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Ms. Cindy K. Bladey
Chief, Rules, Announcements, and Directives Branch
Office of Administration
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Subject: Industry Response to NRC Request for Potential Alternatives to Resolve Generic Safety Issue 191, Pressurized Water Reactor Sump Performance; Docket ID NRC-2011-0090

Project Number: 689

Dear Ms. Bladey:

In a May 3, 2011 Federal Register Notice, the Nuclear Regulatory Commission requested public comments on potential alternatives for risk-informing the path forward to resolve Generic Safety Issue 191 (GSI-191), Pressurized Water Reactor Sump Performance. The Nuclear Energy Institute (NEI)[1] appreciates this opportunity to provide industry perspectives on various ways and means to risk-inform the path forward.

This opportunity to provide comments is in response to a Staff Requirement Memorandum (SRM) dated December 23, 2010, wherein the Commission directed the staff, in part, to explore alternative paths forward for resolving GSI-191. The SRM stated that the staff should employ <u>innovation and creativity</u> in fully exploring the policy and technical implications of all available alternatives for risk informing the path forward. We welcome the opportunity to resolve GSI-191 in a manner that properly reflects the low risk posed by the postulated events, treats known phenomena in a manner that approaches realistic behavior, and provides a capability to evaluate the impact of new information in a stable and predictable manner.

As early as 2004, the Commission directed the staff to, "implement an aggressive, realistic plan to achieve resolution and implementation of actions related to PWR ECCS sump concerns." The staff response to this direction resulted in a risk-informed framework that is incorporated in Section 6 of

[1] NEI is the organization responsible for establishing unified nuclear industry policy on matters affecting the nuclear energy industry, including the regulatory aspects of generic operational and technical issues. NEI's members include all utilities licensed to operate commercial nuclear power plants in the United States, nuclear plant designers, major architect/engineering firms, fuel fabrication facilities, materials licensees, and other organizations and individuals involved in the nuclear energy industry.

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industry guidance document NEI 04-07, "Pressurized Water Reactor Sump Performance Methodology." This framework, however, has not been fully utilized due to the minimal relaxation of conservative modeling assumptions allowed by the staff approval of NEI 04-07. A desired outcome of the actions taken in response to the December 23, 2010, SRM is greater promotion and increased use of the "Section 6" resolution framework.

The attached comments outline a range of options and potential risk-informed considerations. These options are not comprehensive and are not intended to be reviewed as implementation-ready proposals. Our comments, instead, are intended to promote constructive discussion of various means to risk-inform GSI-191 resolution. We encourage continued discussion of the specific proposals offered in our comments.

Because of the range of designs and operational characteristics represented by the 69 U.S. PWRs addressing GSI-191, it is important to recognize that a single risk-informed pathway is unlikely to provide the desired resolution. Multiple options are appropriate due to the variety of designs and needs.

The proposals offered in our comments can be implemented in various ways using one or more of the existing regulatory frameworks. We believe that the proposals can be implemented within these frameworks without requiring rule changes. This is important since there is a strong desire for expedient resolution by both industry and NRC. While a rule change is an option, the time frame for rule change is generally not consistent with the desired schedule for resolution.

Attachment 1 provides a summary of the three regulatory frameworks that can be utilized to implement the identified comments and proposals identified in Attachment 2. The specifics of each proposal could be tailored to the framework for which it will be applied. Attachment 3 provides a discussion of operability determinations related to GSI-191 and a proposal for a risk-informed Technical Specification change that could be used should the containment sump be determined to be inoperable.

We look forward to meeting with NRC staff to discuss our comments and proposals. If you have any questions, please feel free to contact me at 202-739-8108; jcb@nei.org.

Sincerely,

John C. Butler

Attachments

Regulatory Frameworks for GSI-191 Resolution

The proposals offered in the industry response to the May 3, 2011, Federal Register Notice (76FRN24926) can be implemented in various ways using one or more of the existing regulatory frameworks. These frameworks can be implemented without requiring rule changes. This is important since there is a strong desire for expedient resolution by both industry and NRC. While a rule change is an option, the time frame for rule change is generally not consistent with the desired schedule for resolution.

The comments and proposals identified in Attachment 2 can be implemented in one or more of three regulatory frameworks: 1) Traditional 50.46, 2) NEI 04-07 Section 6 (Transition Break Size), and 3) RG 1.174. These are summarized below for reference:

Traditional 50.46

Treatment of GSI-191 phenomena within current 10 CFR 50.46 requirements has generally entailed treatment of a broad range of conditions and phenomena in a conservative manner, irrespective of likelihood or probability. Known limitations in the knowledge base of these phenomena and associated calculation methods are typically accounted for in a bounding fashion during each phase of the process.

The combined effect of employing bounding calculations in each phase of the process is a pessimistic prediction of Emergency Core Cooling System (ECCS) recirculation performance that, while conservative, provides little insight into the realistically expected performance during a design basis event. Treatment of uncertainties in this manner is only acceptable provided that the level of conservatism is reasonable.

Pursuant to 10 CFR 50.46, an evaluation model must include sufficient supporting justification to show that the analytical technique realistically describes the behavior of the reactor system during a loss-of-coolant accident (LOCA). Uncertainties in individual phenomena do not need to be addressed individually. Uncertainties need only be accounted for, so that, when the calculated ECCS cooling performance is compared to the acceptance criteria, there is a high level of probability that the criteria would not be exceeded.

