approved Analytical Limit
    - Qualitative vs. Quantitative basis?
    - Calculated Core Temperature as surrogate?
    - Peak Fuel Temp, or ECR more appropriate?

Language Impacted by Proposed Change

§50.46c Related LTCC Language

- Federal Register Notice Base Line
  - Paragraph (b)
    - Evaluation model means the calculational framework for evaluating the behavior of the reactor system (including fuel) during a postulated LOCA. It includes one or more computer programs and all other information necessary for application of the calculational framework to a specific LOCA, such as mathematical models used, assumptions included in the programs, procedure for treating the program input and output information, specification of those portions of analysis not included in computer programs, values of parameters, and all other information necessary to specify the calculational procedure.
- This definition does not explicitly exclude LTCC from an Evaluation Model. As written, it must be assumed LTCC is included in the Evaluation Model

§50.46c Related LTCC Language

- Federal Register Notice Base Line
  - Paragraph (c)
    - *Relationship to other NRC regulations*. The requirements of this section are in addition to any other requirements applicable to an emergency core cooling system (ECCS) set forth in this part, except as noted in this paragraph. The analytical limits established in accordance with this section, with cooling performance calculated in accordance with an NRC approved ECCS evaluation model, are in implementation of the general requirements with respect to ECCS cooling performance design set forth in this part, including in particular Criterion 35 of appendix A to this part. If the effects of debris on long-term cooling are evaluated using a risk informed method as described in paragraph (e) of this section, then this method and results can be relied upon to demonstrate compliance with other requirements of this part as allowed by this section and requested in the application.
- The Highlighted Language Drives Prior Approval Regardless of Words Being Present in Any Sub-Paragraph of (g)(1)

§50.46c Related LTCC Language

- Federal Register Notice Base Line
  - Paragraph (d) *Emergency core cooling system design*.
    - (1) ECCS performance criteria. Each LWR must be provided with an ECCS designed to satisfy the following performance requirements in the event of, and following, a postulated loss-of- coolant accident (LOCA). The demonstration of ECCS performance must comply with paragraph (d)(2) of this section:
      - (i) Core temperature during and following the LOCA event does not exceed the analytical limits for the fuel design used for ensuring acceptable performance as defined in this section.
      - (ii) The ECCS provides sufficient coolant so that decay heat will be removed for the extended period of time required by the long-lived radioactivity remaining in the core.
- Language Drives Performance Requirement for LTCC
- Language Drives Prescriptive Metric
- Language Captures Existing 50.46(b)(5)

§50.46c Related LTCC Language

- Federal Register Notice Base Line
  - Paragraph (d) *Emergency core cooling system design*.
    - (2) ECCS performance demonstration. ECCS performance must be demonstrated using an ECCS evaluation model meeting the requirements of either paragraph (d)(2)(i) or (d)(2)(ii), of this section, and satisfy the analytical requirements of paragraph (d)(2)(iii), (d)(2)(iv), and (d)(2)(v) of this section. Paragraph (e) of this section may be used for consideration of debris described in paragraph (d)(2)(iii) of this section. The ECCS evaluation model must be reviewed and approved by the NRC.
      - (i) Realistic ECCS model. A realistic model must include sufficient supporting justification to show that the analytical technique realistically describes the behavior of the reactor system during a loss-of-coolant accident. Comparisons to applicable experimental data must be made and uncertainties in the analysis method and inputs must be identified and assessed so that the uncertainty in the calculated results can be estimated. This uncertainty must be accounted for, so that when the calculated ECCS cooling performance is compared to the applicable specified and NRC-approved analytical limits, there is a high level of probability that the limits would not be exceeded.
      - (ii) Appendix K model. Alternatively, an ECCS evaluation model may be developed in conformance with the required and acceptable features of appendix K to this part, ECCS Evaluation Models.

- Language Drives LTCC to Realistic, or Appendix K
  - No middle ground: Appendix K doesn't apply beyond reflood?
- Language Drives Prior Approval

§50.46c Related LTCC Language

- Federal Register Notice Base Line
  - Paragraph (d) *Emergency core cooling system design*.
    - (2) ECCS performance demonstration. ECCS performance must be demonstrated using an ECCS evaluation model meeting the requirements of either paragraph (d)(2)(i) or (d)(2)(ii), of this section, and satisfy the analytical requirements of paragraph (d)(2)(iii), (d)(2)(iv), and (d)(2)(v) of this section. Paragraph (e) of this section may be used for consideration of debris described in paragraph (d)(2)(iii) of this section. The ECCS evaluation model must be reviewed and approved by the NRC.
      - (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.
      - (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.
      - (v) Modeling requirements for fuel designs: uranium oxide or mixed uranium-plutonium oxide pellets within zirconium-alloy cladding. If the reactor is fueled with uranium oxide or mixed uranium-plutonium oxide pellets within cylindrical zirconium-alloy cladding, then the ECCS evaluation model must address the fuel system modeling requirements in paragraph (g)(2) of this section.
- Language Embodies Existing 50.46(b)(4)
- Language Mandates Addressing Debris; Break Spectrum Impact Extends to LTCC

