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Mr. Gary M. Holahan
Director, Division of Systems Safety and Analysis
Office of Nuclear Reactor Regulation
Mail Stop O10-A1
U. S. Nuclear Regulatory Commission
Washington, DC 20555-0001

SUBJECT: Application of Leak-Before-Break Technology to Pipe Break Debris Generation and Request for Public Comment Opportunity

PROJECT NUMBER: 689

Dear Mr. Holahan:

At an August 29, 2002, meeting, NRC staff identified plans to issue for public comment, a draft revision to Regulatory Guide 1.82, *Water Sources for Long-Term Recirculation Cooling Following a Loss-of-Coolant Accident*.

This regulatory guide provides guidance for evaluating the adequacy of the sumps and suppression pools for long-term recirculation cooling following a loss-of-coolant accident (LOCA). It is being revised to alter debris blockage evaluation guidance for pressurized water reactors as part of the NRC resolution of GSI-191, *Assessment of Debris Accumulation on PWR Sump Performance*.

NEI and the PWR Owners Groups are currently developing a methodology for use by PWR plants in addressing GSI-191 concerns. We intend to actively participate in the public comment phase of the regulatory guide revision process because of the strong overlap between the methodology being developed by the industry and the guidance expected to be included in the draft regulatory guide.

One topic that we expect to address in our comments is the treatment of LOCA-generated debris as a local dynamic effect under the leak-before-break (LBB) provisions of GDC-4. This topic has been discussed before and was most recently addressed by NRC in response to a November 25, 1997, Westinghouse Owners Group (WOG) letter. In a June 9, 2000, response to the letter (Richards to Jacobs), NRC declined a WOG request to incorporate LBB technology by concluding that:

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> *"…although the words in the Statements of Consideration for GDC 4 (cited in your letter) may be interpreted to be applicable to LOCA-generated debris, it was clearly not the intent of the current rule to do this. The intent of the rule change was to allow the removal of numerous pipe whip restraints and jet impingement barriers, which were believed to negatively affect plant performance and safety while not affecting emergency core cooling systems, containments, or environmental qualification. The application of LBB technology to regulations other than GDC 4 was not evaluated during the rule change, and the public was not given the opportunity to comment on your proposed application of LBB. Therefore, we believe that a rulemaking would be required to extend LBB to other regulations as you requested. However, we note that there are other activities that could result in an outcome similar to the changes you are seeking."*

We do not agree with this interpretation. Our review of existing regulations and associated Statements of Consideration concludes that debris generation, as a result of break jet expansion and impingement forces, is a dynamic effect uniquely associated with pipe rupture and, as such, is appropriately encompassed within the scope of the revised GDC-4.

The NRC response stated that "*the application of LBB technology to regulations other than GDC-4 was not evaluated during the rule change…*" We believe that the GDC-4 rule change did evaluate the impact of the change on other regulations and acknowledged that exclusion of local dynamic effects can impact the design basis of ECCS hardware. As stated in 53 FR 11311,

> "*…local dynamic effects uniquely associated with pipe rupture may be deleted from the design basis of containment systems, structures and boundaries, <u>from the design basis of ECCS hardware</u> (such as pumps, valves, accumulators, and instrumentation), and from the design bases of safety related electrical and mechanical equipment when leak-before-break is accepted*" (emphasis added).

The Federal Register Notice also stated that

> *"… while functional and performance requirements for containment, ECCS, and EQ remain unchanged under the now effective modification of GDC-4, the design bases for these aspects of facility design have been modified in that local dynamic effects uniquely associated with ruptures in piping which qualified for leak-before-break may be excluded from consideration."*

Very simply stated, the functional and performance requirements for containment, ECCS and EQ that were retained with the modification of GDC-4, explicitly

excludes local dynamic effects associated with ruptures in LBB piping. Debris generation effects that are uniquely associated with ruptures in piping that is LBB qualified should be excluded from the design bases for containment, ECCS and EQ. The enclosed discussion paper provides a more detailed explanation of industry's position.

Because LOCA-generated debris is a local dynamic effect explicitly addressed in the revision to GDC-4, further rulemaking is not necessary to incorporate debris generation into the LBB provisions of GDC-4.