NEI 04-07 Section 6 (Transition Break Size)

The evaluation methodology presented in Section 6 of NEI 04-07 is modeled after the proposed risk-informed revision to 50.46 (e.g., 50.46a) but maintains conformance with current 50.46 requirements. It allows for use of an alternate break size in analyses of containment recirculation performance. Calculations for break sizes smaller than or equal to the alternate break size use one set of modeling criteria while postulated breaks larger than the alternate break size use a separate set of modeling criteria. Implementation of the Section 6 evaluation methodology involves two separate analysis steps:

- Region I – For pipe breaks up to an alternate break size, analyses of the containment sump performance use the highly conservative analysis methodologies applied in the traditional 50.46 analysis methodology.
- Region II – For pipe breaks larger than the alternate break sizes, analyses of the containment sump performance use risk insights and more realistic analysis methodologies.

The Region I and Region II nomenclature was chosen to provide a clear definition of the two analyses that would not be misinterpreted with other regulatory terminology and has no other significance.

The alternate break size for the Section 6 evaluation methodology is defined as:

- A complete guillotine break of the largest line connected to the reactor coolant system loop piping.
- For main-loop piping, a break size assumed to be equivalent to a guillotine break of a 14-in. schedule 160 line, and equating to an effective break area of 196.6 square inches.

Regulatory Guide 1.174 Resolution Framework

NRC Regulatory Guide 1.174 Revision 2, dated May 2011, provides an acceptable approach for risk-informed changes to the plant's current licensing basis (CLB). The recent revisions do not substantially alter the approach of this regulatory guide, which has been used for over 10 years to enable various types of risk-informed CLB changes, including technical specifications, fire protection, inservice inspection, and others. While there has been an evolution in NRC expectations over the years relative to scope and pedigree requirements for PRA, the use of this regulatory guide has been generally successful. Essentially, the regulatory guide provides that a change can be found acceptable if it:

1. Meets current regulations (or forms the basis for an exemption request under 10 CFR 50.12)
2. Maintains the defense-in-depth philosophy
3. Maintains adequate safety margins
4. Conforms with risk acceptance guidelines (these guidelines address core damage frequency (CDF) and large early release frequency (LERF), and the Regulatory Guide allows that "very small" or "small" increases in risk can be found acceptable if all elements of the process are met)
5. Provides for performance monitoring as appropriate to maintain the validity of the risk model assumptions

Proper use of Reg Guide 1.174 involves a balanced consideration of the above, including consideration of uncertainties in the risk calculation. PRA studies have shown that loss-of-coolant accidents due to large breaks are a relatively low contributor to overall plant risk. Thus, it is reasonable to expect that modeling of the LOCA scenarios leading to recirculation and sump challenges can demonstrate that the residual risk of additional closure actions, following plant modifications conducted to date, is within the risk acceptance guidelines of Reg Guide 1.174. However, modeling uncertainties will be important for this application, and the body of existing work on GSI-191 can provide a reasonable basis to underpin the uncertainty analysis.

NRC's associated Regulatory Guide 1.200 Revision 2 provides NRC expectations for PRA technical adequacy and scope. The body of the Reg Guide discusses general considerations and the appendices provide NRC positions on consensus PRA standards. Reg Guide 1.200 Revision 2 currently addresses at power internal events, internal floods, fires, and external events including high winds, external flooding, and seismic. NRC expects that risk contributors that are "significant to the regulatory decision" be addressed through Reg Guide 1.200 and the PRA standards and peer review process. Most plants have already assessed their internal events PRA models with respect to Regulatory Guide 1.200, and internal events are the primary initiator of interest for resolution of GSI-191.

Seismic initiators can contribute a fraction of the large break LOCA frequency, and this is a plant specific consideration. As part of a Reg Guide 1.174 approach, a plant would likely need to develop qualitative or bounding arguments relative to the impact of seismic initiators on the requested regulatory decision.

The recirculation phase of ECCS is not generally modeled in detail in PRA, and is usually represented as a "conditional probability" that the sump will not perform its function. In order to address GSI-191, it is reasonable to expect that a sufficient basis would be developed for this conditional probability. South Texas Project (STP) is pursuing one such approach, which is described below. Other approaches are possible, and it is also possible that elements of the STP approach can be generically applied.

Regulatory Guide 1.174 provides guidance for consideration of defense-in-depth, and this will be an important element for this application. The Reg Guide provides the following considerations:

- A reasonable balance is preserved among prevention of core damage, prevention of containment failure, and consequence mitigation.
- Over-reliance on programmatic activities as compensatory measures associated with the change in the LB is avoided.
- System redundancy, independence, and diversity are preserved commensurate with the expected frequency, consequences of challenges to the system, and uncertainties (e.g., no risk outliers).

- Defenses against potential common-cause failures are preserved, and the potential for the introduction of new common-cause failure mechanisms is assessed.
- Independence of barriers is not degraded.
- Defenses against human errors are preserved.
- The intent of the plant's design criteria is maintained.

STP's Risk-Informed Approach

Overview

The risk-informed approach is one in which the technical and phenomenological issues related to GSI-191 are incorporated into STP's plant specific PRA. More specifically, the recirculation phase of ECCS operation will be modeled in detail to produce location specific pipe break analyses, location specific debris generation and/or transport analyses, and the associated sump strainer debris loadings for a comprehensive spectrum of conditions. These sequences will be structured to support probabilistic uncertainty analyses sufficient to determine the most likely situations and associated ranges characteristic of probabilistic distributions. Sensitivity studies will also be possible to evaluate the significance of contributors to recirculation phase failure due to sump clogging or in-vessel effects.

