

## PWR SUMP PERFORMANCE GSI-191

TAC Nos. MA6454, MA2452, MA4014, MA0704, M95473, MA6204, MA0698, MB4047, MB6411, MB3103, MB8052, MB7776, MB9470, MB4864, MB9931, MC0307, MC1154, MB9549, MC4272, MC5881, MC6467, MC6470, MB5625, MB4865, MC0725/6, MB5221, MB5964, MB6589, MB7228, MC1627, MB5334, MC2628, MB6946, MC6659, MC6661, MC6730, MC6731, MC7565, MC7564, MC9003, MD1058, and MC9446

Last Update: 03/17/2009  
 Lead NRR Division: DSS  
 Supporting Divisions: DE, DCI, DORL, DRA, and MEEB(RES)

MILESTONES	DATE (T/C) T=target C=complete
<b>PART I: BWR ECCS SUCTION STRAINER CLOGGING ISSUE</b>	
1. Bulletin 96-03, "Potential Plugging of Emergency Core Cooling Suction Strainers by Debris in Boiling-Water Reactors"	10/01 (C)
<b>PART II: NPSH EVALUATIONS</b>	
1. GL 97-04, "Assurance of Sufficient Net Positive Suction Head for Emergency Core Cooling and Containment Heat Removal Pumps" <ul style="list-style-type: none"> <li>o Complete review of licensee responses</li> <li>o Complete revision of RG 1.1/RG 1.82, R3</li> </ul>	03/00 (C) 11/03 (C)
<b>PART III: CONTAINMENT COATINGS</b>	
1. GL 98-04, "Potential for Degradation of the Emergency Core Cooling System and the Containment Spray System after a Loss-Of-Coolant Accident Because of Construction and Protective Coating Deficiencies and Foreign Material in Containment"	07/00 (C)
2. NRC-sponsored research program on the potential for coatings to fail during an accident	03/01 (C)
3. Coatings Condition Assessment Guidance	03/08 (C)
4. Confirmatory Coatings Transport Testing	06/05 (C)
<b>PART IV: GSI 191, "ASSESSMENT OF DEBRIS ACCUMULATION ON PRESSURIZED WATER REACTOR (PWR) SUMP PERFORMANCE"</b>	

MILESTONES	DATE (T/C) T=target C=complete
<p>1. NRC-sponsored research program on the potential for loss of ECCS NPSH during a LOCA due to clogging by debris</p> <ul style="list-style-type: none"> <li>○ Preliminary (qualitative) risk assessment (NRR)</li> <li>○ Complete collection of plant data to support research program</li> <li>○ Integrate industry activities into this Action Plan</li> <li>○ Complete research program on PWR sump blockage</li> <li>○ Evaluate need for regulatory action based on research program results (NRR)</li> </ul>	<p>03/99 (C) 06/99 (C)  04/00 (C) 09/01 (C) 03/02 (C)</p>
<p>2. Chemical effects: Determine if sump pool environment generates by-products which contribute to sump clogging (ANL Testing)</p> <ul style="list-style-type: none"> <li>○ Debris Transport &amp; Head loss: Confirmatory research tests on debris transport of coatings and head losses associated with PWR containment materials with and without chemical effects</li> <li>○ Downstream effects: Confirmatory research on the effect of injected debris on HPSI throttle valve performance</li> </ul>	<p>05/06 (C)  05/06 (C)  03/06(C)</p>