To be consistent with GDC-4, the draft revision to Regulatory Guide 1.82 should incorporate language that acknowledges treatment of debris generation under the LBB provisions of GDC-4. We recommend that the following paragraph be included in the draft revision to the regulatory guide to address debris generation and sources:

> "*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.*"

To provide an opportunity for public comment on this topic, we recommend that the Federal Register notice associated with the draft Regulatory Guide include a specific request for comment on the inclusion of debris generation as a local dynamic effect covered under GDC-4.

The NRC response to the WOG letter identified "*other activities that could result in an outcome similar to the changes you are seeking*." The initiatives referred to in the response will have an impact that is similar to, and the basis for these initiatives supports, the GDC-4 interpretation we seek. However, these initiatives are much broader in their scope and impact and the schedule for their completion is uncertain.

Resolution of GSI-191 on a plant-specific basis could lead to significant and costly changes to the designs for some PWRs. Therefore, it is prudent, as part of the GSI 191 resolution process, to take into account the underlying safety basis of regulatory initiatives that have the potential to obviate the need for some of these design changes. We believe the proper interpretation of GDC-4 to allow

consideration of debris generation as a local dynamic effect accomplishes this. It is important to expeditiously resolve the debris generation portion of GSI-191 in the manner we propose without tying resolution to broader regulatory initiatives.

In summary, we believe that the appropriate interpretation of GDC-4 should be addressed as part of the revision to Regulatory Guide 1.82. GDC-4 supports the requested interpretation and a revision to current rule language is not required. The inclusion of LBB considerations as part of the broader revision to RG 1.82 and resolution of GSI-191 provides assurance that plant safety will be maintained.

The enclosed discussion paper provides additional information on the basis for our requests. Please contact John Butler 202-739-8108, jcb@nei.org, or me if you have any questions on this transmittal.

Sincerely,

Alexander Marion

JCB/maa
Enclosure

c: Mr. John N. Hannon, U. S. Nuclear Regulatory Commission
Mr. Bhagwat P. Jain, U. S. Nuclear Regulatory Commission
Mr. Ralph E. Architzel, U. S. Nuclear Regulatory Commission
Mr. John Lehning, III, U. S. Nuclear Regulatory Commission
Mr. John G. Lamb, U. S. Nuclear Regulatory Commission

Enclosure

Discussion Paper
Application of LBB Technology
to PWR Pipe Break Debris Generation

1. Background

1.1 GDC-4 Revision

In October 1987, General Design Criterion (GDC) 4 in Appendix A to 10 C.F.R. Part 50 was revised to allow the use of leak-before-break technology. Specifically:

> *"**Criterion 4 - Environmental and dynamic effects design bases**. 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, 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."*
> [emphasis added]

The supplementary information section of the Federal Register notice (52 FR 41288) states that the dynamic effects covered by the rule are missile generation, pipe whipping, pipe-break reaction forces, jet impingement forces, decompression waves within the ruptured pipe and dynamic or non-static pressurization in cavities, subcompartments and compartments. But, cavities, subcompartments and compartments necessary to the containment function are not affected by the rule change.

To retain high safety margins, the Federal Register notice states that the application of leak-before-break technology to various piping systems should not decrease the capability of containments to perform their function of isolating the outside environment from potential leaks, breaks, or malfunctions within containment. Containments were designed to accommodate LOCAs resulting from breaks in the reactor coolant system pressure boundary up to and including a break equivalent in size to the double-ended rupture of the largest pipe in the reactor coolant system. Also, the functional design for emergency core cooling systems still retains non-mechanistic pipe rupture.

The Federal Register notice further states:

> *"This rulemaking will introduce an inconsistency into the design basis by excluding the dynamic effects of postulated pipe ruptures while still retaining the nonmechanistic pipe rupture for emergency core cooling systems, containments, and environmental qualification…"*

1.2 Proposed Rulemaking to Extend LBB Applications

In April of 1988, to address the inconsistency introduced by the 1987 modification to GDC-4, the NRC requested public comments (53 FR 11311) on potential additional applications of leak-before-break technology to modifying functional and performance requirements for emergency core cooling systems and for environmental qualification of safety related electrical and mechanical equipment. Modification of functional and performance requirements for containments was explicitly excluded from consideration as part of the Federal Register notice.

