October 7, 2010

MEMORANDUM TO: William H. Ruland, Director
Division of Safety Systems
Office of Nuclear Reactor Regulation

FROM: Stewart N. Bailey, Chief **/RA/**
Safety Issue Resolution Branch
Division of Safety Systems
Office of Nuclear Reactor Regulation

SUBJECT: EVALUATION OF NEW GENERIC SAFETY ISSUE-191 RESOLUTION OPTION PROPOSED BY JAMES BEALL

In an email (enclosed) dated September 10, 2010, Jim Beall of the staff of the Division of Safety Systems described an option that he proposed be considered to resolve Generic Safety Issue (GSI)-191. His proposal combines aspects of two options discussed in SECY-10-0113 (Option 2b and Option 3). Mr. Beall's option would have the Commission agree that the jet impingement exclusion in GDC-4 encompasses debris generation and thus would not require inclusion of such debris in design basis accident (DBA) analyses (SECY Option 3). However, because of the consequences of sump strainer failure and the importance of jet impingement debris (JID) on strainer performance, under his proposal the Commission would also impose a requirement that long-term cooling capability be demonstrated for loss-of-coolant accidents (LOCAs) in leak-before-break (LBB) piping with JID included. However, the long-term cooling capability demonstration could be performed using the relaxed assumptions identified in the proposed 10 CFR 50.46(a) rule (and SECY-10-0113 Option 2b) for beyond-design-basis LOCAs.

As assigned by Office of Nuclear Reactor Regulation (NRR) management, Christopher Hott, Timothy Lupold, John Tsao, and Timothy Collins of the NRR staff met with Mr. Beall on September 14, 2010, to understand and assess the proposal. The review team noted the following:

1. The proposal would extend the flexibility afforded by Option 2b to significantly smaller break sizes since LBB piping is not legally limited to any particular size. The smallest piping that is currently LBB qualified is 6-inch pipe. The transition break size in proposed Title 10 of the *Code of Federal Regulation* (10 CFR) 50.46(a) is 14 inches. The U. S. Nuclear Regulatory Commission (NRC) has not approved any reactor cooling system pipe less than 6 inches in diameter for LBB because of limitations in applying fracture mechanics to small size pipe.

Enclosure:
As stated

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2. The proposal is inconsistent with the well vetted positions taken in the proposed 50.46(a) rulemaking. The proposal would effectively define two transition break sizes: one for evaluations of the recirculation phase, and one for the injection phase (unless the Commission changed the proposed rule to make the TBS the smallest piping size credited for LBB for both phases, which was not proposed by Mr. Beall). In addition, the proposal does not include a demonstration of "very low" risk significance as is required in the proposed 50.46(a) rule. As a result, Mr. Beall's proposal could be better described as a proposed modification to the 50.46(a) rulemaking.

3. As with other variations on the options discussed in the SECY paper, there are significant implementation questions associated with the proposal. In particular, if the proposal is implemented as stated by Mr. Beall (extending GDC-4 for JID but not capturing this in 10 CFR 50.46(a)):

    a. A backfit analysis would likely be required to support imposition of Mr. Beall's proposed new requirement for demonstration of long-term cooling capability that includes consideration of JID. That is, if the Commission concludes that the jet impingement exclusion in GDC-4 encompasses debris generation, what basis would the NRC have for requiring the additional demonstration of core cooling capability?

    b. If the backfit analysis supported the new requirement, GDC-4 would need to be revised by rulemaking.

4. Mr. Beall contended that the SECY paper did not identify a sufficient number of options for Commission consideration. However, the staff considered possible variations on each of the options provided in SECY-10-0113 but concluded that the variations did not have sufficient individual merit to justify a separate option in the SECY paper. The Commission has the flexibility to choose variations on the proposed options as it sees fit.

Discussion and Recommendation

The proposed "Option 4" is bounded by those already evaluated by the staff and discussed in the SECY paper. Specifically, Option 3 in the SECY paper would require no additional analysis if LBB credit is granted for debris generation. Option 1 in the SECY provided no credit for LBB and no credit for reduced analysis assumptions. Option 2 discussed a risk-informed option that allows credit for reduced analysis assumptions for a limited spectrum of breaks based upon the 50.46(a) rulemaking.

Mr. Beall's approach is similar to SECY Option 2b and is effectively another risk-informed alternative with the basis for the scope of application being the 1984-85 GDC-4 LBB rulemaking (the intent of which was not to risk-inform the emergency core cooling systems (ECCS) requirements). As with other variations to the currently proposed options, it has benefits and drawbacks and is not an "analysis only" solution.

