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LTR-NRC-23-2

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Subject: Westinghouse Comments on Petition for Rulemaking re: Licensing Safety Analysis for Loss-of-Coolant Accidents [Docket No. PRM–50–124; NRC–2022–0178]

On November 23, 2022, the Federal Register (FR) published a notice of docketing and request for comment on a petition for rulemaking (PRM) re: Licensing Safety Analysis for Loss-of-Coolant Accidents (LOCAs) [Docket No. PRM–50–124; NRC-2022-0178].

Enclosure 1 of this letter provides Westinghouse Electric Company LLC ("Westinghouse") general comments on this PRM.

Westinghouse appreciates the opportunity for stakeholder involvement provided by the NRC petition for rulemaking process.

Correspondence regarding this letter and the enclosed comments should reference LTR-NRC-23-2 and should be addressed to Zachary S. Harper, Manager, Licensing Engineering, Westinghouse Electric Company, 1000 Westinghouse Drive, Building 1, Cranberry Township, PA 16066.

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Enclosures:
(1) Westinghouse Comments on Petition for Rulemaking re: Licensing Safety Analysis for LOCAs (Non-Proprietary)

Enclosure 1

Westinghouse Comments on Petition for Rulemaking re: Licensing Safety Analysis for LOCAs

(Non-Proprietary)

(7 pages including this cover page)

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Westinghouse would like to provide the following comments on the petition for rulemaking (PRM) from Ralph O. Meyer dated August 1, 2022, requesting that the Nuclear Regulatory Commission (NRC) revise its regulations regarding the licensing safety analysis for loss-of-coolant accidents. The PRM was published on the Federal Register (Vol. 87, No. 225, Wednesday, November 23, 2022, Docket No. PRM-50-124). The Westinghouse comments are organized by first addressing the summary provided in the PRM. Second, by addressing shortcomings of the paper enclosed in PRM (Ref. 1), including the noted German safety analysis requirements. Finally, Westinghouse acknowledges that the underlying concerns raised by petitioner could potentially be addressed via sensible, wholistic rulemaking in the context of industry initiatives that are directly tied to the cause of those concerns.

The PRM explicitly lists three perceived problems with Loss-of-Coolant Accident (LOCA) safety analyses of record, the Emergency Core Cooling System (ECCS) acceptance criteria of United States (US) Code of Federal Regulations (CFR), Title 10, Part 50, Section 50.46 (i.e., 10 CFR 50.46), and the proposed 10 CFR 50.46c regulation. First, the petitioner notes that, "Current acceptance criteria become ineffective at moderate fuel burnups because burst fuel rods experience massive fuel loss and do not 'retain the UO_2 fuel pellets in their separate fuel rods and therefore remain in an easily coolable array' as intended." No supporting information is provided by the petitioner. The safety of the plants under moderate burnups has been studied and addressed by industry and the NRC for over a decade. In 2011, the Pressurized Water Reactor Owner's Group (PWROG) and Boiling Water Reactor Owner's Group (BWROG) performed margin assessments for the operating fleet of plants relative to the research findings underpinning the 10 CFR 50.46c rulemaking demonstrating that the licensees continue to operate safely (Ref. 2). These assessments have been updated by industry several times since the original issuance and have been maintained by the NRC on a yearly basis (e.g., Ref. 3). Furthermore, the NRC was performing analyses to predict the extent of fuel dispersal during a LOCA, as evident in various publications such as Ref. 4 from 2014. In light of this information, the NRC Staff issued SECY-15-0148 (Ref. 5) wherein it was concluded that "*Research and analyses provide reasonable assurance that no imminent safety concern exists with operating reactors*." Further, the NRC Staff has provided their conservative interpretation of the research on fuel fragmentation, relocation, and dispersal (FFRD) at high burnup in RIL 2021-13 (Ref. 6), which notes a 55 GWd/MTU pellet average burnup empirical threshold for when significant fine fragmentation begins. This RIL does not counter prior work discussed in SECY-15-0148 that concluded that existing burnup limits for fuel in operating reactors are acceptable. Based on the available experimental data to date, Westinghouse agrees that the noted threshold in RIL 2021-13 is indeed conservative.