Once incorporated into the PRA, the risk significance of the current plant design (with high fiber insulation) will be compared to a revised plant design (with no high fiber insulation). The change in risk for both cases will be calculated and the change in risk (i.e., delta CDF and delta LERF) will be compared to the risk significance guidelines contained in Reg Guide 1.174. If Reg Guide 1.174 low-risk significance guidelines are met, then STP will seek exemption through a license amendment request (LAR) from certain portions of 10CFR50.46 while comporting with guidance contained in Reg Guide 1.174 (e.g., defense-in-depth, safety margin). If Reg Guide 1.174 guidelines are not met, then STP would use the risk-informed approach to identify the major contributors and either perform additional analyses to further support the risk-informed approach or specifically address major contributors to risk through various means such as procedures and/or modifications until the non-risk significant criteria are met and the appropriate exemptions identified (i.e., LAR). A key objective of the risk-informed approach is that the methods and technology will be transferrable to other utilities that might desire to pursue the risk-informed approach. Additionally, the risk-informed method will provide a means to assess operability margins that may come into question due to degradation or other material issues associated with the recirculation phase of ECCS operation.

In order to incorporate the phenomena associated with GSI-191 issues, a detailed set of technical models will be developed. These models will be structured to provide the deterministic and probabilistic data and information suitable for incorporating into a plant specific PRA. A more detailed discussion of these technical models is provided below. A key element of this risk-informed approach is the development of visual simulation methods to provide plant specific design perspectives for postulated pipe breaks at different locations. In order to provide an acceptable technical risk approach, detailed plant specific computer aided drawing (CAD) models will be used in conjunction with quantitative risk models having comprehensive treatments of uncertainty to probabilistically address the phenomena associated with the recirculation phase of emergency core cooling systems (ECCS) operation. Location specific pipe breaks will be postulated within the reactor coolant system (RCS) with debris and subsequent transport of debris to emergency containment sump strainers being dependent upon location, etc. Detailed risk models addressing the recirculation phase of ECCS recirculation mode of operation for location specific pipe breaks will be developed and are described for the following areas:

PRA Risk Quantification (PRA)

A probabilistic risk assessment (PRA) model of the ECCS recirculation mode of operations is required to account for GSI-191 phenomena and to provide the Core Damage Frequency (CDF) and Large Early Release Frequency (LERF) estimates for STP. The resulting PRA is quantified assuming that the existing STP piping insulation is replaced with insulation that prevents sump blockage (NBI) when stripped from the piping as opposed to the insulation now installed (PBI) at STP (which presumably has greater propensity to produce debris blocking sump material). The increase in CDF and LERF above the values when using NBI as opposed to PBI would be compared to RG1.174 Reg Guide 1.174 risk acceptance guidelines. The PRA is based on an event tree model that requires uncertainties (distributions) for key systems including (importantly) new performance of ECCS considering sump blockage possibility and possible effects of PBI (and NBI) on core cooling performance.

Thermal-Hydraulics (TH)

RCS pipe insulation material is hypothesized to be removed by jets formed when piping fails. The boundary conditions for jet models are required to produce necessary inputs to calculate debris generation. A RELAP5 model of STP that includes the ECCS response and Operator actions during hypothesized LOCA events is required to develop the necessary jet model boundary conditions. Boundary conditions will be required for different scenarios including break size, break location, break opening characteristics (1 ms, 50 ms, 100 ms, etc.), and ECCS availability scenarios (one HHSI, all HHSI, two LHSI, one LHSI, etc.). The TH model will provide the necessary distribution for whether or not recirculation will be required for success. That is, if recirculation is not required, then no further analysis is required against the sump performance.

Debris Generation, Transport, and Consequential Sump Blockage (DTSB)

An integrated model will be used to model creation of debris (using jet models for ablation) using boundary conditions provided by the TH calculations and then provide the necessary head loss distribution for Safety Injection (SI). The jet, hydromechanics, and ablation models would develop a stochastic distribution of the sump performance (head loss) and thereby provide the PRA with the necessary information for success criteria in terms of SI pumping performance. The pumping performance distribution as well as the debris characterization that passes through the sump screen is a boundary condition required for the downstream effects model.

Downstream Effects (In-Vessel), Core Blockage, Coolable Geometry (DEM)

A model of the core cooling performance is required for PRA success criteria. That is, even though the SI flow is sufficient, a few possibilities must be considered regarding the ability for the provided flow to keep the core sufficiently cooled to prevent core damage. The model requires boundary conditions of debris quantity and type (size, make up, chemical properties), heat generation (core decay heat), stored energy, and hydraulic boundary conditions (flow rate, flow energy, fluid state, etc.), and core power sharing. The model will provide the core pin failure distribution (distribution of failed pins) required for the PRA success criteria under different hypothesized scenarios. The model must provide results for both NBI and PBI cases.

Piping Failure Likelihoods

The RCS piping may fail at several different locations with different probability and in different ways (with different probabilities for each way). These pipe breaks would be the initiating events resulting in a spectrum of loss-of-coolant accidents (LOCAs) ranging from large break LOCA (LBLOCA) to small break LOCA (SBLOCA). Each of these LOCA scenarios would have different break opening rates producing different boundary conditions for the TH model (and subsequently, the jet model in the DTSB model). The pipe failure model described here is one that is capable of producing probabilistic distributions for the break location likelihood, size, and break opening rates.

The STP risk-informed approach is currently working on a three year schedule. Key milestones for 2011 are the initial PRA calculations with all the models described above incorporated. In 2012, the key contributors to uncertainty identified from the 2011 efforts will be further evaluated and refined. It is possible that some testing structured for the risk-informed approach may be performed. The remaining year, 2013, would be finalizing the analyses and associated LAR.