The staff does not support Mr. Beall's proposal for the following reasons:

1. It would be inconsistent with the staff and ACRS thinking on risk-informing the ECCS regulations that has evolved through extensive evaluation and is represented by proposed

10 CFR 50.46(a). Specifically, it would establish a significantly smaller transition break size than is currently proposed in 50.46a and thus reduce protection for a much larger scope of LOCA initiators. The transition break size selected in the proposed 50.46a rule was established after lengthy deliberations that considered the large uncertainties associated with the expert elicitation process, operating experience that includes LBB piping and non-LBB piping, other LOCA initiators that were not included in the elicitation study, actual plant piping configurations, and the need for regulatory stability (i.e., margin so that revisions to the TBS are not likely to be needed due to future operating experience). The staff does not find new information in Mr. Beall's proposal that would warrant revisiting these evaluations.

2. Its implementation would be complex, likely requiring a new rulemaking that would extend, not accelerate, resolution of GSI-191.

The staff plans to forward Mr. Beall's proposal and this response to the Commission for information as it considers path forward on GSI-191 and 10 CFR 50.46(a). While the staff does not support taking this proposal forward, Mr. Beall's submittal of it is an example of innovative thinking that is needed to bring GSI-191 to closure.

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E-Mail from James Beall to Michael Scott – September 10, 2010
A Potential New Approach to Resolving GSI-191: "SECY-10-0113 Option 4"

Presented below are items 1 through 6 that contain historical context, address various Generic Safety Issue (GSI)-191 elements in SECY-10-0113 and elsewhere, and support the potential new approach to resolving GSI-191 presented in item 7.

1) **Leak-before-break has always accepted an absence of defense in depth**

The application of leak before break (LBB) was (in 1984) the method to resolve safety issues that included in-vessel asymmetric loadings from the massive blow-down following a double-ended guillotine break (DEGB) loss-of-coolant-accident-(LOCA). (See NUREG-1061, Vol. 3)

LBB drew from earlier work, including USN-related, that dated back into the 1970s. Among the safety issues addressed by LBB was that asymmetric in-vessel loadings had the potential to damage the internals and preclude a coolable geometry. The pipe whip restraints were not primarily to manage jet impingement, they were intended to hold the pipes in place after a rupture to prevent the "double ended" nature of the DEGB itself in the largest bore pipes and, by doing so, preclude the forces that generated the postulated asymmetrical loading values. Thus, the LBB-justified removal of pipe whip restraints accepted that there would be no defense-in-depth for in-vessel damage which could preclude coolable core geometry following a DEGB. Therefore, LBB has always used the extremely low event frequency of a DEGB to justify an absence of defense in depth for potential DEGB effects. GSI-191 application of LBB would thus be no outlier but, rather, would be consistent with the original applications of LBB, as presented in NUREG-1061.

From NUREG-1061, Section 2.1, "Evolution of Requirements":

> The "design basis accident", "maximum credible accident," and "maximum hypothetical accident" have been used as terms describing what was generally the double-ended guillotine break. The concept was originated by the U.S. Atomic Energy Commission for the multiple purpose of sizing containments and establishing "accident" doses and later, the sizing of emergency core cooling systems. The original concept was quite straightforward; namely, an instantaneous DEGB of a major pipe in the primary system of a light water reactor (LWR) would maximize the fluid release and establish an upper bound for the design pressure established for a containment. This optimized the containment volume vis-a-vis a reasonable design accident pressure.
>
> Later changes in regulatory philosophy, primarily with regard to seismic design, tended to shift the DEGB from a hypothetical accident to one having increasing credence. It was a relatively short step from the hypothetical to a belief in major pipe breaks. A natural consequence of an accepted pipe break was the assumption of a terminal end (reactor pressure vessel nozzle) break and the asymmetric loading of the reactor pressure vessel (Generic Issue A-2). If one accepts a DEGB, then massive pipe restraints to minimize pipe deflection

become a natural consequence, and backfitting requirements follow automatically.

A reassessment of the overall probability of a large pipe break, particularly in reactor primary systems, undermined the basic premise that a DEGB was an accepted event. Both probabilistic studies on pressurized waters (Westinghouse and Combustion Engineering), deterministic studies, and an assessment of failure statistics in large pipes and non-nuclear vessels led to the same conclusion: the probability of a DEGB is extremely low.

The "probabilistic studies" referenced above were performed by Lawrence Livermore and generated values for a per plant direct DEGB annual incidence in the E-10 to E-14 range. The document characterized such numbers as "a vanishingly low probability of rupture." (in "1.0 Introduction")

2) **Jet impingement: "local effects" versus "global effects"**

SECY-10-0113 contains the assertion that the jet impingement following a LOCA is a global effect. A global effect is more usually of the sort described in the first paragraph cited above in NUREG-1061. That is, they are effects that occur irrespective of what happens at the break location, such as the effects of released energy and mass on containment temperature and pressure, or the adequacy of makeup capacity for systems. Note that the SECY-10-0113 reasoning behind the progression of break location effects being considered as global effects closely matches the NUREG-1061 explanation as to why LBB was originally developed.

