From: Ralph Meyer
To: NRCExecSec Resource
Cc: Mirela Gavrilas; Andrea Veil; John Tappert; Freebairn, William; UHLE, Jennifer; Edwin Lyman
Subject: [External_Sender] PRM-50-124
Date: Sunday, August 25, 2024 7:21:21 PM
Attachments: Secretary of NRC 08-25-2024.pdf
Proposed LOCA Rule 2024-03-29.pdf

Carrie Safford,

Please see the attached letter and its attachment. The original is being sent by USPS.

Ralph Meyer

28705 Hope Circle
Easton, MD 21601
August 25, 2024

Carrie M. Safford
Secretary of the Commission
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Subject: PRM–50–124

Dear Ms. Safford,

Nuclear power reactors are being operated without valid assurance that their Emergency Core Cooling Systems are adequate because 10 CFR 50.46(b)(1) *Peak Cladding Temperature* does not ensure coolable fuel geometry as assumed. A petition for rulemaking to correct this problem was filed more than two years ago, and no Planned Rulemaking Activities are listed for this docket. The basis for the petition was a peer-reviewed article in *Nuclear Engineering and Design* that was in turn based on NRC-funded research.

From 35 years of working for NRC in this technical area (SLS with a PhD), I may be better qualified than current staff to formulate a replacement rule. Therefore I have attached a description of how the rule could be greatly simplified in a way that would correct the current inadequacy. I have had a lot of informal correspondence with NRC executives with no results. Action on this petition is needed.

Sincerely,

Ralph Meyer

Ralph Meyer
NRC (retired)

Attachment: Petitioner's Proposed Rule

Copies:
Mirela Gavrilas, EDO
Andrea Veil, Director, NRR
John Tappert, Director, RES
William Freebairn, Associate Editorial Director, Nuclear Power, SPGLOBAL
Jennifer Uhle, Vice President, Technical & Regulatory Services, NEI
Edwin Lyman, Director, Nuclear Power Safety, UCS

Petition for Rulemaking, PRM–50–124
Licensing Safety Analysis for Loss-of-Coolant Accidents
Petitioner's Proposed Rule
March 29, 2024

A rule change is needed because peak cladding temperature and maximum oxidation, as currently applied, are not effective. They are supposed to prevent fuel loss during a LOCA by avoiding embrittlement in a cladding balloon, and thereby avoiding breakage, but there is already a hole in the balloon that is large enough to permit fuel loss. Thus the rule should focus on the hole in the balloon rather than embrittlement in the balloon. Following are the changes needed in 50.46 and RG 1.157. Appendix K would be eliminated and all plants would need to be re-analyzed.

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§ 50.46 Acceptance criteria for emergency core cooling systems for light-water nuclear power reactors

(a)(1)(i) Each boiling or pressurized light-water nuclear power reactor fueled with uranium or mixed uranium-plutonium oxide pellets within cylindrical ~~zircaloy or ZIRLO~~ zirconium alloy 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. ~~Except as provided in paragraph (a)(1)(ii) of this section, the~~ The evaluation 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 criteria set forth in paragraph (b) of this section, there is a high level of probability that the criteria would not be exceeded. ~~Appendix K, Part II Required Documentation, sets forth the documentation requirements for each evaluation model.~~ This section does not apply to a nuclear power reactor facility for which the certifications required under § 50.82(a)(1) have been submitted.

~~(ii) Alternatively, an ECCS evaluation model may be developed in conformance with the required and acceptable features of appendix K ECCS Evaluation Models.~~

(2) The Director of Nuclear Reactor Regulation may impose restrictions on reactor operation if it is found that the evaluations of ECCS cooling performance submitted are not consistent with paragraphs (a)(1) (i) ~~and (ii)~~ of this section.

(3)(i) Each applicant for or holder of an operating license or construction permit issued under this part, applicant for a standard design certification under part 52 of this chapter (including an applicant after the Commission has adopted a final design certification regulation), or an applicant for or holder of a standard design approval, a combined license or a manufacturing license issued under part 52 of this chapter, shall estimate the effect of any change to or error in an acceptable evaluation model or in the application of such a model to determine if the change or error is significant. ~~For this purpose, a significant change or error is one which results in a calculated peak fuel cladding temperature different by more than 50 °F from the temperature calculated for the limiting transient using the last acceptable model, or is a cumulation of changes and errors such that the sum of the absolute magnitudes of the respective temperature changes is greater than 50 °F.~~

…………….

[Delete (b)(1) *Peak cladding temperature* and substitute the following.]

(b)(1) *Preventing Significant Fuel Loss from Ballooned and Burst Cladding*. The occurrence of burst balloons shall be calculated with the Meyer-Wiesenack correlation.[1] The emergency core cooling system shall function to assure that specified acceptable fuel burst limits, expressed as a percentage of fuel rods in the core that burst as a function of burnup, are not exceeded as a result of reactor coolant loss.

[Delete (2) *Maximum cladding oxidation* and substitute the following.]