Second, the petitioner notes, "Calculations of temperature and oxidation within the burst region of a fuel rod are extremely difficult to the point of being meaningless. Independent of our conclusion, the Reactor Safety Commission (RSK) in Germany has stated that 'In the opinion of the RSK, such a safety demonstration is currently not possible.'" Westinghouse strongly disagrees with this statement. LOCA methodologies utilized to demonstrate compliance with the 10 CFR 50.46 acceptance criteria are required to meet the following (as described in 10 CFR 50.46 (a)(1)(i)):

> *… ECCS cooling performance must be calculated in accordance with an acceptable evaluation model … 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…*

Thermal-hydraulic codes utilized for LOCA analysis and the associated evaluation models contain sufficient complexity (and/or conservatisms) to perform the requisite analyses. Conservatisms are included to ensure regulatory criteria are met with high probability, including the balloon and burst region. The more modern best-estimate (plus uncertainty) methods account for fuel fragmentation and relocation into the ruptured region of the fuel rod and oxidation on the inner surface at the rupture location. The calculations of the cladding temperature and local oxidation at the hottest spot on the most limiting rods are then used to demonstrate compliance with the 10 CFR 50.46 criteria for the entire core. As such, while Westinghouse agrees that the calculations of cladding temperature and oxidation are complex; current technologies, which are benchmarked against meaningful experimental data and consider the uncertainties associated with important phenomena, are capable of performing these calculations.

Specific to the balloon and burst region, it is also pertinent to note that the NRC Staff performed a significant amount of testing and analysis to support the performance-based embrittlement criteria proposed as part of the draft 10 CFR 50.46c rulemaking. The embrittlement research findings summarized in Ref. 7 discuss the absence of credible analysis of loads, cladding stresses, and cladding strains for a core degraded by LOCA conditions. The NRC Staff noted that, “there are no absolute metrics to determine how much ductility or strength would be needed to provide absolute assurance that fuel-rod cladding would maintain its geometry during and following post-LOCA quench.” NRC-sponsored research summarized in Ref. 8, which examined the bending moment and failure energy using four-point bend tests to determine the resistance to fracturing of ballooned cladding during a LOCA, showed that if wall thinning and double-sided oxidation are accounted for, then hydrogen-based embrittlement limits, such as the limit provided in Figure 2 of Regulatory Guide (RG) 1.224, “Establishing Analytical Limits for Zirconium-Alloy Cladding Material”, are sufficient to ensure reasonable behavior of the ballooned and ruptured region. As such, cladding temperature and oxidation calculations utilizing NRC-approved LOCA methodologies, including the ballooned and ruptured region, support the demonstration of a coolable core geometry and continued safe operation under postulated LOCA conditions.

Further, Westinghouse would like to address the RSK statement related to the safety demonstration referenced in the PRM from Ref. 9. The RSK statement quoted in PRM was made in the context of safety demonstration for cladding by means of an ECR(H) limit curve (Section 3.2

of Ref. 9). However, further discussion on this concern was provided in Section 3.4 of Ref. 9, which stated,

> *Against the background of the findings presented under a) to c), the RSK comes to the conclusion that the ECR(H) limit curve of the NRC [Draft Regulatory Guide DG-1263[1]] can be used for the demonstration of a sufficient limitation of the ECR value in the deformation and burst range since – according to current knowledge – it sufficiently limits the degree of oxidation for the deformation and burst range in dependence of the operational hydrogen up-take. This covers implicitly the embrittling effect of the hydrogen up-take from secondary hydrogen up-take. The present experiment results show that if the ECR value is limited in accordance with the limit curve of the NRC, a sufficient residual strength in the deformation and burst area is ensured so that a fragmentation of the cladding upon quenching can be excluded. Hence, no additional data beyond the operational hydrogen content and the maximum ECR value resulting from the high-temperature oxidation are necessary for the demonstration.*

RSK concluded that the draft 10 CFR 50.46c rulemaking, which relies on the on NRC-sponsored research summarized in Ref. 8, is sufficient and the quoted statement from RSK in the PRM is taken out of context with respect to the proposed 10 CFR 50.46c rulemaking in the US.

