UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
WASHINGTON, DC 20555 - 0001

April 19, 2016

Mr. Victor M. McCree
Executive Director for Operations
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

SUBJECT: REGULATORY GUIDE 1.229, "RISK-INFORMED APPROACH FOR ADDRESSING THE EFFECTS OF DEBRIS ON POST-ACCIDENT LONG-TERM CORE COOLING"

Dear Mr. McCree:

During the 633rd meeting of the Advisory Committee on Reactor Safeguards, April 7-9, 2016, we reviewed Draft Regulatory Guide 1.229, “Risk-Informed Approach for Addressing the Effects of Debris on Post-Accident Long-Term Core Cooling.” Our Metallurgy and Reactor Fuels Subcommittee reviewed this matter on November 3, 2015, and March 22, 2016. During these reviews, we had the benefit of discussions with the NRC staff and representatives of the Nuclear Energy Institute. We also had the benefit of the referenced documents.

CONCLUSION AND RECOMMENDATIONS

1. If implemented properly, the approaches outlined in Regulatory Guide 1.229 provide reasonable alternatives to support a risk-informed regulatory decision about the effect of debris on long-term cooling and the potential need to remove sources of debris from the containment. Regulatory Guide 1.229 should be issued after the staff addresses the following recommendations.

2. The staff should clarify expectations for the assessment of scenarios that involve recirculation from the containment sump, but are not initiated by a loss of coolant accident (LOCA).

3. The staff should clarify expectations for the assessment of uncertainties, with particular attention to how uncertainties about debris generation, transport, and deposition on strainers and downstream coolant flow paths are used to support the risk-informed conclusions.

4. The staff should clarify how the "base PRA" or other techniques should be used to define the most limiting equipment operating configurations and flow scenarios for a simplified assessment. The staff should also clarify that the post-assessment PRA models should be updated to include the risk from debris-related scenarios consistently with the scope and level of detail applied in these analyses.

BACKGROUND

In our February 23, 2016 letter report, we recommended that draft final rule 10 CFR 50.46c, “Emergency Core Cooling System Performance During Loss-of-Coolant Accidents (LOCA)” and associated Regulatory Guides 1.222, 1.223, and 1.224 should be issued, but that Regulatory Guide 1.229 should not be issued, pending our review of that guidance. Regulatory Guide 1.229 contains methods and approaches for demonstrating compliance with voluntary, risk-informed alternatives for addressing the effects of debris on long-term core cooling, as provided in Section 50.46c(e) of the rule.

DISCUSSION

Regulatory Guide 1.229 describes two methods for assessing the risk that is associated with debris which may either obstruct the strainers that protect the containment recirculation sumps or prevent adequate flow of cooling water through the reactor core.

The “detailed approach” uses the plant probabilistic risk assessment (PRA) to identify scenarios that will generate debris, with their associated event severities, occurrence frequencies, and system operating configurations. The analyses include scenario-specific evaluations of the debris generation mechanisms, size distribution, transport and accumulation on strainers, strainer head loss and criteria for strainer failure, penetration through the strainers, effects on core cooling flow paths downstream from the strainers, and chemical effects that could increase flow resistance and head loss through debris beds. The PRA models, modified to account for these effects, are then used to quantify the cumulative frequency of all scenarios that result in core damage or a large early release. Those results are compared to the risk from a "clean" plant (i.e., one with no debris in the containment) to determine whether the incremental risk from the presence of debris is acceptable.

The “simplified approach” is conceptually similar to the detailed approach. It contains a simplified process to identify the event scenarios that may generate debris. The expected debris load for each scenario is then compared with the results from strainer performance tests. If the calculated scenario debris load exceeds the maximum amount of debris that was empirically shown to sustain adequate core cooling flow, it is assumed that the scenario will result in core damage. If the debris load is less than that maximum, the scenario is assigned to a successful long-term core cooling condition. The cumulative frequency of all scenarios that result in excessive debris is then used as an approximate estimate of the incremental risk from the presence of debris.

