BACKGROUND DISCUSSION AND TECHNICAL ISSUES

DESCRIPTION OF DEBRIS-INDUCED CLOGGING

A fundamental function of the containment sump strainer is to support the recirculation function of the emergency core cooling system (ECCS) and containment spray system (CSS). The containment sump recirculates water that has collected at the bottom of the containment following a postulated loss-of-coolant accident (LOCA). Breaks in the reactor coolant system (RCS) piping, known as LOCAs, are part of every plant's design basis. Hence, nuclear plants are designed and licensed with the expectation that they are able to remove decay heat following a LOCA and prevent core damage.

If a LOCA were to occur, piping thermal insulation and other materials will be dislodged by the jet emanating from the broken RCS pipe. The flow coming from the RCS break or from the CSS may transport debris (e.g., insulation) to the pool of water that would be present at the bottom of containment. Once transported to the sump pool, the debris could be drawn towards the sump strainers, which are designed to prevent debris from entering the ECCS and CSS. If this debris were to clog the strainers, reactor core and containment cooling would be lost, leading to potential core damage and containment failure.

Some debris would pass through the sump strainer (termed sump strainer "bypass") and be available to lodge in the core (known as in-vessel effects). This could result in reduced core cooling and potential core damage, even if the containment sump strainer were to perform as designed. Therefore, the evaluations for Generic Safety Issue (GSI)-191, "Assessment of Debris Accumulation on PWR [Pressurized-Water Reactor] Sump Performance," have been expanded to include in-vessel effects.

HISTORICAL BACKGROUND

In 1979, as a result of evolving staff concerns related to the adequacy of PWR recirculation sump designs, the U.S. Nuclear Regulatory Commission (NRC) opened Unresolved Safety Issue (USI) A-43, "Containment Emergency Sump Performance." To support the resolution of USI A-43, the NRC undertook an extensive research program, the technical findings of which are summarized in NUREG-0897, "Containment Emergency Sump Performance, Technical Findings Related to Unresolved Safety Issue A-43" (Agencywide Documents and Access Management System (ADAMS) Accession No. ML112440046) issued October 1985. The staff subsequently documented the resolution of USI A-43 in Generic Letter (GL) 85-22, "Potential for Loss of Post-LOCA Recirculation Capability Due to Insulation Debris Blockage" (ADAMS Accession No. ML031550731), dated December 3, 1985. Although the staff's regulatory analysis concerning USI A-43 did not support imposing new sump performance requirements on licensees of operating PWRs or boiling-water reactors (BWRs), the staff found in GL 85-22 that the 50-percent blockage assumption (under which most nuclear power plants had been licensed) identified in Revision 0 to Regulatory Guide (RG) 1.82, "Sumps for Emergency Core Cooling and Containment Spray Systems" (ADAMS Accession No. ML111680318), issued June 1974, should be replaced with a more comprehensive requirement to assess debris effects on a plant-specific basis. As a result, the staff updated the NRC's regulatory guidance in Section 6.2.2 of NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR [Light-Water Reactor] Edition," and RG 1.82 to reflect the USI A-43 technical findings documented in NUREG-0897.

Following the resolution of USI A-43 in 1985, several BWR [boiling-water reactor] ECCS suction strainer plugging events occurred (e.g., Barseback Unit 2 in Sweden; Perry Unit 1 and Limerick Unit 1 in the United States) that challenged the conclusion that no new requirements were necessary to prevent the clogging of ECCS strainers at operating BWRs. In response to these ECCS suction strainer plugging events, the NRC issued several generic communications over the period of 1993 to 1996 (Bulletin 93-02, Supplement 1, "Debris Plugging of Emergency Core Cooling Suction Strainers" (ADAMS Accession No. ML031190684) dated February 18, 1994; Bulletin 95-02, "Unexpected Clogging of a RHR [Residual Heat Removal] Pump Strainer While Operating in Suppression Pool Cooling Mode" (ADAMS Accession No. ML082490807), dated October 17, 1995; and Bulletin 96-03, "Potential Plugging of ECCS [Emergency Core Cooling System] Suction Strainers by Debris in BWRs" (ADAMS Accession No. ML082401219) dated May 6, 1996). These bulletins requested that BWR licensees implement appropriate procedural measures, maintenance practices, and plant modifications to minimize the potential for the clogging of ECCS suction strainers by debris accumulation following a LOCA. The staff subsequently concluded that all BWR licensees had sufficiently addressed these bulletins.

