March 4, 2004

Mr. Antony Pietrangelo
Nuclear Energy Institute
1776 I Street, NW
Suite 400
Washington, DC 20006-3708

SUBJECT: NUCLEAR ENERGY INSTITUTE'S PROPOSALS FOR DETERMINING LIMITING PIPE BREAK SIZE USED IN ASSESSING DEBRIS GENERATION FOLLOWING A DESIGN BASIS LOCA (TAC NO. MC1154)

Dear Mr. Pietrangelo:

By letters dated October 4, 2002, April 8, 2003, and October 10, 2003, you submitted two proposals. In the first proposal, the Nuclear Energy Institute (NEI) stated that local debris generation due to the dynamic effects associated with the postulated double ended guillotine break (DEGB) of leak-before-break (LBB) approved piping be excluded from facility design and licensing bases through the modification of a regulatory guide. In the second proposal, NEI recommended taking the crack opening area associated with the LBB "leakage flaw" size and multiplying it by a factor of 1000 in order to determine an effective "breach size" which would be applied as a circular hole of a given diameter in the primary system piping. After careful review, the Nuclear Regulatory Commission (NRC) staff has concluded that the NEI proposals are not acceptable for the purpose of defining the spectrum of break sizes for debris generation and containment sump strainer performance. The basis for this finding is documented in the enclosed Safety Evaluation.

Although the NRC staff does not endorse proposals submitted by NEI for use of LBB or fracture mechanics, the NRC staff plans to discuss, in public meetings, the use of current or planned work to risk-inform Title 10, *Code of Federal Regulations* Section 50.46, "Acceptance criteria for emergency core cooling system for light-water nuclear power reactors," as a suitable technical basis for defining a spectrum of break sizes for debris generation and containment sump strainer performance.

If you have any questions regarding this letter, please contact, Michael Marshall, 301-415-2734.

Sincerely,

/RA/

Suzanne C. Black, Director
Division of Systems and Safety Analysis
Office of Nuclear Reactor Regulation

Enclosures: As stated

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OFFICE OF NUCLEAR REACTOR REGULATION
MATERIALS AND CHEMICAL ENGINEERING BRANCH
EVALUATION OF NUCLEAR ENERGY INSTITUTE PROPOSALS RELATED TO SPECTRUM OF POSTULATED BREAK SIZES TO BE USED TO ADDRESS DEBRIS GENERATION AND PRESSURIZED WATER REACTOR SUMP PERFORMANCE

1.0 Introduction and Background

The Nuclear Regulatory Commission (NRC) staff has been working for several years to address issues related to pressurized water reactor (PWR) containment sump performance during loss-of-coolant accident (LOCA) scenarios. The U. S. NRC staff's efforts to better understand debris generation, debris transport, and the effect of debris on containment sump strainer blockage and loss of emergency core cooling system (ECCS) pump net positive suction head have been the focus of NRC Generic Safety Issue (GSI) 191, "PWR Sump Performance." Through the GSI-191 process and interactions with the U.S. nuclear industry the NRC staff revised Regulatory Guide (RG) 1.82, "Water Sources for Long-Term Recirculation Cooling Following a Loss-of-Coolant Accident" and define appropriate containment sump strainer performance goals.

An important part of this work has been to define the spectrum of primary system failures, and their associated consequences, which should be considered when evaluating the potential for debris generation. Consistent with the basis for Title 10 of the Code of Federal Regulations Part 50 Section 46 (10 CFR 50.46), "Acceptance criteria for emergency core cooling systems for light-water nuclear power reactors," the NRC staff initially considered the spectrum of primary system failures for debris generation to include break sizes up to the double-ended guillotine break (DEGB) of the largest diameter primary system piping, with guidance on the evaluation of debris generated from these breaks given in RG 1.82. Subsequently, the Nuclear Energy Institute (NEI) proposed by letters dated October 4, 2002, April 10, 2003, and October 10, 2003, alternative bases upon which to define the spectrum of break sizes and their associated consequences for the purpose of evaluating debris generation.

