UNITED STATES
NUCLEAR REGULATORY COMMISSION
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US NUCLEAR REGULATORY COMMISSION STAFF OBSERVATIONS ON FRAMATOME WHITE PAPER, "REGULATORY ENGAGEMENT FOR HIGH BURNUP FUEL FRAGMENTATION, RELOCATION AND DISPERSAL" (EPID NO. L-2023-LRO-0059)

SPONSOR AND SUBMITTAL INFORMATION

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Brief Description of the White Paper: By letter dated August 4, 2023 (Agencywide Documents Access and Management System Accession No. ML23219A031), Framatome, Inc. (Framatome) requested written feedback on issues associated with its proposed near-term approach for addressing fuel fragmentation, relocation, and dispersal (FFRD) in high burnup (HBU) fuel following a postulated loss-of-coolant accident (LOCA). Framatome specifically requested U.S. Nuclear Regulatory Commission (NRC) staff feedback on the following three "conceptual items of its plan":

1. It is acceptable to employ risk and safety significance to define the appropriate level of reasonable assurance of adequate protection of public health and safety.
2. A level of reasonable assurance commensurate with risk, but lower than the traditional high probability level, is justifiable for extremely low frequency of occurrence large piping breaks, and
3. It is acceptable to employ a supplemental analysis using the level of reasonable assurance defined above to demonstrate that LOCA-related Final Safety Analysis Report (FSAR) safety analyses remain applicable, and plants remain in compliance with existing regulations.

TECHNICAL ASSESSMENT

The NRC staff reviewed the Framatome white paper and provides the observations listed below. These observations do not constitute a final agency decision or position. The NRC staff observations in this response are not intended as comprehensive feedback. Lack of comment or observations regarding a certain aspect of the white paper should not be interpreted as NRC agreement with Framatome's position.

GENERAL OBSERVATIONS:

The possibility for FFRD occurs in HBU fuel following a postulated LOCA. This phenomenon is a matter not explicitly addressed within current NRC regulations. However, existing regulations set forth in Title 10 of the *Code of Federal Regulations* (10 CFR) 50.46(b)(4) and in General Design Criterion (GDC) 35, "Emergency Core Cooling," in Appendix A, "General Design Criteria for Nuclear Power Plants," to 10 CFR Part 50, both require the preservation of a coolable core geometry. The requirements in 10 CFR 50.46(a)(1)(i) further establish that licensees must evaluate "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." If expected to occur in a significant amount that has not been addressed within an existing analysis, FFRD may lead to a condition that is inconsistent with these requirements.

The NRC staff would consider a topical report describing an approach to addressing FFRD that aligns with conceptual items 1-3, above, using its available guidance on risk-informed decision-making and assess whether the approach appropriately addresses the regulatory requirements of 10 CFR 50.46 and GDC 35. According to the Office of Nuclear Reactor Regulation (NRR) Office Instruction LIC-209, "Integrated Risk-Informed Decision-Making for Licensing Reviews," Appendix C, "Use of Probabilistic, Risk, and PRA Insights for Technical Reviewers," the term "risk" is defined as:

> …a measure combining failure modes, likelihood of occurrence, and consequences. Risk is defined as the 'probability and consequences of an event,' as expressed by the 'risk triplet,' that is, the answer to the three questions in the risk triplet…

According to LIC-209, Appendix C, the three questions in the risk triplet are:

1. What can go wrong?
2. How likely is it to occur?
3. What are the consequences if it occurs?

Upon the submittal of a TR describing an approach to addressing FFRD in the manner described by Framatome, the NRC staff would factor these considerations into its evaluation, as reflected in the feedback below.

Feedback on Item 1

The NRC staff employs risk and safety significance to define the appropriate level of reasonable assurance of adequate protection of public health and safety. Employing risk and safety significance in this fashion is aligned with Commission directives and existing guidance. As a general matter, the NRC staff presumes that reasonable assurance of adequate protection of public health and safety is established when the applicable regulatory requirements set by the Commission are satisfied. Pertaining to regulatory requirements applicable to FFRD, the NRC staff would consider the core coolability requirements set forth in 10 CFR 50.46(b) and in GDC 35.

The NRC staff considers both risk and safety significance when (1) evaluating whether any proposed activity can be conducted in compliance with the applicable regulatory requirements, and (2) considering any actions that may be necessary when ongoing research improves our understanding of a technical issue, such as FFRD, and what impact that issue may have on operating reactor safety.

Feedback on Item 2

The NRC staff has long accepted 95-percent confidence and 95/95 tolerance limits[1] as an acceptable means to address a number of regulatory requirements, including not only in realistic LOCA analysis in accordance with 10 CFR 50.46(a)(1)(i), but also in non-LOCA analysis, critical heat flux, and criticality analysis, to provide several examples. However, the NRC staff could consider whether a level of assurance commensurate with risk, but lower than the traditional high probability level, can be adequately justified for large piping breaks of extremely low frequency of occurrence, given a reasonably complete assessment of the associated risk. The justification for this level of assurance would need to be consistent with the 10 CFR 50.46(a)(1)(i) requirement that, “when the calculated ECCS [emergency core cooling system] cooling performance is compared to the criteria set forth in paragraph (b) of this section, [emphasis added] *there is a high level of probability that the criteria would not be exceeded*.”