However, findings from research to resolve the BWR strainer clogging issue raised questions concerning the adequacy of PWR sump designs. In comparison to the technical findings of the earlier USI A-43 research program on PWRs, the BWR research findings demonstrated that the amount of debris generated by a high-energy line break could be greater, that the debris could be finer (and thus more easily transportable), and that certain combinations of debris (e.g., fibrous material plus particulate material) could result in a substantially greater blockage than an equivalent amount of either type of debris alone. These research findings prompted the NRC to open GSI-191 in 1996. This resulted in new research for PWRs in the late 1990s. GSI-191 focuses on reasonable assurance that the provisions of Title 10 of the *Code of Federal Regulations* (10 CFR) 50.46(b)(5) are met. This rule, which is deterministic, requires maintaining long-term core cooling after initiation of the ECCS. The objective of GSI-191 is to ensure that post-accident debris blockage will not impede or prevent the recirculation operation of the ECCS and CSS. The NRC completed its review of GSI-191 in 2002 and documented the results in a parametric study that concluded that sump clogging at PWRs was a credible concern.

On June 9, 2003, after completing the technical assessment of GSI-191, the NRC issued Bulletin 2003-01, "Potential Impact of Debris Blockage on Emergency Sump Recirculation at Pressurized-Water Reactors" (ADAMS Accession No. ML031600259). (The endorsement by the Committee to Review Generic Requirements (CRGR) of this bulletin can be found in ADAMS Accession Nos. ML030830459 and ML031210035.) As a result of the emergent issues discussed in the bulletin, the staff requested an expedited response from PWR licensees on the status of their compliance with regulatory requirements concerning the ECCS and CSS recirculation functions, based on a mechanistic analysis. The staff asked licensees that chose not to confirm regulatory compliance to describe any interim compensatory measures that they had implemented or would implement to reduce risk until the analysis could be completed. All PWR licensees have responded to Bulletin 2003-01.

In developing Bulletin 2003-01, the staff recognized that it might be necessary for licensees to undertake complex evaluations to determine whether regulatory compliance exists in light of the concerns identified in the bulletin and that the methodology needed to perform these evaluations was not currently available. As a result, the NRC did not request that information, but licensees were informed that the staff was preparing a generic letter that would request this information. GL 2004-02, “Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors” (ADAMS Accession No. ML042360586) dated September 13, 2004, was the follow-on information request referenced in the bulletin. This document set the expectations for resolution of PWR sump performance issues identified in GSI-191. (The CRGR endorsement can be found at ADAMS Accession Nos. ML040430074 and ML040840034). In addition, the staff issued substantial guidance on the subject, including a detailed safety evaluation (SE) (ADAMS Accession No. ML043280007) in December 2004 of the Nuclear Energy Institute’s (NEI’s) guidance document, NEI 04-07, “Pressurized Water Reactor Sump Performance Evaluation Methodology” (ADAMS Accession No. ML050550138). The SE provided a conservative “baseline” deterministic evaluation method and a more risk-informed alternative method that accounted for the extremely low probability of the largest postulated pipe breaks. (The CRGR review of the SE can be found at ADAMS Accession No. ML042710247.)

Guided by the GL, the staff’s SE, and other staff correspondence, the PWR licensees made significant progress in addressing GSI-191. In addition to strainer enlargements at all PWRs, individual licensees made various plant-specific changes. Some removed fibrous or particulate insulation, while others changed their sump pH buffers to reduce the potential for chemical effects or installed debris interceptors to reduce the amount of debris that can reach the sump strainers. However, encouraged by the NRC to take near-term actions to improve strainer performance, licensees often made plant changes before testing had been done to demonstrate the adequacy of the changes. Most licensees engaged various vendors to build and test a section of their strainer in a test flume at the vendor’s facility. The staff found a number of issues with the testing. The staff communicated extensively with the vendors and licensees to address these issues and, by and large, the staff now considers the latest vendor test protocols to be acceptable.