In the supplementary information section of the Federal Register notice, the NRC provided a clarification on the specific functional and performance requirements retained when leak-before-break was accepted under the 1987 modification to GDC-4:

1. *For Containments. Global loads and environments associated with postulated pipe ruptures, including pressurization, internal flooding, and elevated temperatures.*
2. *For ECCS. Heat removal and mass replacement capacity needed because of postulated pipe ruptures.*
3. *For EQ. Pressure, temperature, flooding level, humidity, chemical environment, and radiation resulting from postulated pipe ruptures.*

In SECY-88-325 (November 22, 1988) the NRC staff addressed public comments on extending LBB applicability to ECCS and EQ functional and performance requirements. In this SECY, the staff recommended that no rulemaking be undertaken to apply LBB to either environmental qualification or ECCS. The reason cited was that safety benefits for ECCS could be more readily obtained under the recently revised ECCS rule, which enabled the use of best estimate LOCA methodologies. Also, the GDC-4 final rule already permitted the use of exemptions for EQ, which the NRC felt had not been utilized by the industry. The Commission, in an April 13, 1989, SRM, approved the NRC staff position.

2 Discussion Points

The application of LBB as a consideration in debris generation would have a significant impact on ongoing PWR sump performance evaluations. Its application would allow resources to be focused on more risk-significant aspects of PWR sump performance by eliminating the need to address local debris generation characteristics for LBB qualified piping. In doing so, it is anticipated that resolutions for and closure of PWR sump performance issues can be expedited for all PWRs.

The following discussion questions address key focus areas raised in prior discussion on this topic.

- Is debris generation within the zone of influence of a break a "local dynamic effect" covered by GDC-4?
- Does debris generation fall within the scope of functional and performance requirements retained in the GDC-4 revision?
- What is the scope of the application of LBB toward consideration of debris generation?
- Would safety be enhanced by implementing leak-before-break for LOCA-generated debris as part of the revision to Regulatory Guide 1.82?

The following sections provide a discussion on these questions.

2.1 Is debris generation within the zone of influence around a break a "local dynamic effect" covered by GDC-4?

The dynamic effects addressed by GDC-4 are delineated in the Federal Register notice that modified GDC-4 (52 FR 41288):

> *"Dynamic effects of pipe rupture covered by this rule are missile generation, pipe whipping, pipe break reaction forces, jet impingement forces, decompression waves within the ruptures pipe and dynamic or nonstatic pressurization in cavities, subcompartments and compartments."*

This is further restated in 53 FR 11311:

> *"'Local dynamic effects uniquely associated with pipe rupture' means dynamic effects due to pipe whipping, jet impingement, missiles, local pressurizations, pipe break reaction forces, and decompression waves in the intact portions of piping postulated to rupture."*

These forces are a dominant source of debris in containment following a postulated LOCA. As stated in Section 2.4 of NUREG/CR-6224, "Parametric Study of the Potential for BWR ECCS Strainer Blockage Due to LOCA Generated Debris,":

"The initial blast wave exiting a DEGB and the ensuing break jet expansion and impingement forces are the dominant contributors to insulation debris generation following a LOCA. Other contributors, such as pipe whip and pipe impact, have been studied and shown to be of secondary importance."

Conclusion

Debris generation as a result of break jet expansion, impingement forces, pipe whip and pipe impact is a "dynamic effect uniquely associated with pipe rupture" and is encompassed within the scope of GDC-4.

2.2 Does debris generation fall within the scope of functional and performance requirements for containment, ECCS and EQ that were retained in the GDC-4 revision?

In its modification of GDC-4, the NRC limited the application of LBB to local dynamic effects uniquely associated with ruptures in piping that is qualified for leak-before-break. Non-mechanistic pipe rupture was retained as a part of the functional and performance requirements for containment, ECCS and EQ.