A substantial element of the NEI proposals and NRC staff evaluation concerns 10 CFR Part 50, Appendix A, General Design Criterion 4 (GDC-4). In the 2003 Edition of the Code of Federal Regulations, GDC-4 reads as follows:

> Structures, systems, and components important to safety shall be designed to accommodate the effects of and to be compatible with the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents, including loss-of-coolant accidents. These structures, systems, and components shall be appropriately protected against dynamic effects, including the effects of missiles, pipe whipping, and discharging fluids, that may result from equipment failures and from events and conditions outside the nuclear power unit. However, the dynamic effects associated with postulated pipe ruptures in nuclear power units may be excluded from the design basis when analyses reviewed and approved by the Commission demonstrate that the probability of fluid system piping rupture is extremely low under conditions consistent with the design basis for the piping.

The last sentence in the excerpt above was introduced into GDC-4 in 1987 [Reference 1], and represents the broadening of similar language introduced in 1986 [Reference 2] which only addressed PWR primary coolant loop piping. In the Statements of Consideration for the proposed and final rules which modified GDC-4 in 1986 and 1987, the phrase, "...when analyses reviewed and approved by the Commission demonstrate that the probability of fluid system piping rupture is extremely low under conditions consistent with the design basis for the piping," was coupled with the analyses and acceptance criteria specified in Reference 3. Analyses consistent with NUREG-1061, Volume 3 (and the subsequent Reference 4) are known as Leak-Before-Break (LBB) analyses.

The principle elements of an acceptable LBB analysis, consistent with the guidance in References 3 and 4, may be concisely summarized as follows. First, a piping system may be demonstrated to be a candidate for LBB approval by an evaluation which shows that it is not particularly susceptible to failure due to the effects of corrosion (including stress corrosion cracking), erosion, water hammer, creep damage, or low and high cycle fatigue. Piping systems which are particularly susceptible to degradation mechanisms such as stress corrosion cracking may be considered as candidates for LBB approval provided that two mitigative methods have been applied to the piping system to address the potential degradation mechanism.

Once a piping system is determined to be a candidate for LBB approval, two circumferential through-wall flaw sizes are established for the most limiting location (i.e., the location having the worst combination of high stresses and low material toughness properties) in the piping system. The first, known as the "leakage flaw" size, is the flaw which under normal operating conditions would leak at a rate 10 times greater than the established sensitivity of the facility's leakage detection system. The second, known as the "critical flaw" size, is the smallest through-wall flaw which would lead to a DEGB of the piping system under the most limiting design basis loading event (usually a safe shutdown earthquake). If an acceptable margin exists (usually a factor of 2) between the length of the leakage flaw and the length of the critical flaw, the piping is determined to have passed the criteria for LBB approval.

2.0 Nuclear Energy Institute Proposals

In NEI's October 4, 2002 letter, NEI recommended that the potential for debris generation should be limited by crediting approved LBB analyses granted to licensees in the context of 10 CFR Part 50, Appendix A, GDC-4. Specifically, NEI requested that local debris generation due to the dynamic effects associated with the postulated DEGB of LBB approved piping be excluded from facility design and licensing bases. NEI recommended that the following paragraph be included in RG 1.82 to address this concept:

> Consistent with the requirements of 10 CFR 50.46, debris generation should be calculated for a number of postulated LOCAs of different sizes, locations, and other properties sufficient to provide assurance that the most severe postulated LOCAs are addressed. In accordance with GDC-4, dynamic effects associated with postulated pipe ruptures (including local debris generation) may be excluded from the design basis when analyses reviewed and approved by the Commission demonstrate that the probability of fluid system piping rupture is extremely low under conditions consistent with the design basis for the piping.

The October 4, 2002 NEI letter also notes that an equivalent proposal had been addressed with the NRC staff in a letter from the Westinghouse Owners Group (WOG) dated November 25, 1997 [Reference 5]. The NRC responded to the WOG letter on June 9, 2000, [Reference 6] and declined the WOG proposal.