On November 16, 2007, the staff updated the Commission on the resolution status of GSI-191 (ADAMS Accession No. ML071930243). The update noted that the industry had not made progress in resolving the remaining technical issues as rapidly as the staff had anticipated. The staff also discussed research regarding chemical effects that showed that these effects required extensive evaluation and were a more significant concern than initially thought. The update also noted that some licensees might need to replace problematic insulation to attain successful strainer headloss tests.

As the staff’s knowledge increased from evaluations of licensee-sponsored tests and evaluations, as well as the chemical effects research, the staff issued supplemental review guidance in March 2008 (ADAMS Accession No. ML080230234) to address headloss testing, coatings evaluations, and chemical effects.

Temporary Instruction (TI) 2515/166, “Pressurized Water Reactor Containment Sump Blockage [NRC GL 04-02]” (ADAMS Accession No. ML060760340) was written to provide guidance to NRC inspectors to determine the adequacy of licensee actions taken in response to GL 2004-02. The TI inspection activities were to verify that the implementation of plant modifications and procedure changes were completed as committed to by each licensee and to verify that the changes were completed in accordance with 10 CFR 50.59. The TI has been completed at all operating domestic PWRs. Inspection Procedure (IP) 71111.17, “Evaluation of Changes, Tests, or Experiments and Permanent Plant Modifications,” IP 71111.18, “Plant Modifications,” and IP 71111.20, “Refueling and Other Outage Activities,” have been revised to include guidance to ensure that conditions that could affect sump performance will be considered during routine inspection activities.

One member of the staff's sump review team filed a differing professional opinion (DPO) in 2008. The DPO (ADAMS Accession No. ML100990063) expressed the opinion that the staff procedure and closure process resulted in a review that was unnecessarily focused on compliance versus a determination that the underlying safety issue had been satisfactorily addressed. The DPO panel found that, while the resolution of GSI-191 is focused on compliance, compliance with the regulatory requirements presumptively ensures that adequate safety is maintained. Therefore, the panel found the current approach to be appropriate. The Director of the Office of Nuclear Reactor Regulation agreed with the panel (ADAMS Accession No. ML100990069).

Prior to the Commission meeting on April 15, 2010, concerning GSI-191, the staff had concluded that industry attempts to refine test and evaluation methods to reduce perceived conservatisms would not likely be successful in the near term. As such, the staff had developed a format for draft letters under 10 CFR 50.54(f) to the affected licensees that would ask them to provide information on how they would show adequate strainer performance using methods consistent with the SE for NEI-04-07. During the April 15, 2010, Commission meeting, industry representatives expressed concern that forcing near-term issue resolution using staff-accepted methods would lead to large radiation exposures to plant staff without significant safety benefit. The Commission issued Staff Requirements Memorandum (SRM)-M100415 (ADAMS Accession No. ML101370261), dated May 17, 2010, requesting the staff to write a Notation Vote policy paper on potential approaches to bring GSI-191 to closure.

In response to SRM-M100415, the staff developed SECY-10-0113, "Closure Options for Generic Safety Issue-191, Assessment of Debris Accumulation on Pressurized Water Reactor Sump Performance" (ADAMS Accession No. ML101820296), dated August 26, 2010. That paper provided three options for closing GSI-191, addressing methods for complying with 10 CFR 50.46. The paper also discussed the timeframes for plant modifications. During the Commission meeting on September 29, 2010, industry representatives again expressed their concerns about forcing near-term resolution, particularly with the understanding that in-vessel effects could be limiting. The industry representatives noted that industry and staff had reached agreement on the additional testing and analyses needed to bring GSI-191 to closure. In SRM-SECY-10-0113 (ADAMS Accession No. ML103570354) dated December 23, 2010, the Commission directed the staff, in part, to consider all options, including a risk-informed approach, while the industry completed testing in 2011 and to submit a SECY paper identifying proposed policy options for resolving GSI-191. This paper responds to SRM-SECY-10-0113.

<u>TECHNICAL ISSUES</u>

The staff knew at the time that the GL and SE were issued that certain aspects of plant post-LOCA behavior needed further research and evaluation. Notable among these phenomena were chemical effects and downstream effects. Chemical effects refer to the potential for chemical species in the containment to interact with materials, such as insulation debris, to form a product that could cause or aggravate the potential for impeding flow through the strainer or debris deposited in the reactor core. Downstream effects refer to the potential for materials that bypass the ECCS strainer to impact downstream components (e.g., valves, pumps, and the reactor core).