§50.46c Related LTCC Language

- Federal Register Notice Base Line
  - Paragraph (d) *Emergency core cooling system design*.
    - (3) Required documentation. Upon implementation of this section in accordance with paragraph (o) of this section, the documentation requirements of this paragraph apply and supersede the requirements in appendix K to this part, section II, "Required Documentation."
      - (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.
      - (B) A complete listing of each computer program, in the same form as used in the evaluation model, must be furnished to the NRC upon request.
      - (ii) For each computer program, solution convergence must be demonstrated by studies of system modeling or noding and calculational time steps.
      - (iii) Appropriate sensitivity studies must be performed for each ECCS evaluation model, to evaluate the effect on the calculated results of variations in noding, phenomena assumed in the calculation to predominate, including pump operation or locking, and values of parameters over their applicable ranges. For items to which results are shown to be sensitive, the choices made must be justified.
      - (iv) To the extent practicable, predictions of the ECCS evaluation model, or portions thereof, must be compared with applicable experimental information.
      - (v) Elements of ECCS evaluation models reviewed will include technical adequacy of the calculational methods, including: for models covered by paragraph (d)(2)(ii) of this section, compliance with required features of section I of appendix K to this part; and, for models covered by paragraph (d)(2)(i) of this section, assurance of a high level of probability that the performance criteria of paragraph (d)(1) of this section would not be exceeded.
- Implication to LTCC in Conjunction with Paragraph (b) Wording
  - Conflicts with current Appendix K application to LTCC?

§50.46c Related LTCC Language

- Federal Register Notice Base Line
  - Paragraph (m) *Corrective Action and Reporting*. Each entity subject to the requirements of this section must comply with paragraphs (m)(1) through (3) of this section. Each entity demonstrating acceptable long-term core cooling under the provisions of paragraph (e) of this section shall also comply with the requirements of paragraph (m)(4) of this section
    - (1) *Categories of changes, errors, or operation inconsistent with the ECCS evaluation model*.
    - (2) *Significant change or error in the ECCS evaluation model.* For the purposes of paragraph (m)(1) of this section, a significant change or error in an ECCS evaluation model is one that results in a calculated -
- Implication to LTCC in Conjunction with Paragraph (b) Wording
  - Implication not previously considered
    - (d)(1)(i) mandate not tracked in (m)(2)

Unintended Consequences

- The FRN Published Rule Poses Problems for LTCC
- Seemingly Simple Change Has Ripple Effects
  - Proposed language of (g)(1)(v) not performance based
    - (d)(1)(i) prescribes metric
  - If acceptable methods are “Approvable” going forward on a technical basis, there are still new requirements imposed
    - It will be difficult to resolve paragraph(m) without full rule text.
  - Existing language uses “Acceptable” standard
    - Proposed language drives to an “Approved” standard

Implementation Impact

Implementation Impact

- Potential Implementation Schedule
  - Original concept with no impact to LTCC
- In light of proposed wording:
  - Level of Effort to meet “Approvable” method significant
    - Licensing Topical Reports (LTR’s) may need Revision/Supplementation (NEDO-20566A)
    - Where LTR’s don’t exist, they must be prepared.
  - Jeopardizes schedule for fully approved methods / QA program approvals to be in place supporting §50.90 development

Discussion

Discussion

- Keep Current 50.46(b)(4) and (5)
- Performance Based Language Approach Alternative
  - Proposed Example:
    - (v) Long-term cooling. Appropriate core cooling performance metrics supporting paragraph (d) requirements shall be approved by the NRC.
  - Related Rule Language Needs Cleanup. As an Example:
    - (d)(1)(i) Core temperature during ~~and following~~ the LOCA event does not exceed the analytical limits for the fuel design used for ensuring acceptable performance as defined in this section.
- Specifics Belong in Regulatory Guidance
- Making Final Language Self Consistent, and Consistent with the Statements of Consideration will be a Challenge
- Move Appendix K to a Regulatory Guide
  - Alternatively clarify in the SOC, that LTCC outside of Appendix K