NEI Comments in Response to Federal Register Notice (76FRN24925) Docket ID NRC–2011–0090

General Comments

As early as 2004, the Commission directed the staff to, "implement an aggressive, realistic plan to achieve resolution and implementation of actions related to PWR ECCS sump concerns." The staff response to this direction resulted in a risk-informed framework that is incorporated in Section 6 of industry guidance document NEI 04-07, "Pressurized Water Reactor Sump Performance Methodology." This framework, however, has not been utilized due to the minimal relaxation of conservative modeling assumptions allowed by the NRC Safety Evaluation Report on NEI 04-07. The comments provided in this attachment offer a number of areas where bounding calculations in each phase of the process can be relaxed such that uncertainties are accounted for, so that, when the calculated Emergency Core Cooling System (ECCS) cooling performance is compared to the acceptance criteria, there is a high level of probability that the criteria would not be exceeded.

The comments provided in this attachment outline a range of options and potential risk-informed considerations. These options are not comprehensive and are not intended to be reviewed as implementation-ready proposals. Our comments, instead, are intended to promote constructive discussion of various means to risk-inform GSI-191 resolution. We encourage continued discussion of the specific proposals offered in our comments.

The proposals offered in this attachment can be implemented in various ways using one or more of the existing regulatory frameworks outlined in Attachment 1. These frameworks can be implemented without requiring rule changes. This is important since there is a strong desire for expedient resolution by both industry and NRC. While a rule change is an option, the time frame for rule change is generally not consistent with the desired schedule for resolution.

Recommendations for Incorporating Risk Insights into GSI-191 Resolution

1. Break Selection – Revision of break location selection criteria

For the purposes of debris generation, the location of postulated breaks should be limited to terminal ends and locations where the stresses exceed those specified in Branch Technical Position (BTP) 3-4 of NUREG-0800, "Postulated Rupture Locations in Fluid System Piping Inside and Outside Containment."

<u>Discussion</u>

On July 19, 1987, the NRC issued Generic Letter 87-11, "Relaxation in Arbitrary Intermediate Pipe Rupture Requirements." The Generic Letter informed licensees that the NRC had finalized a revision to Branch Technical Position MEB 3-1 of the Standard Review Plan Section 3.6.2 in NUREG-0800[1]. The revision eliminated all dynamic effects (missile generation, pipe whipping, pipe break reaction

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[1]BTP 3-4 replaced MEB 3-1 in Revision 2 (03/2007) of Section 3.6.2 of NUREG-0800.

forces, jet impingement forces, compartment, subcompartment and cavity pressurizations, and decompression waves within the ruptured pipe) and all environmental effects (pressure, temperature, humidity, and flooding) resulting from arbitrary intermediate pipe ruptures.

Arbitrary intermediate pipe ruptures, which previously were specified in B.1.c.(1)(d) of MEB 3-1 for ASME Code Class 1 piping and in B.1.c.(2)(b)(ii) of MEB 3-1 for ASME Code Class 2 and 3 piping, are now no longer mentioned or defined in MEB 3-1. Besides the relaxation in requirements relating to arbitrary intermediate pipe ruptures, the revised Standard Review Plan Section 3.6.2 updated the citations to the ASME stress limits to achieve consistency with current practices, and introduced other minor changes. The requirements for postulated terminal end pipe ruptures, postulated intermediate pipe ruptures at locations of high stress, and high usage factor for leakage cracks were retained in the revision to MEB 3-1.

Consistent with a plant's licensing basis, MEB 3-1 may be used to select break locations for evaluating post-accident sump operability. The application of MEB 3-1 is appropriate for this purpose as it focuses attention on high stress and fatigue locations. Guidance provided in Generic Letter 87-11, *Relaxation in Arbitrary Intermediate Pipe Rupture Requirements (Reference 66) and the associated Branch Technical Position MEB 3-1, Postulated Rupture Locations in Fluid System Piping Inside and Outside Containment*, should be used to identify postulated primary-side break locations. The use of MEB 3-1 to identify the break locations is within the design basis as discussed in the background of that document:

> *This position on pipe rupture postulation is intended to comply with the requirements of General Design Criteria 4 of Appendix A to 10 CFR Part 50 for the design of nuclear power plant structures and components...The rules of this position are intended to utilize the available piping design information by postulating pipe ruptures at locations having relatively higher potential for failure, such that an **adequate and practical level of protection may be achieved** (emphasis added).*

As discussed in NUREG-1829, expert elicitation gave strong weight to penetration integrity for the large and medium break sizes and steam generator tube failures for small break sizes. They also gave strong weighting to breaks in locations that have welds based on the high residual stress, the preferential attack of many degradations mechanisms, and the high likelihood of defects in these locations. These locations are considered to be more probable than a circumferential break in a smooth piping segment.

In the development of MEB 3-1, it was recognized that some pipe break locations were of sufficiently low probability that these locations did not require additional design considerations to limit their consequences. Consequently, MEB 3-1 identifies that the dynamic effects of pipe breaks need only be considered for high-stress and high-fatigue pipe locations, such as at the terminal ends of a piping system at its connection to the nozzles of a component. Breaks at locations other than those prescribed by MEB 3-1 have been determined by the NRC staff to be of sufficiently low probability that the design need not accommodate their dynamic effects. The position taken in MEB

3-1 is confirmed by the NRC's Expert Elicitation Panel as documented in NUREG-1829. Consideration of breaks in loop piping at locations identified in MEB 3-1 (or BTP 3-4) provides confidence that an adequate and practical level of protection is achieved.