In doing so, the NRC acknowledged that application of LBB to local dynamic effects has the potential to affect the design basis of ECCS hardware. As stated in 53 FR 11311, "*…local dynamic effects uniquely associated with pipe rupture may be deleted from the design basis of containment systems, structures and boundaries, from the design basis of ECCS hardware (such as pumps, valves, accumulators, and instrumentation), and from the design bases of safety related electrical and mechanical equipment when leak-before-break is accepted.*" (emphasis added)

The Statement of Consideration in 53 FR 11311 states:

"Thus, while functional and performance requirements for containment, ECCS, and EQ remain unchanged under the now effective modification of GDC-4, the design bases for these aspects of facility design have been modified in that local dynamic effects uniquely associated with ruptures in piping which qualified for leak-before-break may be excluded from consideration."

This clearly identifies that local dynamic effects uniquely associated with ruptures in LBB qualified piping, may be excluded by consideration, even though this exclusion may impact the design bases for containment, ECCS and EQ.

The specific functional and performance requirements retained when GDC-4 was amended are as follows (53 FR 11311):

1. *For Containments. Global loads and environments associated with postulated pipe ruptures, including pressurization, internal flooding, and elevated temperatures.*

2. *For ECCS. Heat removal and mass replacement capacity needed because of postulated pipe ruptures.*

3. *For EQ. Pressure, temperature, flooding level, humidity, chemical environment, and radiation resulting from postulated pipe ruptures.*

Containment: The supplemental information in 53 FR 11311 provides further clarification on the "containment" exclusion:

> *"Global pressurizations, temperature transients, and flooding transients on containment systems and structures are not local dynamic effects and may not be uniquely related to pipe rupture, and therefore are retained for containment design."*

Thus, evaluations of debris generation and transport potential resulting from the global pressure and temperature changes in containment following a postulated pipe rupture, along with washdown and flooding effects will continue to include the effects resulting from a full range of break sizes and locations (up to a full DEGB) and cannot consider LBB technology.

ECCS: The "ECCS" exclusion addresses the design-basis criteria, assumptions and models used in determining that the Emergency Core Cooling System (ECCS) meets applicable regulations, e.g., 10 C.F.R. 50.46. The primary impact of this exclusion is a continued need to address a full range of break sizes and locations as part of ECCS calculations (i.e., double-ended guillotine breaks must be considered). In 1988, the NRC requested public comments on the extension of LBB applications to include ECCS functional and performance requirements (53 FR 11311). In reviewing public comments (SECY-88-325), the NRC noted that extension of LBB technology to include ECCS functional and performance requirements would allow smaller pipe ruptures to be postulated but that the main benefits of this change would also be obtained under a then recent change to the ECCS rule to allow use of best estimate LOCA technology. On this basis, the exclusion of LBB technology application to ECCS functional and performance requirements was maintained.

Thus ECCS design bases must continue to consider a full range of postulated break locations and sizes even though some of the postulated break locations involve LBB qualified piping. The only exception allowed is the exclusion of local dynamic effects uniquely associated with ruptures in LBB qualified piping.

Environmental Qualification (EQ): The "EQ" exclusion provides assurance that systems, structures and components will continue to be qualified for operation in the global environment (pressure, temperature, flooding level, humidity, chemical environment, and radiation) resulting from postulated pipe ruptures up to and including full DEG breaks.

Conclusion

The functional and performance requirements for containment, ECCS and EQ that were retained with the modification of GDC-4, excludes local dynamic effects that are uniquely associated with ruptures in LBB piping. Debris generation that is uniquely associated with ruptures in piping that is LBB qualified may thus be excluded from the design bases for containment, ECCS and EQ.

2.3 What is the scope of the application of LBB toward consideration of debris generation?

Debris sources during and following a design-basis LOCA can be divided into two categories:

1. Within the zone of influence around a postulated break location, materials are subject to the local dynamic forces of the break.

   These include insulation, painted surfaces, and fibrous, cloth, plastic, or particulate materials. This category can be further subdivided based on the qualification of piping at each location:

   A) Material within the zone of influence around a break location for LBB qualified piping
   B) Material within the zone of influence around a break location for piping not qualified for LBB

2. Outside the zone of influence around a postulated break location, materials are subject to the global loads and environments associated with a break (e.g., pressurization, internal flooding, elevated temperatures and washdown).

