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UNITED STATES NUCLEAR REGULATORY COMMISSION
Protecting People and the Environment

10 CFR 50.46c Long Term Cooling Public Workshop

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Existing Regulation

General Design Criteria 35

The system safety function shall be to transfer heat from the reactor core following any loss of reactor coolant at a rate such that (1) fuel and clad damage that could interfere with continued effective core cooling is prevented and (2) clad metal-water reaction is limited to negligible amounts.

Existing Regulation

10 CFR 50.46(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.

Past Practice

- Commercial nuclear power plants have demonstrated compliance to these generalized requirements using numerous analytical techniques to evaluate core thermal and hydraulic behavior.
  - For example, applicants have demonstrated that the core remains covered with a two-phase mixture while predicted recirculation flow exceeds heat removal flow requirements for decay heat.

- The staff has found these approaches acceptable for decades.

Potential Non-Compliance

- The self-evident and non-controversial label used by the AEC strongly implies that “continued effective core cooling” requires ECCS performance such that core temperatures continue to diminish following the initial quench.

- Limitations in ECCS capability or phenomena interfering with ECCS coolant delivery which result in a post-quench reheat transient may be interpreted as non-compliance with the long-term cooling requirements.

Debris Considerations

- Consideration of debris effects in long-term cooling introduces further complexity in the simulation of accident progression and may require additional analytical rigor and operator actions.

- Recognizing that debris may interfere with ECCS coolant flow delivery, and that this may result in a temporary, post-quench reheat transient, the staff is considering expressly addressing this situation.

Approach

- 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.

- If a post-quench reheat transient occurs, then the staff believes that a more rigorous analysis may be required, which evaluates the fuel and cladding damage that may interfere with continued effective cooling.

Proposed LTC Language

(g)(1)(v) *Long-term cooling*. After any calculated successful initial operation of the ECCS, 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.

Fuel Integrity

- Existing regulation minimizes the release of radioactive nuclides during the long-term period by ensuring continued effective core cooling.
  - Fuel rods that retained their integrity as a fission product barrier during the initial transient would likely continue to retain their integrity during the long term.
- The proposed LTC rule language would allow an applicant to predict a post-quench reheat transient during a postulated LOCA, provided the overarching safety goals of preserving a coolable geometry, removing decay heat for the extended period of time required by the long-lived radioactivity remaining in the core, and minimizing the release of fission products are satisfied.

Fuel Damage

- If an applicant calculates a post-quench reheat, they should demonstrate that no further fuel cladding failure occurs, beyond that which may occur during the short-term period.
- Fuel cladding failure includes, but is not limited to, perforations due to excessive local oxidation, ruptures due to differential pressure, and cladding fragmentation due to loss of ductility.

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Fuel Testing

- NRC LOCA research program only addressed fuel performance during the short term period (i.e., PQD)

- If an applicant calculates a debris-induced post-quench reheat, they would need to conduct research on post-quench fuel specimens to (1) identify all degradation mechanisms, cladding failure modes, and any unique features of fuel rod performance during the predicted long-term temperature history and (2) establish analytical limits and analytical requirements which demonstrate no further fuel cladding failure occurs.

Additional Requirements

- Preservation of adequate heat-transfer area requires the prevention or limitation of the deposition of material on the fuel cladding surface.

- Preservation of coolant-flow geometry requires that the coolant-flow channels remain open and that the deposition of debris does not adversely affect the coolant flow.
  - If an applicant calculates a post-quench reheat, they should demonstrate that no significant change in coolant-flow geometry occurs, beyond that which may occur during the short-term period. Geometric changes include, but are not limited to, fuel rod ballooning due to differential pressure and blockage caused by debris.

Unintended Consequences

- Does the new LTC regulatory basis introduce unforeseen or unintended consequences for existing plants or DCD/COLs?

Conclusions

- The existing generalized LTC regulations do not recognize nor accommodate debris-induced, post-quench reheat transients.
- Regulatory basis is being revised to allow debris consideration, but require more explicit safety demonstration.
- The proposed LTC regulation does not introduce new requirements or burden for plants able to demonstrate minimal debris effects (either by deterministic or risk-based methods).