2. Break Characteristics – Effective break opening for debris generation

This alternative was developed and previously submitted to NRC as a means to reflect the behavior of qualified low stress piping. The process incorporates accepted fracture mechanics techniques for high-quality large bore piping to identify a conservative breach size for use in evaluating local debris generation. Subjected to initiating flaws, the resulting maximum opening in this piping would be used for establishing the break opening size for consideration of the effective diameter for jet impingement considerations.

Discussion

The April 8, 2003 letter from NEI (ML031130541), provides the results of maximum expected openings on qualified low stress reactor coolant loop piping from Nuclear Steam Supply System (NSSS) vendor evaluations. The NEI paper proposes that the maximum expected openings be increased by three orders of magnitude to provide conservatism in the approach. From this approach, there are two paths that could be considered for establishing an appropriate zone of influence (ZOI) for this opening.

a. As described in the NEI letter, the effective opening could be treated as a circular opening in the piping, for which a ZOI could be developed using the current guidance of NEI 04-07.

b. The effective opening could be treated as a full circumferential break of the piping with the ZOI being determined through the use of the Boiling Water Reactor Owners Group (BWROG) Utility Resolution Guidance (URG) for piping breaks with axial offset with minimal radial offset.

More recently, the analysis reported in NUREG-1829 enables a further refinement of this proposed definition. NUREG-1829 has identified that the frequency of breaks of developing in qualified low stress main coolant loop piping for PWRs is extremely small. The expert elicitation process of NUREG-1829 supports the conclusion that complete rupture of a smaller pipe or non-piping component is more likely than an equivalent size opening in a larger pipe because of the increased susceptibility to fabrication or service cracking. Additionally, smaller bore piping, compared to larger bore piping, is more highly stressed while the large piping has more stress margin. This is a primary reason why the largest contributors in each loss-of-coolant accident (LOCA) category tend to be the smallest pipes which can lead to that size LOCA.

3. Break Configuration – Break configuration for large bore piping

A double ended guillotine break (DEGB) of piping should not also consider the break ends to be in a full offset configuration in instances where constraints exist to restrain lateral pipe movement.

Discussion

A full offset of the ends of piping that have been subjected to a DEGB is not credible for all reactor coolant containing piping systems. Many of the PWRs currently operating were designed or modified with the assumption that the main coolant loop piping would fail through a DEGB with full offset of the ends of the piping. This condition created the greatest asymmetrical loading on the reactor core and reactor vessel. As a result of these considerations, main coolant loop design included additional restraints and supports to prevent the full offset. Many of these design features are still installed in containments. Additionally, due to the strength of the main coolant loop materials, a full offset is not expected to occur. By not considering a full offset, the guidance contained in the BWROG URG could be used to establish a ZOI for these breaks.

Also, other high energy piping systems inside containment were assumed to fail. Where determined to be necessary, pipe whip or rupture restraints were installed to prevent adverse interaction between the faulted pipe and nearby structures, systems and components (SSCs) needed to mitigate the consequences of an event. Many of these design features are still installed in containment, which would prevent a full offset of the ends of the piping.

Supporting this alternative are the criteria specified in NUREG-0800, BTP 3-4, Section C.(i)(3) which provides for consideration of limiting pipe restraints or structural members, or demonstrated piping stiffness from inelastic limit analysis (e.g., a plastic hinge in the piping is not developed under loading).

4. Debris Generation – Removal of 40% destruction pressure penalty

The NRC Safety Evaluation Report on NEI 04-07 imposed a 40% penalty on the destruction pressure for many insulation materials. This penalty was based predominantly on a single test performed by Ontario Power Generation on a Calcium Silicate target with aluminum jacketing. The 40% reduction in debris source material destruction pressure for insulation should be removed.

Discussion

This is supported by the work that has been previously performed that determined that the materials utilized in the NSSS and attached piping will not instantaneously fail.

Any size piping that is qualified as low stress piping does not have to be considered to open upon failure in the previously assumed several millisecond time period. Utilizing a more realistic failure opening time, as described in the October 10, 2003, letter from NEI to the NRC (ML032900916), will result in eliminating the postulated pressure wave preceding the two-phase fluid that would be discharged from the break. This increased opening time would allow for recapture of the target material 40% destruction pressure reduction that was mandated in the SER to NEI 04-07.

5. Debris Generation – Treatment of debris generation as beyond design basis

The December 23, 2010, Staff Requirements Memorandum (SRM) and associated Voting Records encouraged the consideration of possible means to address debris generation as beyond design basis. Such an approach would allow for realistic assessment of plant design features and operator actions that reduce sump clogging likelihood (e.g., strainer backwashing) or reduce plant dependence on sump recirculation for long-term cooling (e.g. refill of the RWST, cross tie to another RWST if available, manage use of containment spray).

6. Debris Generation – Credit for improved insulation jacketing

Use of Sure-hold or double stainless steel jacketing with overlap both axially and circumferentially, and diametrically opposed seams allows reduction of the destruction ZOI to an extremely low, or zero, value. Previously performed testing demonstrated that a double jacketing system prevents destruction of the underlying insulation.

7. Debris Generation – Use of more realistic values for debris size distributions as a function of distance from the break.

Testing has demonstrated that the size distribution of debris is a function of the distance of the target from the break location. For fibrous insulation, the force of the jet will tend to dislodge larger pieces of the insulation and propel them away from their original location. There will be minimal fines generated from this interaction between the jet and the insulation.