The principal differences between the two methods are that the simplified approach includes a less detailed assessment of the event scenarios that may generate debris, and it uses empirical results from testing as a coarse “pass-fail” acceptance criterion, without detailed scenario-specific evaluations of debris generation, transport, deposition, or the composite effects from chemicals and debris. The simplified approach is intended to provide conservative estimates of the overall risk from debris, compared to the detailed approach. If implemented properly, the approaches outlined in this guidance provide reasonable alternatives to assess whether the incremental risk from debris is within the range of acceptance to support a risk-informed regulatory decision according to the process described in Regulatory Guide 1.174.

In the following we elaborate on our conclusion and recommendations concerning specific elements of the guidance.

Scope of the Evaluations

Whether the evaluations are "detailed" or "simplified," the guidance states that they should include any scenario that has the following attributes:

- The scenario response involves recirculation to maintain core cooling, and
- The scenario involves the potential for debris inside primary containment that could adversely affect structures, systems or components needed for recirculation, and
- The scenario involves a mechanism that could transport the debris to the sump, and
- The debris is necessary for the scenario to result in core damage or containment failure.

These attributes encompass all the scenarios that could involve adverse effects on long-term core cooling from debris inside the containment. Unfortunately, much of the guidance is focused exclusively on just scenarios that are initiated by LOCAs. It is noted that a screening process may be used to justify removing certain hazards, initiating events, and plant operating modes if they are deemed to represent an insignificant contribution to the incremental risk from debris or are otherwise not important to the regulatory decision. The strong emphasis on LOCAs may inappropriately overlook other types of scenarios, which can be important to plant-specific risk. Examples of these scenarios include:

- Transient initiating events that disable main feedwater or involve failures of certain support systems can lead to conditions that require operator alignment of feed and bleed cooling, with eventual recirculation from the containment sump. Debris that is mobilized during the blowdown and release of coolant through the pressurizer relief tank could affect long-term recirculation cooling during these scenarios.
- Ruptures of main steam piping or main feedwater piping inside the containment may directly generate debris. Those events also disable controlled heat removal through the faulted steam generator and can lead to conditions that require feed and bleed cooling. The additional debris that is mobilized by the initiating event damage could exacerbate the effects on recirculation flow.
- Seismic events with accelerations that are not sufficient to produce direct or indirect failures of reactor coolant system piping can disable all offsite power supplies and main feedwater, and lead to conditions that require feed and bleed cooling. These events may also produce types and quantities of debris that are not examined during evaluations of high energy line breaks. The additional debris that is mobilized by the initiating event damage could then exacerbate the effects on recirculation flow.

To improve assurance that these types of conditions receive adequate consideration, the staff should clarify expectations in the guidance to include the assessment of scenarios that involve recirculation from the containment sump, but are not initiated by a LOCA.

Assessment of Uncertainties

If a detailed evaluation is performed, the guidance indicates that LOCA frequencies should be represented by probability distributions and that the mean values from those distributions should be used for a quantitative assessment of the risk from debris. However, if a simplified evaluation is performed, the guidance notes that it is not necessary to develop probability distributions for the LOCA frequencies.

The guidance implies that it is not necessary to assess uncertainties in the evaluations of debris generation, transport, deposition on strainers or downstream flow paths, or composite effects from debris and chemicals. For a detailed evaluation, it is noted that the models for these phenomena should "represent or bound" the range of possible conditions. The guidance for a simplified evaluation does not address the assessment of uncertainties. However, with regard to general considerations of uncertainty, it is noted in Regulatory Guide 1.229, Section C.4 that:

> “In addition, portions of the analysis using NRC staff-accepted deterministic methods do not require quantification of uncertainty (model or parametric). The NRC considers the accepted deterministic methods to be conservative enough to compensate for uncertainty.”

