Nuclear Energy Institute

Reconsideration of Application of GDC-4 Exclusion of Local Dynamic Effects to Local Debris Generation

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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]

Simply stated, GDC-4 allows local dynamic effects associated with pipe ruptures in Leak-Before-Break qualified piping to be excluded from the design bases.

Since 1997, Industry has made multiple requests to consider debris generation as a dynamic effect and, as such, allow its exclusion from the design basis for addressing ECCS performance concerns under GSI-191.

While the NRC has accepted debris generation as a local dynamic effect, multiple alternative reasons have been given for rejecting the industry requests.

Reason 1: Application to LOCA-generated debris not the intent of current rule

This reason was first given in a June 2000 response [1] to a November 1997 request [2] by the PWROG and states that application of the GDC-4 exclusion for LBB piping is limited to the specific examples identified in the rule Statements of Consideration (e.g., removal of pipe whip restraints and jet impingement barriers).

June 9, 2000 Letter, Stuart Richards to Karl Jacobs:
On the basis of our review, we concluded that although the words in the Statements of Consideration for GDC-4 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.

This reason is countered by the numerous applications of the GDC-4 exclusion that extend beyond the specific changes cited above. In May 2007, NRC prepared the Leak-Before-Break Knowledge Management Document [3] to clearly describe the NRC's policy and practice on the application of LBB. This document acknowledges that application of the GDC-4 exclusion extends beyond removal of pipe whip restraints and jet impingement barriers.

LBB Knowledge Management Document, C2. Allowable licensing/design basis changes via LBB applications:
When LBB is approved for a particular piping system, applicants are to exclude from the design basis only local dynamic effects associated with postulated pipe ruptures in that system in the nuclear power unit. The local dynamic effects are:

- *Missiles,*
- *Pipe whipping,*
- *Pipe break reaction forces, and*
- *Discharging fluids.*

For each local dynamic effect listed above, the applicant, upon NRC approval, is permitted to perform a well defined plant activity as a result of excluding this dynamic effect from the design basis. The permitted plant activities are, in the order of local dynamic effects:

- *Remove jet impingement barriers or shields,*
- *Remove pipe whip restraints,*
- *Redesign pipe connected components, their supports and their internals, and other related changes, and*
- ***Disregard jet impingement forces on adjacent components [emphasis added]**, decompression waves within the intact portion of the piping system, and dynamic or nonstatic pressurization in cavities, subcompartments, and compartments*

In 2006, an Ad Hoc Review Panel was established to review a Differing Professional Opinion (DPO) pertaining to the use of LBB technology in the design of new sump strainers at Oconee Units 1 and 2 [4]. In this instance, GDC-4 was applied to exclude local dynamic effects from LBB piping that had the potential to directly affect the newly installed sump strainer replacement at Oconee. In its response to the DPO, the panel noted that neither GDC-4 nor SRP Section 3.6.3 make distinction among SSCs as to which ones could or could not have dynamic effects excluded from their design basis. The panel found that the sole determining factor for exclusion is whether or not the piping whose rupture would produce the dynamic effects has an acceptably low likelihood of rupture prior to producing a detectable indication of impending failures, i.e., leakage.

Reason 1 was also provided in the March 4, 2004 NRC response [5] to NEI requests dated October 4, 2002, April 8, 2003 and October10, 2003. This letter also introduced Reason 2.

Reason 2: Application of LBB to LOCA-generated debris is a detriment to defense-in-depth principles and would require Commission approval

March 4, 2004 Letter, Suzanne Black to Tony Pietrangelo:
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.

Every application of the GDC-4 exclusion, including the original changes cited in the rule SOCs, arguably act to the detriment to "defense-in-depth". The underlying basis given in the March 4, 2004 letter comes down to the potential degree of impact of the proposed change on "defense-in-depth". In 2004, PWRs still retained their original containment sump screen designs. As noted in the 2004 letter, approval of the LBB exclusion in 2004 could have obviated the need for modifications to PWR containment sumps. This could have represented a significant reduction in "defense-in-depth".

Since 2004, every PWR has installed significantly larger strainers, reduced debris sources, enhanced operational and emergency procedures, and has performed conservative design analyses to demonstrate the capability of the ECCS system to withstand postulated LOCAs with no credit taken for the GDC-4 exclusion.