8. Debris Generation – Use of more realistic timing for failure of unqualified coatings.

Testing previously performed on unqualified coatings has demonstrated that there is a significant delay between onset of the accident and failure of the coatings.

9. Debris Transport – Elimination of restriction of transport to inactive volumes

Elimination of the restriction of 15% transport to inactive volumes should be allowed based on CFD modeling and consideration of the inactive volume to active volume ratios.

10. Debris Transport – More realistic treatment of break flow turbulence

Use of more realistic models for break flow entering the active pool based on orientation of the break. For break locations that do not discharge directly downward to the pool, the flow will be distributed over a larger area resulting in significantly less turbulence at the bottom of the pool. There will not be a solid stream striking the pool surface. This distribution can be seen from as simple an experiment as holding a garden hose at various angles and observing the water flow pattern. With less turbulence at the bottom of the pool, more of the fine debris will settle and agglomerate during pool fill.

11. Debris Transport – More realistic treatment of debris accumulation in quiescent pool areas

Allow the use of debris accumulation in quiescent areas of the pool during pool fill as a result of spray and break flows filling the pool. This debris will accumulate in piles in these areas making them significantly more resistant to transport during recirculation. Erosion of these piles of debris will be a function of the flow velocity and turbulence developed during recirculation flow in the pool. The expected erosion can be determined during testing that models the CFD determined velocity and turbulence.

12. Debris Transport – Time dependent debris transport

Allow the use of time dependent debris transport to the strainers. Not all debris will be immediately available for transport to the strainer during recirculation. Examples of this include unqualified coatings (assuming that some will fail in small enough size to allow transport) and those pieces of debris in the pool that will erode over time (Cal-Sil, fiber pieces, etc.).

13. Debris Transport – Greater allowance for fine debris that is not washed back down to the active pool

Fine debris that is distributed to other locations in containment as a result of the break will not be all washed back down to the active pool as fines. Some of this material will be held up on horizontal structural elements, walls, and equipment. Some of the debris would also end up in areas where containment spray does not provide direct coverage. The fine debris would also tend to agglomerate together further resisting washdown.

14. Debris Transport – Use of more realistic debris transport to the strainers

In the active pool, there are flow streams developed that demonstrate that there is not uniform velocity from the top to the bottom of the active pool. During pool fill, debris will tend to settle quickly to the bottom of the pool as a result of the less dense (hotter) water during this stage of the event. During recirculation, laminar layers will be developed in the bulk flow stream with greater laminar resistance being developed at the bottom of the pool, thus minimizing the potential for transport in this region. As the bulk pool approaches the circumscribed area of the strainer, most of the debris will be in the lower regions of the pool, tending to fill the lower portions of the strainer first. This will result in an expected non-uniform distribution of debris on the complex geometry strainers.

15. Debris Transport – Credit for RMI filtering of debris in the pool during fill and recirculation

When metal insulation pieces are generated following the break, a significant quantity of these pieces will be at the bottom of the pool. A large quantity of the other debris materials will be near the bottom of the pool and will interact with the pieces of RMI, removing them from the material that is transported to the strainer. This same consideration should be allowed at installed debris interceptors to which some of the smaller pieces of metal debris will be transported during both pool fill and recirculation.

16. Strainer Debris Accumulation and Head Loss – Use of more realistic debris accumulation on the strainers

Since most debris in the active pool will have a physical tendency to settle to the floor of containment, the accumulation of debris on the strainer will be from the bottom up. This non-uniform debris distribution will result in a significant reduction in strainer head loss and is the more probable scenario for development of a strainer debris bed.

17. Strainer Debris Accumulation and Head Loss – Use of a homogeneous mixture for strainer head loss testing

Following a pipe break, the fine particulates and fibers will become intermixed and be transported to the strainer during recirculation. This will lead to agglomeration of the fibers and particulate debris with the portion of this mix that does not settle on the containment floor depositing on the strainer. At the beginning of recirculation, the pool will contain a mixture of fine particulates and fibers. During the initial stages of the event, the debris fines directly generated by the event (coatings, insulation) along with some of the latent debris will be in the pool, available for transport to the strainer.

18. Strainer Debris Accumulation and Head Loss – Credit for the reduction in ECCS and CSS flow

Incorporating credit for the reduction in ECCS and CSS flow through the procedurally driven actions taken by the Operators will result in reduced demand on the strainer (head loss) prior to a fully developed debris bed being established on the strainer. This would also result in reduced debris transport to the strainer.

19. Strainer Debris Accumulation and Head Loss – Time dependent accumulation of chemical precipitate on the strainer

Chemical precipitates will form over an extended period based on physically required initiators of exceeding solubility limits and the formation of either homogeneous or heterogeneous nucleation mechanisms. These initiators are not expected to be reached until later in the event when increased water level, lower sump pool temperatures, and decreased flow demand on the sump exist, resulting in an increase in available NPSH for the pumps taking suction on the sump.

20. Strainer Debris Accumulation and Head Loss – Settling of chemical precipitates in quiescent regions

Incorporate settling of chemical precipitates in quiescent regions of the sump pool, and accumulation of chemical precipitates on containment surfaces (walls, floors, structural elements, equipment, etc.). The heterogeneous nucleation of these precipitates has been demonstrated to occur during testing.