From vendor testing, it became clear that the results in terms of strainer headloss were quite sensitive to a number of factors under the control of the test vendor. For example, the order of arrival of debris types at the strainer was observed to have an unexpectedly significant impact on the resulting headloss. Since it is difficult to predict that any given debris type would arrive first, the staff expected that the licensees would test with what appeared to be the most limiting sequence or a sequence that was demonstrated to be realistic. The staff's evaluation of the strainer performance and test practices took various forms, including plant-specific audits, reviews of vendor test protocols, staff observation of testing, and detailed reviews of licensee supplemental responses to the GL. To clarify expectations for licensee GL responses that were due at the end of 2007, the staff issued a content guide for GL 2004-02. Despite issuance of the content guide, many licensees' written responses to the GL did not provide the information necessary for the staff to confirm that testing and evaluation methods were acceptable. This resulted in the staff issuing a large number of requests for additional information. Because of the complex nature of GSI-191 issues, the staff performed detailed reviews in each of the technical areas of the problem. The detailed review process led some licensees and other industry stakeholders to express frustration that the staff had focused too much on achieving conservatism in each of the review areas pertinent to strainer performance. Recognizing that conservatism, if present in multiple areas, could result in an overly conservative result, the staff developed the integrated review process to attempt to avoid this problem (ADAMS Accession No. ML073380168). A three-member team of senior staff with the requisite technical expertise (different from the GSI-191 review team) is tasked with reviewing the staff review packages for each licensee that does not meet all of the deterministic criteria to determine whether, given the conservatisms, nonconservatisms, and uncertainties in the various review areas, the licensee has provided reasonable assurance of successful strainer function. This process has been effective in closing sump performance issues for approximately two-thirds of the PWRs.

<u>Refinements to Methodologies</u>

The staff has been and continues to be receptive to refinements in methodologies. For example, the staff accepted a significant reduction in the "standard assumptions" (found in the staff's SE on NEI-04-07) for the amount of fibrous debris generated by long-term erosion of the larger, less transportable pieces of fibrous insulation, based on industry testing.

The staff also accepted several refinements regarding chemical effects. The staff allowed licensees to demonstrate that chemical effects would be delayed for their plant-specific conditions, which significantly improves the predicted margin because strainer headloss remains low until the available net positive suction head (NPSH) is increased by higher subcooling. Delayed chemical effects can also provide time for licensees to throttle ECCS flow so that the required NPSH is decreased. Furthermore, the staff allowed licensees to conduct strainer headloss tests in simulated plant-specific environments instead of testing by adding the pre-mixed WCAP-16530-NP precipitate originally developed by industry. Some licensees have also performed tests by introducing chemical species at their projected release rate over time, which is more representative of plant conditions.

The staff also permitted refinements to the zone of influence (ZOI), the area around the break where the jet generates transportable debris. The staff has allowed licensees to take credit for smaller ZOIs where it was demonstrated that breaks would have limited separation and offset resulting from piping restraints. These ZOI refinements can have significant effects on the amount of debris generated from breaks that qualify for such treatment. The staff also has been open to new ZOI testing, but the testing conducted by several licensees was determined to be flawed (see section on ZOI). Several licensees are still pursuing ZOI testing to reduce the amount of debris assumed to be generated following a pipe break (see section on recent developments).

As another example, latent debris amounts can be important for some low fiber plants. In many cases, the staff has accepted that plants have less than the standard assumption for latent debris (found in the staff's SE on NEI-04-07) in the plant and that they have adequate controls in place to ensure that latent debris will not become a significant factor in the operation of the ECCS system.

In conclusion, the staff has accepted several refinements. The staff will continue to accept refinements proposed by industry if they are adequately justified and can be completed in a timeframe commensurate with the Commission decision in this paper. However, there are many instances in which the staff has not accepted past testing, resulting in continued delays in resolving GSI-191. The following sections discuss three examples of such instances.