MILESTONES	DATE (T/C) T=target C=complete
<p>3. Resolve ECCS suction clogging issue for PWRs (Regulation/Guidance Development and Issuance, Implementation and Verification Stages of GSI process in MD 6.4)</p> <ul style="list-style-type: none"> <li>○ Brief NRR ET to obtain approval to prepare a generic letter (GL) 02/02 (C)</li> <li>○ Public meeting with NEI, WOG, B&amp;WOG, CEOG 03/02 (C)</li> <li>○ ACRS Briefing on proposed draft GL 02/03 (C)</li> <li>○ CRGR Briefing on proposed Bulletin 2003-01 04/03 (C)</li> <li>○ Information Paper to Commission, Issue Bulletin 2003-01 06/03 (C)</li> <li>○ NEI publish PWR Industry Evaluation Guidelines (Draft) 10/03 (C)</li> <li>○ CRGR Briefing on proposed draft GL 02/04 (C)</li> <li>○ Proposed draft GL issued for Public Comment 03/04 (C)</li> <li>○ GL issuance 09/04 (C)</li> <li>○ Issue Safety Evaluation on Methodology 12/04 (C)</li> <li>○ NRC starts Reviews of GL Responses and Selective Audits 09/05 (C)</li> <li>○ GL date for licensees to start modifications 04/06 (C)</li> <li>○ Interim meeting with ACRS on GSI-191 activities 06/07 (C)</li> <li>○ Start review of final supplemental responses to GL 02/08 (C)</li> <li>○ Complete review of supplemental responses to GL 06/09(T)</li> <li>○ Staff completes and documents reviews of RAI responses (except those related to in-vessel downstream effects) and, as appropriate, identifies need for additional interactions with affected licensees 06/09(T)</li> <li>○ Complete Temporary Instruction 2515/166 inspections of plant changes 10/08(C)</li> <li>○ Complete plant audits 04/08 (C)</li> <li>○ PWROG submits revised topical report on in-vessel downstream effects 04/09(T)</li> <li>○ PWROG and staff make presentations to ACRS on PWROG revised topical report on in-vessel downstream effects 06/09(T)</li> <li>○ Staff issues final safety evaluation of PWROG revised topical report on in-vessel downstream effects 12/09(T)</li> <li>○ Staff completes review of RAI responses related to in-vessel downstream effects and revised head loss testing and corresponds with licensees as needed 03/10(T)</li> <li>○ NRC issues GL 2004-02 closure memorandum after having issued GL 2004-02 closure letters to all licensees and closes GSI-191 implementation phase 09/10(T)</li> </ul>	

Description: This action plan was originally prepared to comprehensively address the adequacy of ECCS suction design, and to ensure adequate ECCS pump net positive suction head (NPSH)

during a loss-of-coolant accident (LOCA). Specifically, the concern is whether debris could clog ECCS suction strainers or sump screens during an accident and prevent the ECCS from performing its safety function. The plan is risk informed.

This plan has four parts, two of which have been completed. First, for boiling-water reactors (BWRs), this issue has been addressed by licensee responses to NRC Bulletin 96-03. Second, the adequacy of licensee (both PWR and BWR) net positive suction head (NPSH) calculations was evaluated through NRR review of licensee responses to GL 97-04, "Assurance of Sufficient Net Positive Suction Head for Emergency Core Cooling and Containment Heat Removal Pumps," dated October 7, 1997. The third part of the plan assessed the adequacy of the implementation and maintenance of licensee coating programs through NRR review of licensee responses to GL 98-04, "Potential for Degradation of the Emergency Core Cooling System and the Containment Spray System after a Loss-of-Coolant Accident Because of Construction and Protective Coating Deficiencies and Foreign Material in Containment," dated July 14, 1998. This part of the plan was reopened to track development of guidance for coatings condition assessment and the NRC confirmatory coatings transport testing program.

The remaining part of the action plan is an evaluation of the potential for clogging of PWR ECCS recirculation sumps during a LOCA. RES completed its assessment of the potential for debris clogging to support the resolution of GSI-191, "Assessment of Debris Accumulation on PWR Sump Performance." By memorandum dated September 28, 2001, RES transferred the lead for GSI-191 to NRR.

Historical Background: During licensing of most domestic power plants, consideration of the potential for loss of adequate NPSH due to blockage of the ECCS suction by debris generated during a LOCA was inadequately addressed by both the NRC and licensees. The staff first addressed ECCS clogging issues in detail during its review of Unresolved Safety Issue (USI) A-43, "Containment Emergency Sump Performance." GL 85-22, "Potential for Loss of Post-LOCA Recirculation Capability due to Insulation Debris Blockage," dated December 3, 1985, documented the NRC's resolution of USI A-43. NUREG-0897, Revision 1, "Containment Emergency Sump Performance" (October 1985), contained technical findings related to USI A-43, and was the principal reference for developing revised regulatory guidance.

Since the resolution of USI A-43, new information, including events and research, challenged the adequacy of the NRC's conclusion that no new requirements were needed to prevent clogging of ECCS strainers in BWRs. The Barsebäck event demonstrated that the potential exists for a pipe break to generate insulation debris and transport a sufficient amount of the debris to the suppression pool to clog the ECCS strainers.