Another historical treatment (from author's personal experience) of jet impingement provides additional background. Prior to NUREG-1061, two near-replicate twin-unit plants were constructed with massive and costly guard pipes enclosing the main steam lines from their emergence from the steam generators to their exit into lower containment. The reason for the guard pipes was that NRC required that the design of the steam generator compartments (topped by removable steel domes to facilitate potential steam generator replacement) be able to withstand pipe whip and jet impingement forces from a main steam line break, or to preclude such impacts. The applicant decided that the only feasible approach was to install such guard pipes around the entire length of the main steam lines within the compartments. With those added, the Office of Nuclear Reactor Regulations (NRR) Containment Systems Branch reviewers accepted the design. Later, as the plants neared receipt of operating licenses, reviewers in a different NRR branch raised objections to the design, citing (correctly) that ASME Code Section XI required that the main steam line welds be accessible for inspection. The applicant's initial position was that inspections were not necessary, because the guard pipes mitigated such weld failures. The NRR branch rejected that position and noted that one acceptable approach would be to remove the (already fabricated and installed) guard pipes to allow access to the welds for the required inspections.

Analogous to the above example, licensees could install guard pipes or other extensive jet impingement shields to preclude any jet impingement effects, achieve GSI-191 closure for their plants, and then cite the revised GDC-4 and remove the shields. In fact, if licensees have preserved the devices that they removed in the 1980s, it is possible that they could reinstall them for just that purpose.

Conceptually, if installing devices that had been removed under jet impingement being a local effect in the 1980s can resolve an effect, it seems difficult to define that effect as global. Similarly, the Oconee example in SECY-10-0113 would appear to allow jet impingement damage not to be considered to a strainer, but to require consideration of the effects of damage to co-located insulation.

In any case, precise categorization of jet impingement effects is not critical to the item 7 proposal.

3) **Statements of Consideration**

One SECY-10-0113 position relies on a debatable interpretation of the Statements of consideration (SOC)'s to preclude an action. First, the interpretation itself may not be as clear as the staff appears to assert. Even if it were, however, staff has a very recent precedent (on the Vogtle docket) of taking a position contrary to SOCs.

The applicability of Fitness for Duty (Part 26) requirements during activities under a Limited Work Authorization (LWA) do not begin until a certain point. In the rule language, the wording identified as an example the first pouring of safety-related concrete. In the rule SOCs, installation of backfill was specified as not being in the scope of the rule for FFD. Staff decided that the engineered backfill at Vogtle was of sufficient importance to mandate FFD requirements, contrary to the SOCs, and imposed them anyway. The document trail is presented below.

The rule - 26.3(c)(1) - excerpt:

> "(1) Combined license applicants (under Part 52 of this chapter) who have been issued a limited work authorization under § 50.10(e), if the limited work authorization authorizes the applicant to install the foundations, including the placement of concrete, for safety- and security-related structures, systems, and components (SSCs) under the limited work authorization;"

Source link:

> http://www.nrc.gov/reading-rm/doc-collections/cfr/part026/part026-0003.html

Here is the SOC language (from page 16998 of the SOCs for the March 31, 2008, amendment to 10 CFR Part 26): (underline added)

> "Therefore, the foundation is an integral component of the fabric of a safety- or security-related SSC, while piles, backfill, and retaining walls are not."

Below is the Footnote 5 from the Vogtle SE, NUREG-1923:

> As provided in Part 26, the entities that must comply with Part 26 requirements include "[e]arly site permit holders who have been issued a limited work authorization under § 50.10(e), if the limited work authorization authorizes the early site permit holder to install the foundations, including the placement of concrete, for safety- and security-related

> SSCs under the limited work authorization." of Title 10 of the *Code of Federal Regulations* (10 CFR) 26.3(c)(5). The statement of considerations for Part 26 indicates that entities authorized by an LWA to perform "only the…placement of backfill" will not be required to comply with Part 26, but that entities who are authorized by an LWA "to perform installation of the foundation" for safety- and security-related SSCs will be required to comply. 73 FR 16966, 16998 (Mar. 31, 2008). The staff has determined that because of its implications for seismic safety, the placement of engineered backfill requested as part of the LWA for the Vogtle site represents an integral part of the foundation; accordingly, the staff considers placement of that backfill pursuant to the LWA to be "installation of the foundation" within the meaning of Part 26. Therefore, consistent with the text of the rule, the staff has determined that the applicant is required to comply with the requirements of Part 26 to establish a fitness for duty program.

Source link:

> http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1923/sr1923-ch1.pdf

The item 7 approach probably would require no (or very minor) SOCs revision.