Zone of Influence

During its reviews of plant responses to GL 2004-02, the staff identified that a number of licensees had used ZOI values significantly smaller than the guidance in the staff's SE to NEI-04-07. The small ZOIs were based on jet impingement testing conducted by Westinghouse. The values were judged by the staff to be significantly smaller than would be expected, and the staff issued a number of requests for additional information about the testing. From staff questions, the industry identified several locations in the test loop in which the inside diameter of the piping was significantly smaller than the jet nozzle. The small diameter locations (choke points) upstream of the jet nozzle were postulated to result in a much weaker jet than the tests assumed. The Pressurized-Water Reactor Owners Group (PWROG) performed confirmatory testing in January 2010 that revealed that the jet pressures were much lower than assumed in the ZOI testing reports. Therefore, the staff did not accept the ZOI volumes determined by this test program, and licensees that referenced them had to recalculate debris loads based on accepted ZOI sizing.

Debris Settling

Most strainer headloss testing used test protocols that ensure (through agitation of the fluid in the test tank) that the debris analyzed to reach the strainers is collected on the strainer surfaces. The staff considers this methodology appropriate. However, some licensees ran the strainer headloss tests in a flume designed to simulate containment pool flow conditions in order to credit debris settlement. Results from completed tests have shown significantly reduced transport of debris to the strainer, but licensees did not demonstrate that the debris settling was prototypical. Licensees and test vendors were not able to demonstrate that test flow conditions (e.g., velocity and turbulence), debris-to-debris and debris-to-wall interactions, and methods for preparing debris and adding it to the test flume resulted in realistic or conservative debris transport. Therefore, the staff has not accepted the test results.

In-Vessel Effects

In-vessel effects is the last area to be addressed by industry, even though the guidance has been under development for several years. The PWROG initially addressed in-vessel effects through a series of calculations. However, prompted by comments made by the Advisory Committee on Reactor Safeguards in 2008, the staff requested testing to supplement the analyses. This resulted in a substantial industry test program. Early testing found that fuel assembly headloss was influenced unexpectedly by flow rate and debris combinations. Further testing was conducted to gain a better understanding of these phenomena, and this testing indicated significantly greater core differential pressure for one vendor's fuel as compared to another's. This led the staff to request more testing to determine whether the differences were caused by fuel design differences or the fact that testing had been conducted at different facilities.

The PWROG is addressing in-vessel effects generically through a topical report that is currently under staff review. The in-vessel limits proposed by the PWROG are designed to bound all plants. The limits are very low and are likely limiting for most plants with respect to the amount of fibrous material in containment. Even plants that have acceptable strainer results may need further modifications to achieve acceptable in-vessel results. The industry is currently developing methods to show that higher in-vessel debris limits are acceptable. Testing at higher fiber levels revealed that fiber beds build up at the core inlet and in grid spacers. To date industry has not addressed how higher fibrous debris amounts may affect the timing of boric acid precipitation at higher fiber levels.

To properly address in-vessel effects, the impact of chemical, particulate, and fibrous buildup in the core needs to be evaluated. To demonstrate adequate post-LOCA long-term cooling, one must ensure that sufficient coolant injection reaches the core to (1) match core boil off to preclude core uncovery and heatup, and (2) prevention of boric acid precipitation in the core, which can block the coolant channels and inhibit core cooling. The buildup of fibrous material at the core inlet and lower spacer grid locations may inhibit mixing of the boric acid within the core region or between the core region and the lower plenum region of the vessel, causing earlier boron precipitation. The timing of boron precipitation establishes key operator actions intended to prevent boron precipitation. In the current analyses, precipitation timing is based on uninhibited mixing of boric acid within the core and with the lower plenum. Interruption of this mixing could invalidate the operator action timing in the emergency operator procedures to control precipitation. In order to more fully address long term core cooling, licensees need to show that buildup of chemicals, particulates, and fibrous material in the core will not prevent adequate water from entering the core, and to show that operator actions adequately prevent boron precipitation.

RECENT DEVELOPMENTS

Developments since the issuance of SRM-SECY-10-0113 can generally be categorized in three areas: (1) technical developments (e.g., the testing completed in 2011), (2) developments in the South Texas Project Nuclear Operating Company (STP) pilot program, and (3) developments related to alternative approaches.