(2) *Preventing Significant Fuel Loss from Non-Ballooned Cladding*. For fuel rods with burst balloons, the ballooned region shall be considered to be 3-inches long in the axial direction, and the rest of the cladding of those rods should be treated as non-burst cladding, along with all other rods that do not have burst balloons. For non-burst cladding, the emergency core cooling system shall function to assure that the peak cladding temperature does not exceed 2200° F and the calculated local oxidation of the cladding nowhere exceeds that of the Billone correlation.[2]

<u>Discussion</u>

In (a)(1)(i), mixed uranium-plutonium oxide has been added because it has long been known that the presence of mixed oxides does not affect cladding behavior during a LOCA. This change does not approve the use of mixed oxides, for which there may be other issues, but it clears the way for using 50.46 should mixed-oxide reloads be approved.

Also in (a)(1)(i), "Zircaloy" and "ZIRLO" have been replaced with "zirconium alloy" because NRC'S research has shown that LOCA behavior does not depend on the exact alloy (NUREG/CR-7219). This result is a consequence of high LOCA temperatures that anneal out manufacturing details. Please note that some alloys absorb more hydrogen than others during normal operation, and hydrogen content is explicitly accounted for in the new correlations.

In (a)(1), subparagraph (ii) has been eliminated because old Appendix-K models related to paragraphs (b)(1) and (b)(2) are no longer relevant.

In (a)(3)(i), the 50° F trigger for reporting is no longer needed. The 2200° F peak cladding temperature would remain in the rule for non-ballooned cladding, but with single-sided oxidation and no cladding swelling this temperature is not expected to be limiting.

The current version of (b)(1) and (b)(2) should be deleted because they are ineffective. These criteria should be replaced by criteria related to bursting, and the old criteria that are applied to ballooned regions should not be grandfathered.

The occurrence of bursting should be calculated with the Meyer-Wiesenack correlation for two reasons. First, mechanistic calculations of ballooning deformation and bursting are unreliable as we have determined in agreement with German RSK conclusions (see Meyer-Wiesenack paper). Second, different empirical correlations would not be correct because our correlation is based without bias on all known rod burst data obtained with appropriate internal heating.

Specified acceptable fuel burst limits (SAFBLs) in the form of a percentage of rods in the core that burst would be non-proprietary to ensure transparency. SAFBLs would be a function of burnup, they would be based on FFRD data, and they would be uncertain at first; confirmatory research would be performed and provide a basis for change if needed. This is the same approach that was taken in 1973 when the original criteria were promulgated: significant uncertainty existed in criteria and methods that were to be confirmed by a major research program. The initial estimate of SAFBLs should be as low as tolerable to gain public trust. Remember that, if 10% of the rods burst and release fuel from only 10 axial inches of the rods, the amount of fuel released would be more than half a ton. Ten percent seems small, yet half a ton seems large, so we should do our best to minimize the percentage of rods that burst. This value is intentionally left out of the rule so it can be changed, if necessary, without a rule change.

For non-burst cladding, the Billone correlation should be used for calculating the oxidation limit because it includes the effect of hydrogen content; the research showed that burnup and alloy composition are not important; and the correlation has been widely accepted. The current 17% limit is not valid when hydrogen is present.

Appendix K to Part 50 – ECCS Evaluation Models

[Eliminate Appendix K.]

<u>Discussion</u>

When BE LOCA analysis was approved in 1988, Appendix K was retained as an option for plants that didn't need relief. Because cladding temperature and oxidation limits in the balloon are now known to be inappropriate, all plants will need to be re-analyzed according to the new criteria, and the BE Regulatory Guide (1.157) should be used.

Regulatory Guide 1.157, Best-Estimate Calculations of Emergency Core Cooling System Performance

[There are 20 references to Appendix K in RG 1.157, and these need to be revised or removed.]

3.3 Reactor Core Thermal/Physical Parameters

3.3.1 Thermal Parameters for Swelling and Rupture of the Cladding and Fuel Rods

[Replace with the following.]

For fuel rods with burst balloons, the ballooned region shall be considered to be 3-inches long in the axial direction. The shape of the balloon should be approximately Gaussian (bell shaped) with a maximum circumferential strain of 90 percent at the center of the 3-inch axial length.

Discussion

Ballooning strain (swelling) has been shown to be stochastic, and mechanistic calculations are unreliable. Therefore empirical values should be used. The appropriate data base for such an evaluation includes only tests performed with internal heating as identified in the Meyer-Wiesenack paper. That paper does not examine ballooning strains, but its data base is an extension of that in NUREG-0630 where ballooning strains were evaluated. Figure 8 (p. 23) of NUREG-0630 shows strain data for all heating rates, and the solid curve shows the authors' best estimate (many of the lower strain values were from tests with known biases such that the best estimate is not simply an average of all the values). The best-estimate strain at the peak of the alpha phase is 90 percent. Because this peak will shift in temperature with hydrogen content and alloy composition, it is simpler and adequate to assume 90 percent for all burst temperatures. This assumption should not be a problem because (a) strains of this magnitude improve external heat transfer and (b) two-sided oxidation in balloons is now decoupled from peak cladding temperature.

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[1] Ralph O. Meyer and Wolfgang Wiesenack, "A critique of fuel behavior in LOCA safety analyses and a proposed alternative," *Nuclear Engineering and Design* 394, p. 111816 ff, August 2022, Part 5.1.

[2] M. C. Billone, Y. Yan, T. A. Burtseva, and R. O. Meyer, *Cladding Behavior during Postulated Loss-of-Coolant Accidents*, NUREG/CR-7219, July 2016, Eq. 17, p. 60.