4) **Revision to 50.46a faces significant challenges as a solution to GSI-191**

Staff has stated that revising 50.46a may help resolve GSI-191. As described in SECY-10-0113, defining all breaks above transition size to be beyond DBA would allow a great many things to potentially be credited that cannot be credited in DBA mitigation. Among those tools are the use of best estimate analyses, the absence of an assumed single failure, and potential credit for non-safety mitigative capabilities (for example, backflush). The technical bases for the rule change are not dissimilar to NUREG-1061 (very low event frequency), and allow analytical and mitigative methods for breaks beyond transition break size to be more commensurate with risk.

SECY-10-0113 proposes that licensees could invoke the revised 50.46a rule selectively. Specifically, a licensee could invoke the revised 50.46a only for GSI-191 resolution. Industry has not agreed that this is a practical approach, and has identified as a concern that there is no implementing guidance but, perhaps more importantly, that the transition break size probably will not resolve GSI-191 for many plants. Staff has noted elsewhere that break sizes as small as six inches (and maybe smaller) could threaten sumps at some plants, so the latter industry concern would appear to have bases. Additionally, the 50.46a rulemaking will take considerable time and will not offer even a potential solution path until it is final.

Revising 50.46a has much potential merit but, due to time issues and the current position of external stakeholders, faces significant challenges as a GSI-191 solution.

5) **New safety gains versus original safety gains has not been addressed**

The NRC staff, in GSI-191, identified a safety issue that the staff did not consider when it made its LBB recommendation to the Commission in 1984, and which the Commission approved, based on said recommendation.

The historical LBB documents cite safety gains/risks, and considered the gains greater due to the very low probability of a rupture in LBB piping. SECY-10-0113 did not "revisit" the mathematical bases and trade-offs of LBB by adding the new perceived risks associated with GSI-191 to the 1980s calculations to see if the LBB decision remained appropriate. Instead, the text asserted that the new risks mandated balancing new safety gains (before LBB could be applied). In concept, this appears a flawed approach. It would seem that – before adding new requirements - staff should have a quantitative basis to conclude that the original risk decision is not valid when GSI-191 risks are added to the equations.

In short, the question should not be if there are offsetting new safety gains, but if the original safety gains are (or would be) no longer enough. Such an analysis was not offered in SECY-10-0113. The item 7 proposal does not require such an analysis.

6) **Staff concerns may justify further requirements**

It may not be feasible to quantify the GSI-191 risks with sufficient rigor to be able to re-visit the LBB decisions in the 1980s and make the necessary comparisons. There is, however, some added risk beyond what the staff assumed in its 1984 recommendation to the Commission to approve LBB.

The absence of defense-in-depth in applying LBB to resolve GSI-191 is, even with its clear precedent in LBB, nonetheless a source of potential concern. The item 7 approach offers one method to address those concerns.

7) **A new approach to resolve GSI-191: "SECY-10-0113 Option 4"**

The recommendation is to apply, for GSI-191 purposes, the process for addressing breaks deemed beyond the design basis in the proposed revision to 50.46a to all piping that is LBB-qualified. This essentially combines the SECY-10-0113 Option 2b processes with the Option 3 scope.

NRC would acknowledge that the LBB decision included jet impingement (or may have), but state that the potential containment strainer and ECCS effects of such impingement were not recognized at that time, and that the NRC believes those risks merit mitigation. Nonetheless, NUREG-1061 and all subsequent work (including the technical bass for 50.46a effort) show the event frequency to be very, very low.

To make the additional requirements commensurate with risk, staff would propose crediting the 1984-5 LBB decision to allow analyses and actions taken to mitigate the additional, recently discovered effects of jet impingement resulting from postulated failures of LBB-qualified piping to treat those ruptures as beyond-DBA or severe accidents for the purposes of assuring protection for GSI-191 issues.

The above is not inconsistent with the 1984-5 overall position, though the Office of the General Counsel may or may not declare that some minor edits would need to be made in the SOCs. Treatment of beyond-DBA is well understood, and the LBB bright line would be immediate and far crisper than any future 50.46a line (or lines). That is, all licensees know right now what piping in their facilities is and is not LBB-qualified. In contrast, the transition break size remains

undefined (until the revised and not yet approved 50.46a becomes final), and will vary from design to design, and possibly even plant to plant. Analyses and/or mitigation actions (e.g., backflush) would restore margin and/or defense in depth.

This approach appears to have the potential to address all concerns. Yes, only the local effects of jet impingement were originally considered but there is room for debate, and damaged insulation (and other materials) has potential consequences not recognized in 1984-5. Yes, defense in depth is important, but its absence is not without precedent in LBB. Yes, additional regulatory requirements are appropriate, given the potential effects, but the integrity of historical LBB work remains not in dispute and the very high confidence and the very low initiating event probability justifies this commensurate regulatory treatment.