Events at the Perry Nuclear Power Plant demonstrated high strainer pressure drop caused by the filtering of suppression pool particulates (corrosion products or "sludge") by fibrous materials adhering to the ECCS strainer surfaces. The effect of particulate filtering on head loss had been previously unrecognized. Therefore, its effect had not been considered. An event at Limerick Unit 1 demonstrated the importance of foreign material exclusion practices to ensure adequate suppression pool and containment cleanliness. In addition, the event re-emphasized that materials other than fibrous insulation could clog strainers.

Bulletin 96-03, "Potential Plugging of Emergency Core Cooling Suction Strainers by Debris in Boiling-Water Reactors," was issued on May 6, 1996, requesting BWR licensees to implement appropriate procedural measures and plant modifications to minimize the potential for clogging of ECCS suction strainers by debris generated during a LOCA. Regulatory Guide 1.82,

Revision 2, (RG 1.82), "Water Sources for Long-Term Recirculation Cooling Following a Loss-of-Coolant Accident," was issued in May 1996 to provide non-prescriptive guidance on performing plant-specific analyses to evaluate the ability of the ECCS to provide long-term cooling consistent with the requirements of 10 CFR 50.46. In response to Bulletin 96-03, all affected BWR licensees have installed new larger-capacity passive strainers.

RES conducted an evaluation of the potential for PWRs to lose NPSH due to clogging of ECCS sump screens by debris during an accident because of new information learned during the development and resolution of Bulletin 96-03. With more and finer debris, the potential for clogging of the ECCS sump screens becomes greater, leading to the need to evaluate the potential for clogging of PWR sumps. RES's evaluation included a risk assessment.

Events at a number of plants raised concerns regarding potential for coatings to form debris during an accident which could clog an ECCS suction path. In several cases qualified coatings have delaminated during normal operating conditions. Typically, the root cause has been attributed to inadequate surface preparation. This led the staff to raise questions regarding the adequacy of licensee coating programs. The staff issued GL 98-04 to obtain necessary information from licensees to evaluate how they implement and maintain their coating programs. In addition, RG 1.54 was revised to update guidance for the selection, qualification, application, and maintenance of protective coatings in nuclear power plants to be consistent with the then current ASTM Standards. RES also conducted research aimed at providing technical information regarding the failure of coatings. The program evaluated the failure modes of coatings, the likely causes, the characteristics (e.g., size, shape) of the debris, and the timing of when coatings would likely fail during an accident.

The PWR Industry is implementing a two-step program to assess the current sump conditions and evaluate sump recirculation performance. The program consists of the performance of actions recommended in two NEI guidance documents in order to address an NRC Bulletin and an NRC Generic Letter. The first guidance document, NEI 02-01, "Condition Assessment Guidelines: Debris Sources inside Containment," was published in September 2002. Consistent with the risk significance of the PWR sump clogging concern, the staff issued Bulletin 2003-01 on June 9, 2003, requesting information on compliance with applicable regulatory requirements within 60 days or information on interim compensatory measures to reduce risk until an evaluation to determine compliance is completed. The staff issued requests for additional information for the bulletin as needed, completed the review of licensee's responses, and issued closeout letters. NEI submitted the second guidance document, NEI 04-07 "PWR Containment Sump Evaluation Methodology," on May 28, 2004. This document recommended methodologies for evaluating a PWR's susceptibility to sump clogging. The staff safety evaluation (SE) of the methodology, issued December 6, 2004, provided licensees an NRC-approved methodology to complete the site-specific evaluations called for in Generic Letter 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors."

GL 2004-02, issued in September 2004, called for evaluations of sump performance in the presence of plant-specific post-LOCA debris loading. It also stated that these evaluations, and any needed plant modifications to show satisfactory sump performance, should be completed by December 31, 2007.

The NRC staff received GL responses from all PWR licensees. The staff found that additional information was needed and sent requests for additional information (RAIs) to each PWR licensee in February 2006. The staff subsequently determined that licensees could address the intent of the RAIs in conjunction with each licensee's final supplemental response to GL 2004-02, which the staff expected to receive by December 31, 2007. This date was subsequently extended to February 28, 2008.

One aspect of the sump performance issue, the potential for chemical effects on strainers and downstream components, has revealed itself to be particularly challenging. To address concerns regarding the potential for chemical precipitates and corrosion products to significantly block a fiber bed and increase the head loss across an emergency core cooling system sump screen, a joint NRC/industry Integrated Chemical Effects Testing program was started in 2004 and completed in August 2005. Chemical precipitation products were identified during the test program, and follow-up testing and analyses were performed to address the effect on head loss. Information Notice (IN) 2005-26, "Results of Chemical Effects Head Loss Tests in a Simulated PWR Sump Pool Environment," was issued on September 16, 2005.