Technical Developments

As noted in SRM-SECY-10-0113, the industry was to perform analysis and testing in 2011 important to the closeout of GSI-191. Enclosure 1 to SECY-10-0113 provides a detailed description of the technical issues related to ZOI, debris settlement testing, and in-vessel effects, as well as the problems that industry had encountered in addressing these issues. The industry has performed testing or analysis in these three areas, and the staff has now either completed its review or is in the process of reviewing the results.

Zone of Influence

The PWROG has performed additional ZOI testing that resolves the previous test issues. This includes testing that did not involve an upstream choke location, thus ensuring that the jet pressures were as expected for the plant conditions. The ZOI calculational methodology used for the recent round of testing has not been previously evaluated. Initial staff impressions are that the methodology may be acceptable. The testing included instrumented tests that allow a better understanding of jet behavior, a jet model to validate that ZOI test thermodynamic conditions were as expected, and target tests to determine ZOIs for various insulation systems. The staff has reviewed the jet model and observed some of the instrumented tests. However, it has not received a topical report providing a full description of the ZOI refinements. It is unclear when a final determination of acceptance of the new methodology will be available.

Debris Settling

After numerous discussions with vendors and licensees, the staff has agreed to a generic procedure that can be used to perform testing that allows settling, including a resolution of the issues described above. The procedure requires complex calculations using computational fluid dynamics models and comparisons between the plant and the test flume. The procedures also include hold points that the staff must review if the plant-specific implementation of the procedure does not meet certain criteria. Up to this point, no plant has tested using this procedure, so it is not clear whether it will provide a successful methodology. The industry testing that credits settling is behind the schedule proposed by industry when SRM-SECY-10-0113 was issued.

In-Vessel Effects

At the time SECY-10-0113 was written, several questions existed about the in-vessel effects testing, which had shown unexpected variations in results between fuel types. The PWROG completed testing to answer these questions. The PWROG determined that the fuel types in the test program respond similarly and differences in test results were mostly attributable to test facility differences. The testing completed during the test program provides part of the basis for the latest revision to the fuel test topical report. The PWROG submitted the revised topical report (Revision 2 to WCAP-16793, “Evaluation of Long-Term Cooling Considering Particulate, Fibrous and Chemical Debris in the Recirculating Fluid”) in October 2011. The topical report is currently under staff review. The debris limits based on the generic testing are very low, such that in-vessel effects are expected to be the limiting factor for most plants with respect to the amount of fiber in containment.

The industry plans to perform additional testing and evaluations in an attempt to allow some licensees to increase the limits based on plant-specific parameters. The PWROG provided the staff a white paper for information in November 2011. The methodologies described in the white paper were similar to the generic in-vessel effects testing, but using plant-specific flows and driving heads (or flows and driving heads that bound groups of plants instead of all PWRs) to recover margin. Any additional testing will be completed much later than was originally anticipated, delaying licensees' plans for resolution of GSI-191.

The staff's most significant feedback was that the proposed testing did not consider boric acid precipitation. The staff had previously agreed to keep questions of debris blockage and boric acid separate, and the PWROG had separate programs to address each issue. However, information from the in-vessel effects testing showed that, at least at higher fiber amounts, debris beds within the core could result in early boric acid precipitation. Therefore, the staff informed the PWROG that it would need to address boric acid precipitation as part of any plant-specific in-vessel effects testing attempting to raise the acceptable debris limits.

The PWROG reviewed the questions that its boric acid program was attempting to address and developed a path to answer those questions as they relate to debris. The staff held a conference call on February 21, 2012, expressing general agreement with the approach and providing feedback on specific items. The staff met with the PWROG again on March 7, 2012, to discuss the test plans regarding the combined effects of debris and boric acid. The PWROG planned testing that would bound all licensees and demonstrate acceptable core cooling until hot-side injection was initiated. The staff had numerous questions about the accuracy of the scaling in the proposed testing. The staff's position is that the modeling of flow rates and turbulence in the lower plenum need to be well defined for the test results to be prototypical. Since the meeting, the PWROG has continued to develop its test plans. The PWROG plans to complete the testing by June 2013.

Development of South Texas Project Risk-Informed Approach

Since SRM-SECY-10-0113 was issued, the staff has closely followed STP's efforts to develop a risk-informed method for evaluating GSI-191. STP is comparing the risk, measured in core damage frequency (CDF) and large early release frequency (LERF), between the current condition of STP and the postulated condition with STP as a "clean plant." In a sense, this is determining the GSI-191 contribution to CDF and LERF. Enclosure 3 discusses this approach in more detail.