21. Strainer Debris Accumulation and Head Loss – Utilize the time dependency of the required NPSH

Utilize the time dependency of the required NPSH to show adequacy of strainer head loss. As has been seen in strainer head loss testing, the maximum strainer head loss does not occur until some substantial time after the initiation of the event. As strainer head loss increases, the bulk temperature of the sump pool decreases. This will result in an improved NPSH margin at the time of highest head loss. Since the formation of chemical precipitates will not occur until the sump pool reaches a significantly lower temperature, the available NPSH will be substantially higher at that time due to the lower temperature.

22. Strainer Debris Accumulation and Head Loss – Time dependent debris accumulation on the strainers

Not all debris will be immediately available for accumulation on the strainer during recirculation. Examples of this include unqualified coatings (assuming that some will fail in small enough size to allow transport) and those pieces of debris in the pool that will erode over time (Cal-Sil, fiber pieces, etc.).

23. Strainer Debris Accumulation and Head Loss – Allowance for RMI in debris mix

Allow the introduction of small RMI debris pieces into the mix of debris that can accumulate on the strainer. Based on testing previously performed, a portion of the RMI debris generated will be of a size that could be readily transported. The quantity that could transport to the strainer will be dependent on the velocity and turbulence developed through the debris transport model of the containment pool.

24. Strainer Debris Accumulation and Head Loss – More realistic debris accumulation

Strainer testing should be performed in a more realistic manner in that non-prototypic segregation of debris types should be avoided.

25. Chemical Effects – Use long term release rates for chemical species

Incorporate the use of long term release rates for chemical species instead of the currently applied short term release rates extrapolated over time.

26. Chemical Effects – Time dependent models for chemical precipitate formation

Use time dependent models to determine when chemical precipitates will form.

27. Chemical Effects – Operator control of sump pool temperature without reliance on safety related equipment.

Allow for operator control of sump pool temperature without reliance on safety related equipment. Maintaining temperature above a specified point for the chemical species involved will prevent the formation of chemical precipitates until such time that bulk pool velocities are significantly lower allowing a majority of the precipitates to settle to the containment floor and not be transported to the strainer or downstream of the strainer.

28. Chemical Effects – Lower pH requirements for containment pools

The pH in containment pools is required to be maintained above 7 (typically in the range of 8-9). The pool pH is maintained above 7 to avoid long-term stress corrosion cracking concerns and to increase the retention within the pool of Iodine fission products. NRC Research has been investigating results from testing in France that indicates that Iodine retention is not as sensitive to pH as previously thought. If these results are validated then there is the potential to significantly reduce chemical effects by lowering the containment pool pH.

29. In-Vessel Effects – Use of time dependent debris filtering
Use of time dependent debris filtering that has been demonstrated to occur as a result of recirculation through the sump strainer. Not all debris that enters the reactor vessel will be retained in the vessel.

30. In-Vessel Effects – Use of a homogeneous mixture for in-vessel debris
Use of a homogeneous mixture for in-vessel debris effects more closely models the physical situation than the current test protocol. Following a pipe break, the fine particulates and fibers will become intermixed and be transported to the strainer during recirculation. This will lead to agglomeration of the fibers and particulate debris with the portion of this mix that does not settle on the containment floor arriving at the strainer. Of the material that gets to the strainer, a portion of this material will bypass the strainer (flow through) for introduction to the reactor vessel.

31. In-Vessel Effects – Credit operator intervention
Incorporate operator use of in-core instrumentation during both cold leg and hot leg injection to determine if excessive blockage is developing. This would alert the operators to reconfigure the injection path to "backflush" the material that is leading to the blockage.

32. Strainer Bypass – Use of expected debris transport and accumulation on the strainer
Use of expected debris transport and accumulation on the strainer would result in a reduced probability of debris bypassing the strainer allowing for a greater quantity of debris to be generated during a break thus reducing the quantity of insulation material that would have to be changed out to resolve GSI-191.

33. Strainer Bypass – Time dependent bypass
Use of time dependent strainer bypass would result in reduced quantity of debris bypassing the strainer. As has been demonstrated in previous strainer testing, the strainer and settling will effectively reduce the quantity of debris available for continued recirculation. In other words, a curve could be developed for a specific strainer debris load that could be integrated to determine the total quantity of debris that could be expected to interact with downstream components. The timing of the debris bypass could also be compared to the timing of conditions in downstream components to determine limiting states for those components with regard to debris accumulation.

34. Risk-Informing Water Management
Improvements in the management of water sources associated with the recirculation phase of design basis LOCA events provides multiple benefits; including extending the injection phase to give operators more time to establish normal decay removal pathways and avoid recirculation through the strainer and increasing the degree of debris settlement prior to recirculation; reducing flows through strainers to minimize any resultant headloss across the strainers and extend the time available for mitigative actions.

Only two licensees, one with a large dry containment and one with ice condenser containments, have fully implemented water management. In the case of the large dry containment water management actions resulted in the elimination of containment spray actuation for LOCA events. This design modification was accomplished by crediting the accumulation of radioactive material on the containment fan cooler HEPA filters for their source term analysis and by demonstrating that the containment fan coolers would maintain containment design pressure and temperature within the containment equipment qualification envelope. However, the hoped for effects of reducing the amount of particulate and fine debris transported to the strainer and reduction of downstream effects has not been realized to date due to failure to reach agreement with the NRC staff on a method to credit settling in the low velocity and stagnant regions of the containment pool.

The benefits of water management could also be obtained by:

- Allowing operators to take manual actions to stop redundant ECCS and one or both CSS pumps prior to reaching the Refueling Water Storage Tank (RWST) or Borated Water Storage Tank (BWST) low level transfer point. This will ensure core cooling is maintained while extending the time to transfer to recirculation. (Note that depending on conditions identified in individual licenses, an exemption may be required to implement this proposal.
- Allow the use of more realistic methods for determination of long term containment integrity analysis.