Thirdly, the petitioner notes, “The current acceptance criteria and their analyses are not straight forward... These misconceptions are the result of lack of transparency.” Westinghouse and other fuel vendors have teams of engineers solely focused on LOCA accident modeling and supporting Licensees in demonstrating compliance with the 10 CFR 50.46 criteria. It is understood that the peak cladding temperature and local oxidation limits are surrogates to demonstrate ductility, and by extension a coolable core geometry post-quench of a postulated LOCA accident. Further, Westinghouse notes that the documents generated by the NRC Staff and its contractors to support the 10 CFR 50.46c rulemaking have summarized the history of the LOCA-related regulations (e.g., Section 2 of Ref. 8, Section 1 of Ref. 10).

The PRM went on to state that,

> *… if the rule change is kept simple, unlike the previous attempt to revise 50.46 (42 pages in the Federal Register to announce the rulemaking), the effort will be small and worthwhile. Industry analyses and NRC reviews will be simpler (less expensive), and we cite evidence in our paper that the new analyses may have little impact on operating conditions.*

The effort to establish and implement a new rule (even if simplified) is anything but simple. As noted in the previously quoted portion of 10 CFR 50.46 (a)(1)(i), ECCS cooling performance must be calculated in accordance with an acceptable evaluation model and the evaluation model must

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[1] It is noted the draft Regulatory Guide DG-1263 has been superseded by draft Regulatory Guide 1.224. However, the relevant content discussed herein is unchanged between DG-1263 and draft RG-1.224.

include sufficient supporting justification to show that the analytical technique realistically describes the behavior of the reactor system during a LOCA. Fuel vendors have significant experience in modeling the fuel rod performance under postulated LOCA conditions, with a focus on a compliance demonstration for the most limiting rods in the core (thereby assuring compliance for all of the rods operating in the core). Significant effort would be required to update and license new LOCA methodologies under a new context of analyzing a core-wide census. Then, further effort would be required to implement the new methodologies on a plant-specific basis, all of which would divert resources who are currently studying fuel dispersal as part of ongoing industry initiatives.

Next, Westinghouse notes that the proposed, potential criteria from Ref. 1 of 10% (large-break LOCA) and 1% (small-break LOCA) rod rupture are arbitrary. Consider for example that core-wide rupture exceeded 40% in select cases from Ref. 4, which was published in the year prior to the issuance of SECY-15-0148. The paper enclosed in the PRM states that the authors believe that "the concept of limiting the number of ruptured rods is sound, is workable, and avoids the major problems associated with calculating ECR and PCT." The paper however fails to provide any evidence of how the specifically proposed limits are associated with a demonstration of core coolability. The enclosed paper implies that a limit on fuel rupture would avoid the consequences associated with FFRD. However, the overly simplistic proposal does not account for important aspects of dispersal such as the onset of fine fragmentation, the potential differences in fuel pellet materials (e.g., standard UO_2, chromium doped UO_2, long-term ATF concepts, etc.), fuel pellet fragmentation size, etc., nor does it address any of the potential consequences of dispersal. Determination of such criteria requires supporting evidence (including experimental data and analysis accounting for the physics associated with key phenomena), as well as the associated level of assurance for the compliance demonstration. Further, the enclosed paper states that, "safety analyses in Germany are required to show that no more than 1% of the fuel rods in a core would rupture during a small-break LOCA and no more than 10% of fuel rods in a core would rupture during a large-break LOCA." The paper fails to mention that the noted criteria are related to radiological consequences for which compliance may be demonstrated at less than 95th percentile with 95% confidence (95/95), depending on the calculation method, and that historical ECCS acceptance criteria remain in Germany.