The NRC conducted additional research in certain areas to support evaluation efforts and provide confirmatory information. These areas include research on chemical effects to determine if the pressurized-water reactor sump pool environment generates byproducts which contribute to sump clogging, research on pump head losses caused by accumulation of containment materials and chemical byproducts, and research to predict the chemical species that may form in these environments. Supplement 1 to IN 2005-26, "Additional Results of Chemical Effects Tests in a Simulated PWR Sump Pool Environment," specifically provided additional information regarding test results related to chemical effects in environments containing dissolved phosphate (e.g., from trisodium phosphate) and dissolved calcium. The results discussed in the INs clearly demonstrated the potential for chemical effects to be significant. Follow-on testing sponsored by some licensees has also shown the potential for substantial head loss increases from chemical effects.

Research was also conducted on the transportability of coating chips in containment pool environments, and on the effect of ingested debris on downstream valve performance. Between July and September 2006, the staff completed additional research on various subjects of the sump clogging issue. All planned NRC-sponsored research activities related to PWR sump clogging are now complete and documented, though information obtained as the staff reviews industry activities to support issue closure may indicate the need for additional NRC-sponsored research.

The NRC has developed a web page to keep the public informed of regulatory and research activities related to PWR sump performance:

<http://www.nrc.gov/reactors/operating/ops-experience/pwr-sump-performance.html>

This web page provides links to information regarding NRC interactions with industry (industry submittals, meeting notices, presentation materials, and meeting summaries) and publically available regulatory and research documents. The NRC will continue to update these web pages as new information becomes available.

Proposed Actions: This action plan involves an evaluation of PWR sumps based on new information learned during and following the staff's resolution of Bulletin 96-03. RES conducted a program to evaluate PWR sump designs and their susceptibility to blockage by debris. Risk insights supported the conclusions drawn relative to the need for licensees to address the potential for ECCS suction clogging. The results of the RES parametric evaluation form a credible technical basis for concluding that sump blockage is a generic concern for PWRs. As a result of research work and plant experience, the NRC additionally requested that PWRs evaluate potential downstream and chemical effects as part of the resolution of GSI-191.

Originating Document: Not Applicable.

Regulatory Assessment: Title 10, Section 50.46 of the *Code of Federal Regulations* (10 CFR 50.46) requires that licensees design their ECCS systems to meet five criteria, one of which is to provide the capability for long-term cooling. This criterion requires that, following a successful system initiation, the ECCS shall be able to provide cooling for a sufficient duration such that the core temperature is maintained at an acceptably low value. In addition, the ECCS shall be able to continue decay heat removal for the extended period of time required by the long-lived radioactivity remaining in the core. The ECCS is designed to meet this long-term cooling criterion, assuming the worst single failure.

The staff considers continued operation of PWRs during the implementation of this action plan to be acceptable because the probability of the most challenging initiating event (i.e., large break LOCA) is extremely low. More probable (although still low probability) LOCAs (small, intermediate) will generate smaller quantities of debris, require less ECCS flow, take more time to use up the water inventory in the refueling water storage tank, and in some cases may not require the use of recirculation from the ECCS sump because the flow through the break would be small enough that the operator will have sufficient time to safely shut the plant down. In addition, all PWRs have received approval by the staff for leak-before-break credit on their largest RCS primary coolant piping. While leak-before-break is not acceptable for demonstrating compliance with 10 CFR 50.46, it does demonstrate that leak-before-break-qualified piping is of sufficient toughness that it will most likely leak (even under safe shutdown earthquake conditions) rather than rupture. This, in turn, would allow operators adequate opportunity to shut the plant down safely. Additionally, the staff notes that there are sources of margin in PWR designs which may not be credited in the licensing basis for each plant. For instance, NPSH analyses for most PWRs do not credit containment overpressure (which would likely be present during a LOCA). Any containment pressure greater than assumed in the NPSH analysis provides additional margin for ECCS operability during an accident. Another example of margin is that in many cases, ECCS pumps would be able to continue operating for some period of time under cavitation conditions. Some licensees have vendor data demonstrating this. Design margins such as these examples may prevent complete loss of ECCS recirculation flow or increase the time available for operator action (e.g., refilling the refueling water storage tank) prior to loss of flow. Finally, the staff believes that continued operation of PWRs is also acceptable because of PWR design features which may minimize potential blockage of the ECCS sumps during a LOCA. The RES study on sump blockage attempted to capture many of the PWR design features parametrically. However, it is not possible for a generic study of this nature to capture all the variations in plant-specific features that could affect the potential for ECCS sump blockage (piping layouts, compartments, insulation location within containment, etc.). Therefore, evaluation on a plant-specific basis is necessary to determine the potential for ECCS sump clogging.