There is a potential for a significant reduction in challenge to the recirculation function through use of a water management approach. The industry is ready to discuss with NRC additional areas where benefits could be gained through this approach.

GSI-191 Operability Determinations

In addition to risk-informing resolution strategies for GSI-191, risk should be considered in addressing unexpected conditions associated with post-LOCA recirculation.

Traditional Operability Determinations

The performance of an Operability Determination following the discovery of nonconformances in the general area of containment sump performance can typically be executed using the principles described within NRC Inspection Manual, Part 9900, "Technical Guidance," "Operability Determinations & Functionality Assessments for Resolution of Degraded or Nonconforming Conditions Adverse to Quality or Safety." The document provides guidance on the performance of Operability Determinations following the discovery of degraded and/or nonconforming conditions. Definition 3.4, "Fully Qualified", outlines the foundation upon which the performance of Operability Determinations rests. That section is repeated here, with emphasis added:

> Fully Qualified
> An SSC is fully qualified when it conforms to all aspects of its CLB (current licensing basis), including all applicable codes and standards, design criteria, safety analyses assumptions and specifications, and licensing commitments. **An SSC is considered "not fully qualified," i.e., degraded or nonconforming, when it does not conform to all aspects of its CLB, including all applicable codes and standards, design criteria,** safety analyses assumptions and specifications, and licensing commitments.
>
> The SSCs that TS require to be operable are designed and operated, as described in the CLB, with design margins and engineering margins of safety to ensure, among other things, **that some loss of quality does not result in immediate failure to meet a specified function. The CLB includes commitments to specific codes and standards, design criteria, and some regulations that also dictate margins.** Many licensees add conservatism so that a partial loss of quality does not affect their commitments for design and operational margin. **Loss of conservatism that is not credited in the CLB does not affect operability or functionality**.

The sump strainers currently installed provide substantial safety margins over previous designs. From the Federal Register Notice:

> "Given the vastly enlarged advanced strainers installed, compensatory measures already taken, and the low probability of challenging pipe breaks, adequate levels of safety and defense-in-depth are currently being maintained...."

For example, substantial margins exist on a situational basis in the general areas of postulated break opening times, presumed zone of influence, and debris transport characteristics, which include the tendency for the deposition of debris in inactive regions of the containment.

These identified margins, many of which are identified in Attachment 2, may be appropriately applied in the conduct of Operability Determinations, consistent with Inspection Manual.

Risk-Informed Technical Specification Change

There exists a category of nonconformances associated with containment sump design that would solely impact required Emergency Core Cooling System (ECCS) performance under very low probability accident conditions. Should these low probability accident conditions be determined to fall within a site's Design Basis, then the ECCS may not be Operable.

In such instances, some form of corrective action must be implemented. If this corrective action involves work within the containment, it will involve substantial planning, such as:

- Identification of the scope of work.
- Acquisition of any required materials.
- Acceptance criteria to demonstrate that the corrective action has been successfully completed.
- Personnel training in the proper performance of the corrective action.
- Physical access to affected SSCs,such as scaffolding, shielding, etc.
- Avoidance of excessive radiation exposures.
- Other similar considerations.

Should this corrective action be attempted in an expedited fashion, the considerations introduced above will be likely be inefficiently implemented. In addition, while not a regulatory concern, any inefficiencies encountered will have financial and/or production impacts.

The Owners Group Technical Specifications Task Force (TSTF) has developed, and the NRC has approved, changes to plant technical specifications that provide flexibility in resolving similar situations in which common components cannot perform their specified safety function during low probability initiating events. The changes utilize risk insights to provide additional time to restore the affected systems to Operable status.

- TSTF-372, "Addition of LCO 3.0.8, Inoperability of Snubbers," approved by the NRC in April, 2005, added a new usage rule to the TS which allows licensees to delay declaring supported systems inoperable for up to 72 hours when a supporting snubber is non-functional, provided risk is assessed and managed.
- TSTF-427, "Allowance for Non Technical Specification Barrier Degradation on Supported System OPERABILITY," approved by the NRC in October, 2006, added a similar TS usage rule for non-functional barriers.

- TSTF-358, "Missed Surveillance Requirements," modified TS usage rule SR 3.0.3 to allow a licensee to defer performing a missed Surveillance up to the specified Frequency (often the next refueling outage) provided that risk is assessed and managed.
- TSTF-426, "Revise or Add Actions to Preclude Entry into LCO 3.0.3 - RITSTF Initiatives 6b & 6c," currently under review by the NRC, provides an extended time to repair a system when all trains are inoperable.

In all of the above changes, the risk impact is managed through the program in place to implement 10 CFR 50.65(a)(4) and its implementation guidance, NRC Regulatory Guide 1.182, "Assessing and Managing Risk Before Maintenance Activities at Nuclear Power Plants."

A similar risk-informed TS provision could be crafted to address ECCS sump performance when the cause of the sump inoperability is a very low probability condition. If a licensee can demonstrate that the risk of continued operation is below an established risk threshold, the licensee could defer declaring the ECCS inoperable for a time based on the plant risk, not to exceed the next refueling outage. During the delay time, risk would be assessed and managed using the program in place to implement 10 CFR 50.65(a)(4) and Regulatory Guide 1.182.

NEI and the TSTF are prepared to work with the NRC to establish an acceptable framework for such a change, which can be developed into a TSTF generic change (known as a "TSTF Traveler") and adopted by licensees.