The application of LBB in considering debris generation is limited to debris sources within the zone of influence around a postulated break location (i.e., Category 1) and will not affect sources of debris outside of the zone of influence. In addition, consideration of LBB is limited to those pipe-break locations within piping systems that meet LBB qualification requirements (Category 1A).

This means that consideration of LBB has no effect on debris-source considerations outside the zone of influence around a break (i.e., Category 2) and has no effect on debris-source considerations for break locations that do not meet LBB requirements

(Category 1B). Consideration of debris generation for these sources (Categories 1B and 2) will have to address the effects from a postulated rupture. For non-LBB pipe break locations, debris generation resulting from the initial blast wave and the ensuing break jet expansion and impingement forces for a postulated rupture must be considered. Consideration of debris sources outside of the zone of influence of a break will continue to address the global loads resulting from a range of postulated LOCAs of different sizes and locations (up to and including a double-ended guillotine break) including piping that is LBB qualified.

Conclusion
Use of LBB in considering debris generation following a design basis LOCA is limited to local dynamic effects for LBB-qualified piping systems and does not impact considerations of debris generation at non-LBB piping locations or debris generation resulting from global containment loads.

2.4 Would safety be enhanced by implementing leak-before-break for LOCA-generated debris as part of the revision to Regulatory Guide 1.82?

The ECCS recirculation designs for most PWR plants in the U.S. are based on guidance provided in Revision 0 of Regulatory Guide 1.82, *Sumps for Emergency Core Cooling and Containment Spray Systems*. This guidance accounts for screen blockage in a non-mechanistic fashion by assuming that one-half of the vertical screen area of the sump is unavailable for recirculation flow. Since the impact of LOCA-generated debris on sump blockage is not addressed directly through this approach, consideration of leak-before-break for LOCA-generated debris would have no affect on ECCS designs that utilize this guidance in their design bases.

Subsequent revisions to Regulatory Guide 1.82 (Revision 1 – November 1985, Revision 2 – May 1996) have incorporated a more mechanistic process that provides a more realistic, but conservative, estimate of the debris blockage that PWR sumps could experience following a LOCA. The revised process addresses both the amounts and types of debris that can be generated following a LOCA and specifically accounts for factors that affect the transport of debris to the containment sump and the potential for sump screen blockage. The next revision to Regulatory Guide 1.82, which is actively being developed by NRC, is expected to address these same factors.

Because leak-before-break considerations can not be addressed under the current non-mechanistic design bases of most PWR plants, it will be necessary to revise the design basis to incorporate mechanistic processes that specifically addresses debris generation, transport and sump blockage. This would then allow leak-before-break for LOCA-generated debris to be addressed as part of the process.

A design basis that incorporates a realistic, but conservative, treatment of debris generation, transport and sump blockage is expected to provide a better estimate of

the probability of sump blockage and an enhancement to plant safety compared to the non-mechanistic design bases currently in use.

Conclusion

Implementation of LBB for LOCA-generated debris in conjunction with the other sump blockage factors that must be considered as part of a revision to ECCS sump design bases would provide an enhancement to plant safety over current design bases that rely on the non-mechanistic assumptions of Regulatory Guide 1.82 Revision 0.

3 Summary

Debris generation as a result of break jet expansion, impingement forces, pipe whip and pipe impact is a "*dynamic effect uniquely associated with pipe rupture*" and is encompassed within the scope of GDC-4. Functional and performance requirements for containment, ECCS and EQ that were retained with the modification of GDC-4, exclude local dynamic effects that are uniquely associated with ruptures in LBB piping. Therefore, current regulations allow debris generation, that is uniquely associated with ruptures in piping that is LBB qualified, to be excluded from the design bases for containment, ECCS and EQ. A rulemaking is not required.

The scope of application of the "debris generation exclusion" is limited to local dynamic effects for LBB-qualified piping systems and does not impact considerations of debris generation at non-LBB piping locations or debris generation resulting from global containment loads. Implementation of LBB for LOCA-generated debris in conjunction with the other sump blockage factors that would be considered as part of a revision ECCS sump design bases would provide an enhancement to plant safety over current design bases that rely on the non-mechanistic assumptions of Regulatory Guide 1.82 Revision 0.