As part of the GSI-191 study, Los Alamos National Laboratory, performed a generic risk assessment to determine how much core damage frequency (CDF) is changed by the findings of the parametric analysis. Utilizing initiating event frequencies that consider leak-before-break credit consistent with NUREG/CR-5750, Los Alamos National Laboratory calculated an overall CDF of  $3.3E-06$  when debris clogging as a failure mechanism is not considered, and an overall CDF of  $1.5E-04$  when debris clogging is considered. However, these CDFs were calculated without giving any credit for operator action, and without consideration of whether the ECCS or containment spray pumps would be able to continue operating if the headloss across the sump screen exceeds the calculated licensing basis NPSH margin. The change in CDF is also dominated by small and very small break LOCAs, events for which significant operator actions can be taken to prevent core damage. The risk benefit of certain interim compensatory measures is demonstrated by the NRC-sponsored technical report LA-UR-02-7562, "The Impact of Recovery from Debris-Induced Loss of ECCS Recirculation on PWR Core Damage Frequency," dated February 2003. On this basis, the schedule for issuing generic communications and follow-on actions to address the PWR sump clogging issue is considered to be appropriate.

Current Status: The staff continues to hold regular public meetings with stakeholders including the Advisory Committee on Reactor Safeguards (ACRS), PWR licensees, strainer vendors and the NEI sump performance task force on the progress in resolving GSI-191. Meetings with NEI, licensees, and sump strainer vendors occur as needed, with the most recent in January 2009.

As GSI-191 approaches resolution, the staff is using several approaches to obtaining reasonable assurance that sumps will perform adequately if called upon following a LOCA. First, the staff is reviewing each licensee's final supplemental response to GL 2004-02. In addition, the staff is conducting inspections at each PWR to verify that licensees have made changes to which they have committed in correspondence with the NRC. Finally, the staff conducted comprehensive audits of corrective actions for GL 2004-02 at a sample of PWRs. Audits have been completed and reports issued for Watts Bar, San Onofre, Prairie Island, Millstone, Oconee, Waterford, North Anna, Salem, and Indian Point. Since licensees' chemical effects evaluations were not complete during these audits, the NRC staff concluded that it would be appropriate to perform additional audits focusing only on chemical effects. The staff performed chemical effects audits at North Anna, Palisades, and is considering one more candidate plant.

The NRC reviewed an industry topical report developed to support evaluation and testing of chemical effects. Review of another topical report that addresses effects of debris downstream of sump strainers on components such as pumps and valves has also been completed. Safety evaluations for both reports have been issued. An additional topical report addressing the downstream effects of post-LOCA debris inside the reactor vessel was submitted to the NRC for review in June 2007. NRC staff and ACRS identified technical issues with the WCAP and, therefore, the PWROG is conducting additional testing to respond to these issues. A revised WCAP is scheduled to be submitted on April 13, 2009, and final staff safety evaluation issued on December 30, 2009. The staff has also reviewed several technical reports related to the potential for protective coatings to contribute to the debris source term.

Other current work includes a scoping study sponsored by RES to consider whether certain potential issues raised with regard to chemical effects need additional work. Draft NUREG/CR-6988 on this topic is close to being published. RES is evaluating what future chemical effects research work is warranted. The NRC staff is also interacting with vendors who are performing strainer testing for licensees. The purpose of these discussions, as well as ongoing staff observations of strainer tests, is to gain confidence that the test practices involved are rigorous in order to support reasonable assurance that the technical issues associated with GSI-191 have been addressed.