The white paper states, “Risk-insights are defined in terms of initiating event frequency of occurrence.” The NRC staff observes that risk is traditionally defined as the product of the consequences of an event and its likelihood of occurrence. A more complete consideration of the risk significance of a large-break LOCA (LBLOCA) would include not only the fact that its likelihood is estimated to be low, but also what possible event sequences may follow the postulated LOCA and how likely they would be, given the occurrence of that LOCA.

[1] A 95-percent confidence limit is a measure of statistical assurance that a particular parameter, such as a predicted peak cladding temperature, will fall within the specified limit. A 95/95 tolerance limit is a measure of statistical assurance that a percentage of a population will fall within the limit, i.e., 95-percent confidence that 95-percent of the population will fall within the specified limit. Regulatory Position 4.4 of NRC Regulatory Guide 1.157, “Best-Estimate Calculations of Emergency Core Cooling System Performance,” indicates that the use of a 95-percent confidence limit is acceptable (“…an upper one-sided probability limit can be calculated at the 95% level”), whereas more modern ECCS performance evaluation models such as EMF-2103P-A, Revision 3, “Realistic Large Break LOCA Methodology for Pressurized Water Reactors,” rely on tolerance limits to compare results to regulatory acceptance criteria. Refer to Chapter 9, “Estimation,” of NUREG-1475, “Applying Statistics,” for further information.

Framatome stated, “At this time, during the period while research continues to fill data gaps and the Commission considers potential regulatory infrastructure change, using initiating event frequency as a metric for risk-insights, in lieu of plant-specific quantification of risk attributes (i.e., change in core damage frequency), is appropriate for this application and is consistent with" the treatment of in-vessel downstream effects to resolve Generic Safety Issue 191. It must be noted that in reaching its determination on Generic Safety Issue 191, the NRC staff considered the quantitatively low likelihood of a LBLOCA alongside the qualitative likelihood of specific events to occur following the postulated LOCA, including the likelihoods:

- That the rupture may occur at a location that would dislodge the most debris,
- That a core-blockage-inducing amount of debris could transport to the containment sump,
- That enough debris transported to the containment sump would subsequently bypass its suction strainer and travel to the core,
- That the bypassed debris would transport to the core and form an even bed at the core entrance, and
- That the core-wide bed would form while the core decay heat remains sufficiently high to induce a heatup.

In evaluating the acceptability of a “lower than the traditional high probability level” type demonstration, or a “less certain” assurance that **[[ ]]**, more detailed consideration of the low-probability event sequences would be helpful, even if not explicitly quantitative.

Feedback on Item 3

An applicant may be able to justify a supplemental analysis using the level of assurance described above, in Framatome’s conceptual items 1-2, to demonstrate that LOCA-related FSAR safety analyses remain applicable, and whether using such a supplemental analysis could effectively demonstrate compliance with existing regulations. However, this level of assurance needs to be more clearly defined. An example of such a supplemental analysis, including information about how it would be applied on a plant-specific basis, would be helpful for NRC staff consideration.

In addition, the NRC staff notes that this approach effectively separates the treatment of FFRD for certain post-LOCA transients and seeks to apply different analytic rigor to the demonstration that **[[ ]]**; meanwhile, many existing FSAR ECCS performance evaluations already address **[[ ]]**. Framatome should address how differences between existing analyses that **[[ ]]** and a supplemental evaluation demonstrating **[[ ]]** would be reconciled.

ADDITIONAL CONSIDERATIONS:

The NRC staff observes that there is a well-established precedent concerning acceptable approaches to demonstrate regulatory compliance with GDC 35 and 10 CFR 50.46(b)(4), as

discussed above. These approaches have ensured that catastrophic failure of the fuel structure and loss of fuel bundle configuration do not occur during design-basis accident LOCA scenarios. To the extent Framatome believes that a certain level of assurance that **[[ ]]** is reasonable, but possibly inconsistent with existing NRC requirements, specific exemptions to NRC requirements may be requested. As noted in Regulatory Guide 1.174, Revision 3, "An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant-Specific Changes to the Licensing Basis," proposed changes must meet the current regulations unless they are related to requested exemptions (i.e., specific exemptions under 10 CFR 50.12). More information is needed concerning potential approaches Framatome envisions licensees would need to take to address meeting the applicable regulatory requirements.

In Section 3 of the white paper, Framatome states, "several recent studies will be cited which conclude the HBU fuel fragmentation and dispersal would not increase the radiological source term released into containment or the public exposure to radiation beyond the bounding analysis docketed in each plant's FSAR." In evaluating a comparison like this, the NRC staff would consider the likelihood of an initiating event leading to such a source term in comparison to the likelihood of the LBLOCA under consideration in this FFRD approach.

CONCLUSIONS:

Conceptually, the NRC staff believes that the approach to addressing FFRD for HBU fuel proposed by Framatome could be evaluated, but additional detail is needed, as described above, for a complete NRC staff evaluation.

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