The staff held 12 public meetings with STP to discuss the details of its approach. The staff also visited the plant in November 2011 and attended an STP technical meeting (which was also attended by other licensees that are interested in the approach) in April 2012. The staff has been providing feedback on sensitivities and critical assumptions, both in the meetings and in a letter dated May 4, 2012 (ADAMS Accession No. ML121080006), which STP is factoring into the evaluation. For example, at the staff's prompting, STP is conducting plant-specific testing to validate the chemical effects and the strainer headloss models used in their evaluations.

The staff has been following STP closely to understand how the risk analyses are performed, to assess the viability of a risk-informed approach for the rest of the industry, and to gain insights into areas of conservatism and alternative methods for closing GSI-191. Insights from STP led the staff to recommend Option 2 of this paper, which permits interested licensees to use a risk-informed approach. Insights from STP also led the staff to develop specific conditions other licensees would need to meet to follow STP's approach. Based on STP's preapplication activities, the staff expects that a licensee that chooses to use a risk-informed approach will be able to identify, early in the process, whether the approach will be successful or whether significant modifications (e.g., insulation replacement) will be needed. Option 2 is structured such that licensees would be in a good position to fall back to a deterministic approach with no significant delay in the modifications if the risk-informed approach will not be successful. This is an important aspect of Option 2.

Insights from STP also led the staff to develop Option 3, which permits in-vessel effects to be addressed in a risk-informed manner. STP's evaluation highlighted the importance of event timing and the importance of hot-side injection, which provides a flowpath around any core inlet blockage (although this may not be the case for all plants). It also indicates that the limiting cases modeled and tested by the PRWOG (and that led to the 15 gram in-vessel limit) are unlikely because, for the majority of break sizes and locations, ECCS injection flow is expected to make it to the core even in the event of core inlet blockage. Questions remain about boric acid precipitation, but these questions would be addressed in a risk assessment of in-vessel effects.

Efforts to Identify Alternative Resolution Paths

The staff consulted industry and other stakeholders with the intent of developing alternative solutions, as directed by SRM-SECY-10-0113. The first public meeting was with NEI on January 27, 2011. In that meeting, industry presented its testing plans for ZOI and in-vessel effects, discussed the need for additional guidance for operability determinations, and presented the approach being developed by STP. Industry and staff laid out general plans for future meetings and agreed to further develop the actions.

The staff issued a *Federal Register* (FR) notice (76 FR 24925) on May 3, 2011, which requested public comment on innovative and creative options to close GSI-191 for the staff's consideration. Industry provided comments in two consolidated letters, one from NEI (ADAMS Accession No. ML11189A080) and one from Westinghouse (ADAMS Accession No. ML11188A125). The NEI letter included three attachments covering (1) regulatory frameworks, (2) operability determinations, and (3) recommendations for relaxations in the conservative modeling. NEI noted that the recommendations provided by the letter were not comprehensive and were not ready for implementation, but were intended to promote discussions of potential methods to risk inform the resolution of GSI-191. The Westinghouse letter did not provide alternative options, but endorsed those provided by NEI.

The regulatory frameworks discussed by the NEI letter were varying degrees of risk informing the GSI-191 issue. The potential methods range from the existing deterministic approach to a fully risk-informed approach being developed by STP. Intermediate approaches included the use of a transition break size (TBS). For breaks smaller than the TBS, the issue would be addressed deterministically using existing guidance. For breaks larger than the TBS, the licensee could use a more realistic evaluation, credit operator actions, and defense-in-depth, and design-basis rules would not apply. The staff had already issued a methodology for using the TBS approach as part of its SE on NEI 04-07. The NEI letter stated that the TBS approach in the staff's SE to NEI 04-07 had not been fully utilized because the conservative modeling assumptions approved by the staff SE had not been adequately relaxed.