This guidance is not consistent with NUREG-1855, where it is noted that an assessment of model uncertainties may not be needed when a consensus model is used. However, the guidance in NUREG-1855 clearly states that use of a consensus model does not eliminate the need to assess the effects from uncertainties in the parameters evaluated by that model.

Regulatory Guide 1.229 indicates that the methods and guidance in Regulatory Guide 1.82 can be used to evaluate the effects from debris generation, transport, and deposition. Regulatory Guide 1.82 does not include a quantitative or qualitative assessment of uncertainties, relying rather on recommendations that analysts should use models, analyses, and assumptions that are either "bounding" or "conservative" for the particular application.

Selective assessment of uncertainties in only the LOCA frequencies and for only a detailed evaluation is not consistent with the guidance in NUREG-1855 or the principles of risk-informed decision making in Regulatory Guide 1.174. Even if the inherent uncertainties are not evaluated quantitatively for each element of the scenario analyses, qualitative assessments can provide important information about the amount of conservatism in the nominal analyses and the available margins to regulatory acceptance criteria. The staff should clarify expectations for the assessment of uncertainties in the detailed and simplified evaluations, with particular attention to how uncertainties about debris generation, transport, and deposition on strainers and downstream coolant flow paths are used to support the risk-informed conclusions.

Use and Updates of the "Base PRA"

Under either the detailed or simplified approach, the analysis defines a "base PRA" that is used to evaluate the risk from a "clean" plant. If a detailed evaluation is performed, the guidance indicates that it may be necessary to modify the base PRA models to appropriately account for specific equipment operating configurations that are not differentiated in those models. For example, it may be important to know which particular combinations of injection pumps and containment spray pumps are running, because the plant-specific containment geometry may affect the amount of debris that is delivered to the sump screens, the rate of that delivery, and the consequences if one or more screens are clogged for each equipment combination. Those effects will also vary, depending on the location of the debris release. Furthermore, the most limiting flow configurations may be different for evaluations of core damage and containment failure. The guidance for a detailed evaluation appropriately alerts analysts to these considerations and staff expectations.

The guidance indicates that no changes to the base PRA are needed for a simplified evaluation. It is noted only that the evaluation should account for initiating events that can mobilize debris, scenarios that can transport the debris to the screens, and comparisons between the amount of deposited debris and the acceptable debris loads determined by testing. In particular, the guidance neither explicitly recommends that these analyses should be performed for the most limiting configurations of operating equipment, nor provides expectations for methods to define the appropriate flow scenarios for each release location. The staff indicated that those conditions may be inferred from the methods and guidance in Regulatory Guide 1.82. Because Regulatory Guide 1.229 provides the framework and technical context for these risk-informed evaluations, the guidance in this document should clarify how the existing base PRA models or other techniques should be used to define the most limiting equipment operating configurations and flow scenarios for each debris release, accounting for how these scenarios affect core cooling and containment protection.

The guidance does not recommend that the base PRA models should be updated to account for the risk from scenarios that deposit sufficient debris to prevent long-term core cooling. If an applicant successfully demonstrates that the incremental risk from these scenarios is acceptable for this risk-informed regulatory decision and no further action is needed, the PRA models should subsequently account for that risk consistently with the as-operated plant configuration. The supporting analyses for these evaluations may contain substantial conservatism. However, it is normal practice to use simplified models, methods, or assumptions to provide assurance that a PRA contains a complete evaluation of many other contributors that are similarly not significant to overall plant risk. The staff should clarify that the post-assessment PRA models should be updated to include the risk from debris-related scenarios consistently with the scope and level of detail applied in these analyses.

Partitioning of LOCA Frequencies

The guidance in Section C.2.b and Appendix C recommends that the plant-wide LOCA frequencies should be derived from the arithmetic mean aggregation results in NUREG-1829. The summary LOCA frequency estimates in NUREG-1829 are derived from a geometric mean aggregation method. The arithmetic mean aggregation method was examined as one of several sensitivity analyses in that report. It provides estimated LOCA frequencies that are higher than those derived from the geometric mean aggregation method, especially for larger break sizes. In our December 20, 2007 letter report on NUREG-1829, we recommended that regulatory decisions should be based on the totality of the results from the sensitivity studies, rather than the results from individual methods of expert judgment aggregation.