In NEI's April 8, 2003 letter, NEI proposed what it termed a "fracture mechanics approach" for high-quality large bore piping to identify a conservative "breach size" for use in evaluating "debris that is generated by the LOCA and is transported by blowdown forces (e.g., insulation, paint)." In this case, "large bore piping" appears to refer mainly to the primary coolant loop piping in Westinghouse, Combustion Engineering, and Babcock and Wilcox designed PWRs. As stated in the technical basis paper which described NEI's proposal, "...[t]he fracture mechanics techniques described in the current document are the same techniques that have been used successfully in the demonstration of Leak-Before-Break (LBB) and the application of LBB to postulated leakage cracks in large reactor coolant piping in PWRs." In summary, the NEI proposal recommended taking the crack opening area associated with the LBB "leakage flaw" size (as defined in Section 1.0 above) and multiplying it by an arbitrary factor of 1000 in order to determine an effective "breach size" which would be applied as a circular hole of a given diameter in the primary system piping. The maximum pipe breach areas for use in evaluating debris generation for each of the PWR nuclear steam supply system (NSSS) designs were given in the NEI technical basis paper as:

NSSS Design	Breach Area	Equivalent Circular Hole (Diameter)
Babcock and Wilcox	83 sq. in.	10.28 inches
Combustion Engineering	40 sq. in.	7.10 inches
Westinghouse	40 sq. in.	7.10 inches

In NEI's October 10, 2003 letter, NEI summarizes both of the proposals from its October 4, 2002 and April 8, 2003 letters. In addition, according to the technical basis report submitted with NEI's October 10, 2003 letter, NEI appears to propose to generalize the fracture mechanics approach to make it applicable to "...all high-energy RCS [reactor coolant system] piping."

3.0 NRC Staff Evaluation

3.1 LBB Proposal

The NRC staff first evaluated the proposal by NEI to extend the use of LBB to exclude local debris generation associated with the postulated rupture of LBB approved piping systems. NEI provided an extensive regulatory analysis based upon both the wording of GDC-4 and References 1 and 7 of the NRC staff's intent when GDC-4 was modified to include consideration of LBB. NEI argues that local debris generation due to the dynamic effects associated with a postulated pipe rupture is already encompassed within the scope of issues addressed by the "Leak-Before-Break clause" in GDC-4.

The NRC staff's position regarding the application of LBB toward the issue of local debris generation was addressed in Reference 6 and has not changed. The NRC staff does not dispute the point made by NEI that the generation of debris due to jet impingement, generation of acoustic/rarefaction waves, etc., could be logically considered to be a dynamic effect associated with the postulated pipe rupture. However, although the words in References 1 and 7 may be interpreted in such a way as to make the language of GDC-4 applicable to LOCA-generated debris, this "application" of LBB was not considered by the NRC staff at the time the changes to GDC-4 were enacted. The NRC staff's intent when GDC-4 was modified can best be summarized by a statement from Reference 1, the Statements of Consideration accompanying the final rule modifying GDC-4:

> The Commission recognizes the need to address whether and to what extent leak-before-break analysis techniques may be used to modify present requirements relating to other features of facility design. However, this is a longer term evaluation. For the present, the proposed rule allows the removal of plant hardware which it is believed negatively affects plant performance, while not affecting emergency core cooling systems, containments, and environmental qualification of mechanical and electrical equipment.

The end result of the NEI proposal to extend LBB to cover local debris generation would not have the effect of justifying "the removal of plant hardware which it is believed negatively affects plant performance." Rather, the NEI proposal asks the NRC staff to limit facility design bases in such a way as to potentially obviate the need for licensees to make modifications to PWR containment sumps which may otherwise be necessary if local debris generation due to the postulated failure of LBB piping were included. This could lead to a condition where common mode failure of ECCS pumps would likely occur due to debris accumulation on the sump screen if a DEGB of a LBB approved line were to occur in service. It is the NRC staff position that although an acceptable LBB evaluation provides assurance with regard to the low probability of piping failure, it is consistent with the Commission's defense-in-depth principle, given the consequences of sump failure, to expect containment sump operability under such circumstances. Thus, the NRC staff concludes that any decision to extend LBB for the purpose of addressing LOCA-generated debris and sump performance to the detriment of defense-in-depth principles is, at a minimum, a policy decision which would require Commission approval.