The operability determinations discussed in the NEI letter relate to the industry's concern that discoveries of nonconforming conditions in the plant (e.g., finding material that could contribute to ECCS strainer or in-vessel blockage that was not considered in the plant evaluations) will result in the determination that the ECCS is inoperable. The NEI letter expressed the position that conservatisms associated with the currently installed strainers should be credited if an emergent condition associated with strainer operability is discovered. The letter also stated that it may be appropriate to develop a risk-informed technical specification for sump strainers if the risk of continued operation in a degraded condition is below an established threshold. The staff is open to consideration of such an effort and is awaiting industry action on this issue. (The staff proposed that Option 3 of this paper could be used for operability determinations.)

Regarding the recommended relaxations in the deterministic methods contained in the NEI letter, in general the proposals were already in use by licensees, were industry works in progress, or were general ideas that were not fully developed. The staff had already reviewed, but not accepted, some of the recommendations. Therefore, the staff concluded that the response to the FR notice provided little in the way of innovative or creative suggestions that would readily assist in the near-term closure of GSI-191.

The staff met with NEI on September 21, 2011, to discuss its response to the FR notice in more detail. Industry representatives agreed to further develop those recommended relaxations that were perceived to provide the most benefit and that were most likely to receive near-term staff approval, based on the staff's feedback at the meeting. However, by the time of the meeting, it had become apparent that in-vessel effects would be the limiting factor for most plants with respect to the amount of fiber in containment. The perception was that refinements to limiting assumptions, even when combined, would not help a plant meet the very low fiber limits for in-vessel effects. In summary, in-vessel effects significantly restricted the alternatives for resolving GSI-191.

Following the September 2011 meeting, the industry (NEI and the PWROG) further developed several of the options and relaxations and provided white papers to the staff either for review or for information. Those white papers are discussed in more detail under the pertinent technical issues sections in this paper.

<u>Staff Consideration of Alternative That Credits Leak Before Break for In-Vessel Effects</u>

SECY-10-0113 contained considerable discussion about using leak before break (LBB) for GSI-191 evaluations and concluded that LBB should not be used for sump strainer issues. In Option 3 of the current SECY, the staff proposed to separate the manner in which in-vessel effects and strainer clogging are addressed. LBB is one means considered by the staff for addressing in-vessel effects. The staff does not recommend this approach.

The staff position in SECY-10-0113 was that LBB should not be applied to GSI-191 sump strainer evaluations: LBB may be applied to local dynamic effects but not to global dynamic effects. The staff considered debris generation within GSI-191 to have global dynamic effects because of the potential to render the containment sump unable to fulfill its safety functions. That is, the containment systems, ECCS, and equipment qualifications are related to global effects; therefore, as described in the Statements of Consideration (SOCs) accompanying the final rule modifying General Design Criterion 4, "Environmental and dynamic effects design basis," of Appendix A to 10 CFR Part 50, LBB was not applicable. The SOCs state:

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

The staff found that while the application of LBB to the containment sump evaluations may have alleviated the need for licensees to modify containment sumps or remove fibrous pipe insulation, it could threaten successful strainer performance. The staff did not find this reduction of defense-in-depth to be acceptable.

In the present case, the staff finds that applying LBB only to in-vessel effects continues to result in a decrease in defense-in-depth, however, the extent of that decrease is reduced. Licensees would still be required to modify containment sumps and remove sufficient fibrous insulation to demonstrate post-LOCA sump strainer performance is acceptable, such that ECCS and CSS would remain operable. Potential in-vessel blockage would not render containment cooling or pressure control inoperable, fission product scrubbing (via CSS) would still be available, and sufficient ECCS flow would likely reach the core for most break sizes and locations (e.g., via ECCS hot-side injection if it is initiated early enough). However, in-vessel effects could obstruct the normal flow paths from the ECCS to the core, and thus would fall under “affecting emergency core cooling systems” as discussed in the SOCs.

If LBB were applied to in-vessel effects, in-vessel evaluations would only consider latent debris and debris generated from breaks in nonqualified piping. Debris from breaks in LBB-qualified piping could be treated as beyond design basis, meaning the debris would be treated as a severe accident for which licensees would be expected to prepare prevention and mitigation strategies, accordingly.

However, this approach may not result in a significant reduction in the scope of modifications and associated occupational exposure needed to resolve GSI-191, latent debris would still need to be addressed, and there is no clear increase in safety to counter the potential reduction in defense-in-depth that this approach would entail. Furthermore, no licensee has expressed interest in this approach. Therefore, the staff does not recommend this approach.