Appendix C contains guidance for a "bounding approach" to partition plant-wide LOCA frequencies among break sizes and locations that may generate sufficient amounts of debris to obstruct sump strainers or prevent adequate flow of cooling water through the reactor core. An earlier version of Appendix C described two additional methods with successive refinements for partitioning the LOCA frequencies. The staff noted that concerns about specific elements of those methods require further consideration before they can be included in the regulatory guidance. Those options would provide acceptable methods for applicants to further refine their analyses without the need for focused staff reviews of plant-specific modifications to the recommended "bounding approach." We were informed that the staff is evaluating improvements to address the concerns with each method, and they plan to issue a revision to Appendix C when concurrence is reached. We look forward to continuing our interactions with the staff as the LOCA partitioning methods are refined and improved guidance is developed for treatment of uncertainties associated with the various expert aggregation methods in NUREG-1829.

Sincerely,

/RA/

Dennis C. Bley
Chairman

REFERENCES

1. U.S. Nuclear Regulatory Commission, Draft Regulatory Guide 1.229, "Risk-Informed Approach for Addressing the Effects of Debris on Post-Accident Long-Term Core Cooling," March 3, 2016 (ML16062A015).

2. U.S. Nuclear Regulatory Commission, Preliminary Draft Regulatory Guide 1.229, "Risk-Informed Approach for Addressing the Effects of Debris on Post-Accident Long-Term Core Cooling," October 19, 2015 (ML15292A012).

3. Advisory Committee on Reactor Safeguards, "Draft Final Rule 10 CFR 50.46c, 'Emergency Core Cooling System Performance during Loss-of-Coolant Accidents (LOCA)' and Associated Regulatory Guides," February 23, 2016 (ML16048A522).

4. U.S. Nuclear Regulatory Commission, Regulatory Guide 1.174, “An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant-Specific Changes to the Licensing Basis,” Revision 2, May 2011 (ML100910006).

5. U.S. Nuclear Regulatory Commission, NUREG-1855, “Guidance on the Treatment of Uncertainties Associated with PRAs in Risk-Informed Decisionmaking,” Revision 1, Pre-Publication, April 10, 2015 (ML15026A512).

6. U.S. Nuclear Regulatory Commission, Regulatory Guide 1.82, “Water Sources for Long-Term Recirculation Cooling Following a Loss-of-Coolant Accident,” Revision 4, March 2012 (ML111330278).

7. U.S. Nuclear Regulatory Commission, NUREG-1829, “Estimating Loss-of-Coolant Accident (LOCA) Frequencies Through the Elicitation Process,” Volumes 1 and 2, April 2008 (ML080630013, ML081060300).

8. Advisory Committee on Reactor Safeguards, “Draft Final NUREG-1829, 'Estimating Loss-of-Coolant Accident (LOCA) Frequencies Through the Elicitation Process,' and Draft NUREG-XXXX, 'Seismic Considerations for the Transition Break Size',” December 20, 2007 (ML073440143).

9. U.S. Nuclear Regulatory Commission, Federal Register Notice, “Performance-Based Emergency Core Cooling System Requirements And Related Fuel Cladding Acceptance Criteria,” January 19, 2016 (ML16005A128).

10. U.S. Nuclear Regulatory Commission, Preliminary Draft, "Draft Appendix C – Partitioning Plant-Wide LOCA Frequency," October 19, 2015 (ML15292A010).

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9. U.S. Nuclear Regulatory Commission, Federal Register Notice, “Performance-Based Emergency Core Cooling System Requirements And Related Fuel Cladding Acceptance Criteria,” January 19, 2016 (ML16005A128).

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