Finally, it is important to address the shortcomings of the Westinghouse paper (Ref. 11) referenced in the enclosed paper to the PRM, which was cited as evidence that implementation of the proposed criteria may have little impact on operating conditions. The referenced Westinghouse paper had the stated objective to assess the extent of failure and the effect of rupture on the peak cladding temperature and maximum local oxidation for the large-break LOCA scenario, with and without detailed treatment of uncertainties. Inputs that have a first order effect on the LOCA response and the effectiveness of the ECCS were set to more favorable values than would be analyzed for a licensing basis LOCA analysis. Further, the vintage of the noted study predates the consideration of fuel pellet thermal conductivity degradation and other important high burnup phenomena in Westinghouse fuel rod design and LOCA methodologies. Also, plant type, fuel type, and plant-specific design features (which were not specifically considered in the paper) can have a significant effect on the predicted LOCA results. Therefore, the conclusions from that paper are not appropriate to characterize the impact that would be associated with implementation of the criteria proposed in the PRM.

In closing, Westinghouse recommends that the PRM should be rejected in its current form. The main underlying concern identified in Ref. 1 is the effect of dispersed nuclear fuel on the ability of the plant's ECCS to effectively maintain a core coolable geometry under postulated LOCA conditions. An extensive, industry-wide effort including experimentation and analysis to better understand the thresholds, phenomena, and consequences associated with fuel dispersal is ongoing as part of industry initiatives to increase fuel rod burnup and enrichment limits (which are enabled with advanced fuel concepts). As noted, the public health and safety has been addressed by the NRC Staff in the interim, allowing time for experimental data and knowledge with respect to FFRD to be generated by industry. The industry has an opportunity to move forward with a sensible regulatory framework that leverages risk-informed insights and wholistically considers the effects of all known cladding embrittlement mechanisms, ATF concepts, increased burnup and enrichment limits, and fuel dispersal relative to a demonstration of core coolable geometry following a postulated LOCA. Westinghouse supports such an approach.

References

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2. NRC, "ECCS Performance Safety Assessment and Audit Report," February 2012. ML11262A017.
3. NRC, "50.46C EMERGENCY CORE COOLING SYSTEM SAFETY ASSESSMENT – 2017 UPDATE," February 2018. ML18039A102.
4. Raynaud, P., Porter, I., "Predictions of Fuel Dispersal During a LOCA," Proceedings of WRFPM 2014, Sendai, Japan, Paper No. 100026, September 2014.
5. NRC SECY-15-0148, "EVALUATION OF FUEL FRAGMENTATION, RELOCATION AND DISPERSAL UNDER LOSS-OF-COOLANT ACCIDENT (LOCA) CONDITIONS RELATIVE TO THE DRAFT FINAL RULE ON EMERGENCY CORE COOLING SYSTEM PERFORMANCE DURING A LOCA (50.46c)," November 2015. ML15230A200.
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7. U.S. Nuclear Regulatory Commission, Federal Register Notice, "Performance-Based Emergency Core Cooling System Requirements And Related Fuel Cladding Acceptance Criteria (10 CFR Parts 50 and 52, RIN 3150-AH42)," March 2016. ML15238B016.
8. NUREG-2119, "Mechanical Behavior of Ballooned and Ruptured Cladding," February 2012.
9. RSK, "Demonstration of residual ductility/residual strength by means of an ECR limit curve," Recommendation to the 476th meeting of the Reactor Safety Commission (RSK), June 2015.

10. NUREG/CR-6967, "Cladding Embrittlement During Postulated Loss-of-Coolant Accidents," July 2008.

11. Nissley, M.E., Frepoli, C., Ohkawa, K., "Realistic Assessment of Fuel Rod Behavior Under Large-Break LOCA Conditions," Proceedings of the Nuclear Fuels Sessions of the 2004 Nuclear Safety Research Conference, 2005.