Application of the GDC-4 exclusion today, no longer presents the potential for a significant reduction in "defense-in-depth" that was possible in 1994. As such, the NRC staff decision to require Commission approval should be, at a minimum, reevaluated.

The March 2004 letter also introduced Reason 3.

Reason 3: Primary Water Stress Corrosion Cracking (PWSCC) is a concern

March 4, 2004 Letter, Suzanne Black to Tony Pietrangelo:
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.

GDC 4 provides a clear requirement for prior approval of LBB piping systems as a condition to implementing designs that exclude the dynamic effects associated with postulated pipe ruptures. GDC 4 states that "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."

PWSCC is a generic issue potentially affecting all past and future approval of piping systems. In September 2005, the Electric Power Research Institute Materials Reliability Program issued MRP-

139, "Materials Reliability Program: Primary System Piping Butt Weld Inspection and Evaluation Guideline," [6] that all PWR plants agreed to implement under the industry's "Materials Initiatve." MRP-139 provides industry guidance for the inspections of dissimilar metal butt welds in PWR primary systems and discusses volumetric inspection techniques that the industry has qualified for the detection of PWSCC. PWR licensees are addressing the potential for PWSCC to occur in Alloy 82/182 butt welds through a rigorous program of inspecting and mitigating susceptible welds.

While PWSCC potentially affects the piping systems for which the GDC-4 exclusion can be applied, it should not be used to selectively eliminate the local dynamic effects allowed under the GDC-4 exclusion.

Reason 4: ECCS functional performance is directly affected by the containment sump performance

Reason 4 was introduced, almost as a side note, in the LBB Knowledge Document

Leak-Before-Break Knowledge Management Document (page 6)
Although one may not consider the sumps serving the ECCS and the containment spray system part of the ECCS, the ECCS functional performance is directly affected by the containment sump performance. Therefore, requiring the dynamic effects such as debris generation associated with the postulated DEGBs of LBB-approved piping be included in the sump performance evaluation is a logical extrapolation of the Section C3 limitations on LBB.

Section C3 of the LBB Knowledge Management Document (see below) covers the GDC-4 rule limitations on applying LBB to containment design, ECCS and EQ. As noted in section C3, the GDC-4 rule language and SOC allows local dynamic effects to be excluded from the design basis of ECCS hardware. The current GDC-4 rule does not support Reason 4.

Leak-Before-Break Knowledge Management Document, Section C3 (page 5)
It is apparent that there is no inconsistency if one considers that although pipe whip effects and jet impingement effects are local, their effects on containment pressure boundaries and primary structures are global. This is a good example showing that the distinction between local effects from pipe ruptures and global effects from pipe ruptures are not always clear.

Pipe rupture dynamic effects that can be excluded from an LBB applicant's plant design bases for containment, ECCS and EQ are further explained in Reference 5:

> *…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.*

Similar to Section C2 regarding allowable licensing/design basis changes in LBB applications, local dynamic effects uniquely associated with pipe rupture may be deleted from the design basis of containments, ECCS and EQ. For example, the local dynamic effects of jet impingement deleted from the design basis are not considered in the functional design of ECCS components, such as sump screens. So far, such a list of local dynamic effects or plant activities does not exist. However, considering the limited number of LBB applications related to containments, ECCS, and EQ to date, the staff has found it unnecessary to come up with the list of postulated applications. Instead, the staff will rely on fundamental principles to decide on a case-by-case basis when a proposed area of LBB application appears to be new.

References:

1. 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 Coating Deficiencies and Foreign Material in the Containment," June 9, 2000

2. 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.

3. Memorandum from Michele G. Evans, Director, Division of Component Integrity, NRC to John A. Grobe, Associate Director for Engineering and Safety Systems, NRC, "Division of Component Integrity Response, May 29, 2007

4. Memorandum from John A. Grobe to J. E. Dyer, Differing Professional Opinion Panel Response to DPO-2006-002, November 13, 2006

5. Letter from Suzanne C. Black, Director, Division of Systems and Safety Analysis, NRC to Anthony Pietrangelo, NEI, "Nuclear Energy Institute's Proposals for Determining Limiting Pipe Break Size used In Assessing Debris Generation Following a Design Basis LOCA," March 4, 2004

6. EPRI Report 1015009, "Material Reliability Program: Primary System Piping Butt Weld Inspection and Evaluation Guideline (MRP-139), December 2008