In addition to requiring a policy change that the Commission would have to approve, a significant technical issue also exists with respect to extending the application of LBB technology for the purpose of addressing local debris generation. Since the fall of 2000, operational experience has suggested that piping butt welds made from Alloy 82/182 material may be susceptible to primary water stress corrosion cracking (PWSCC). Domestic experience with this phenomena was observed at the Virgil C. Summer facility as documented in References 8, 9, and 10. At this time, the NRC staff must consider PWSCC to be a potentially active degradation mechanism in all PWR primary piping systems which contain 82/182 butt welds. This would include a significant fraction of the large bore PWR piping systems which were previously approved for LBB. Piping systems which are known to be potentially susceptible to degradation mechanisms such as PWSCC would not be considered as candidate piping systems for LBB approval unless steps had been taken to apply two mitigative methods to address the potential degradation mechanism. The NRC staff is not aware of actions which

have been taken by the U.S. nuclear industry to address this inconsistency between the basis upon which the NRC originally granted LBB approvals to the majority of PWR licensees and our current understanding of the susceptibility of many of these systems to PWSCC.

Therefore, until such time as the NRC staff and the U.S. nuclear industry can resolve the impact of PWSCC of Alloy 82/182 piping butt welds on existing LBB approvals, the NRC staff is reluctant to generically extend the application of LBB to modify facility licensing bases by permitting LBB to be used as the justification for eliminating local debris generation in the context of containment sump strainer analyses.

3.2 Fracture Mechanics Proposal

A limited "technical" basis was provided for this proposal in NEI's letters dated April 8, 2003, and October 10, 2003. Inasmuch as NEI's "fracture mechanics analysis" proposal is linked to LBB analysis procedures, it suffers from the same weakness as LBB with respect to the question of PWSCC of Alloy 82/182 butt welds. Without an adequate degree of assurance that large, part through-wall circumferential flaws cannot exist, there is little or no basis for taking the LBB "leakage flaw" size as a meaningful starting point for determining an "effective" pipe rupture.

3.3 Recent Commission Policies

The NRC staff would note that information from the Commission regarding the 50.46 Option 3 effort would also seem to weigh against NEI's proposal to permit licensees to completely dismiss certain break sizes/locations from the evaluation of local debris generation based on either NEI's proposed LBB or "fracture mechanics approach." In Reference 13, the Commission states:

> The staff must establish the appropriate risk "cutoff" for defining the maximum LOCA size. The risk metric recommended by the staff should take into account the uncertainties in the PRA analysis as well as the uncertainties in estimating the initiating event frequencies for rare events (e.g., 95% probability with a 95% confidence limit).
>
> In parallel with the above technical work, the staff should prepare a proposed rule change to 10 CFR Part 50 that allows for a risk-informed alternative to the present maximum LOCA break size. The rule should be very specific, ensuring that the pertinent risk parameters are addressed and only the non-significant contributions to risk are handled through severe accident risk management.
>
> While pertinent changes in the design basis and associated analysis would be expected to occur naturally, the Commission agrees with the staff that changes in hardware and operation "...would require that it be demonstrated that the ECCS functional reliability is commensurate with the frequency of accidents in which ECCS success would prevent core damage or a large early release." The Commission does not support changes to functional requirements unless they are fully risk-informed and protective of public health and safety. For example, the Commission would not support actual changes to ECCS coolant flow rates or

containment capabilities to mitigate accidents, but would support changes that provide for risk-informed sequencing of equipment with demonstrated functionality and reliability requirements that arise from the alternate criteria.

It is the NRC staff's understanding that the Commission makes two points above which are pertinent to the NEI proposals. First, the Commission appears to state that even those LOCAs which may be determined through 50.46 Option 3 analyses to be non-significant contributors to overall plant risk must be handled through severe accident risk management guidelines. Second, the Commission notes that it does not support use of results of the 50.46 Option 3 effort to make actual changes to ECCS coolant flow rates or containment capabilities to mitigate accidents.

If the NRC staff agreed with the NEI proposals and limited the spectrum of break sizes which licensees were required to consider when evaluating local debris generation, the likely end result would be that many facilities' containment sumps would not end up having the ability to support long-term cooling of the reactor core in the event of a DEGB of the largest lines in the RCS. Even if the DEGB of the largest lines in the RCS was considered to be an extremely low probability event, it is the NRC staff's understanding that the Commission's expectation is that facilities will maintain some capability to mitigate such an event, consistent with severe accident management guidelines. That is, no matter whether the most severe failures of the RCS are considered to be "design basis events" or "severe accidents," there would still be a need for licensees to have designed their containment sumps in such a way as to be effective and reliable at performing their safety-related function under such circumstances.

4.0 Conclusion

The NRC staff has concluded that the NEI proposals do not provide an adequate basis, consistent with NRC policy, upon which to define the spectrum of break sizes for debris generation and containment sump strainer performance.

5.0 References

1. Federal Register Volume 52, page 41288, "Modification of General Design Criterion 4 Requirements for Protection Against Dynamic Effects of Postulated Pipe Ruptures," October 27, 1987.

2. Federal Register Volume 51, page 12502, "Modification of General Design Criterion 4 Requirements for Protection Against Dynamic Effects of Postulated Pipe Ruptures," April 11, 1986.

3. NUREG-1061, Volume 3, "Report of the U.S. Nuclear Regulatory Commission Piping Review Committee," November 1984.

4. Federal Register Volume 52, page 32626, "Standard Review Plan; Public Comment Solicited," (3.6.3 Leak-Before-Break Evaluation Procedures), August 28, 1987.

5. Letter from Thomas V. Greene, Chairman, Westinghouse Owners Group, to Office of Nuclear Reactor Regulation, "Request for the Application of Leak Before Break (LBB) in Response to Draft Generic Letter: Potential for Degradation of the Emergency Core

Cooling and Containment Spray Systems Following a Loss of Coolant Accident due to Construction and Protective Coating Deficiencies and Foreign Material in the Containment," November 25, 1997.

6. Letter from Stuart A. Richards, Director, Project Directorate IV and Decommissioning, to Karl Jacobs, Westinghouse Owners Group, "Request for Application of Leak Before Break in Response to Draft Generic Letter, 'Potential for Degradation of the Emergency Core Cooling and Containment Spray Systems Following A Loss-Of-Coolant Accident Due to Construction and Protective Coatings Deficiencies and Foreign Material in the Containment'," June 9, 2000.

7. Federal Register Volume 53, page 11311, "Leak-Before-Break Technology; Solicitation of Public Comment on Additional Applications," April 6, 1988.

8. NRC Information Notice 2000-17, "Crack in Weld Area of Reactor Coolant System Hot Leg Piping at V. C. Summer," October 18, 2000.

9. NRC Information Notice 2000-17, Supplement 1, "Crack in Weld Area of Reactor Coolant System Hot Leg Piping at V. C. Summer," November 16, 2000.

10. NRC Information Notice 2000-17, Supplement 2, "Crack in Weld Area of Reactor Coolant System Hot Leg Piping at V. C. Summer," February 28, 2001.

11. Materials Reliability Project Draft Report, "PWR Materials Reliability Project Interim Alloy 600 Safety Assessment fo US PWR Plants (MRP-44), Part 1: Alloy 82/182 Pipe Butt Welds ," April 2001.

12. Letter from Brian W. Sheron, Associate Director for Project Licensing and Technical Analysis, Office of Nuclear Reactor Regulation to Alex Marion, Nuclear Energy Institute, "Staff Findings Regarding 'PWR Materials Reliability Project Interim Alloy 600 Safety Assessment for US PWR Plants (MRP-44), Part 1: Alloy 82/182 Pipe Butt Welds," June 14, 2001.

13. Memorandum from Annette L. Vietti-Cook to William D. Travers, "Staff Requirements - SECY-02-0057 - Update to SECY-01-0133, "Fourth Status Report on Study of Risk-Informed Changes to the Technical Requirements of 10 CFR Part 50 (Option 3) and Recommendations on Risk-Informed Changes to 10 CFR 50.46 (ECCS Acceptance Criteria)," March 31, 2003.