Many licensees have completed integrated head loss testing. Some of these licensees may have to retest based on staff questions regarding the test procedures that were used. These licensees are currently performing additional testing, or are scheduled to test when test facilities become available. The testing being performed by these licensees is termed "test for success." The test for success program tests various plant configurations including the current configuration, and, if required, modified plant configurations containing less debris. The test defines any modifications that the plant will have to make to demonstrate adequate ECCS and CS pump operation in recirculation.

All PWRs have substantially enlarged their sump strainers, typically by one to two orders of magnitude. Some licensees have obtained permission from the NRC to complete certain corrective actions later than the December 31, 2007 due date in GL 2004-02. The staff has based authorization for such extensions (typically for a few months) on information provided by the requesting licensee that shows the extension to be of low risk and on criteria the staff identified to the Commission in SECY-06-0078, Status of Resolution of GSI-191, "Assessment of [Effect Of] Debris Accumulation on PWR Sump Performance," dated March 31, 2006.

NRR Lead PMs: Joe Golla, DPR 415-1002 (GL 2004-02)

NRR Lead Branch Chief: Michael Scott, SSIB, 415-0565

NRR Technical Contacts: Ralph Architzel, SSIB, 415-2804 (Audit Team Lead, Historical Perspective)  
John Lehning, SSIB, 415-1015 (NPSH and Head loss)  
Paul Klein, CSGB, 415-4030 (Chemical Effects)  
Matt Yoder, CSGB, 415-4017 (Coatings)  
Steve Smith, SSIB, 415-3190 (Head Loss Testing)  
Ervin Geiger, SSIB, 415-5680 (Downstream Effects)

RES Technical Contacts: Rob Tregoning, DE, 301-251-7662  
John Burke, MEEB, 301-251-7628

References:

Regulatory Guide 1.54, "Quality Assurance Requirements for Protective Coatings Applied to Water-Cooled Nuclear Power Plants" (Draft DG-1076, Proposed Revision 1, published March 1999), dated June 1973.

NRC Bulletin 93-02, "Debris Plugging of Emergency Core Cooling Suction Strainers," dated May 11, 1993.

NRC Bulletin 93-02, Supplement 1, "Debris Plugging of Emergency Core Cooling Suction Strainers," dated February 18, 1994.

NUREG/CR-6224, "Parametric Study of the Potential for BWR ECCS Strainer Blockage Due to LOCA Generated Debris" dated October 1995.

NRC Bulletin 95-02, "Unexpected Clogging of Residual Heat Removal (RHR) Pump Strainer While Operating in Suppression Pool Cooling Mode," dated October 17, 1995.

NRC Bulletin 96-03, "Potential Plugging of Emergency Core Cooling Suction Strainers by Debris in Boiling-Water Reactors" dated May 6, 1996.

NRC Bulletin 2003-01, "Potential Impact of Debris Blockage on Emergency Sump Recirculation at Pressurized-Water Reactors" dated June 9, 2003.

Regulatory Guide 1.82, Revision 3, "Water Sources for Long-Term Recirculation Cooling Following a Loss-of-Coolant Accident," dated November 2003.

GL 97-04, "Assurance of Sufficient Net Positive Suction Head for Emergency Core Cooling and Containment Heat Removal Pumps," dated October 7, 1997.

GL 98-04, "Potential for Degradation of the Emergency Core Cooling System and the Containment Spray System after a Loss-of-Coolant Accident Because of Construction and Protective Coating Deficiencies and Foreign Material in Containment," dated July 14, 1998.

Memorandum from Richard J. Barrett to John N. Hannon, "Preliminary Risk Assessment of PWR Sump Screen Blockage Issue," dated March 26, 1999.

Memorandum from K. Kavanagh to G. Holahan, "Report on Results of Staff Review of NRC Generic Letter 97-04, 'Assurance of Sufficient Net Positive Suction Head for Emergency Core Cooling and Containment Heat Removal Pumps,'" dated June 26, 2000.

Letter from Gary M. Holahan to James F. Klapproth, "NRC Staff Review of GE Licensing Topical Report NEDC-32721P, 'Application Methodology for the General Electric Stacked Disk ECCS Suction Strainers,' TAC Number M98500," dated June 21, 2001.

NUREG/CR-6762, "GSI-191: Parametric Evaluations for Pressurized Water Reactor Recirculation Sump Performance," dated August 2002.

Memorandum from Ashok C. Thadani to Samuel J. Collins, "RES Proposed Recommendation for Resolution of GSI-191, 'Assessment of Debris Accumulation on PWR Sump Performance,'" dated September 28, 2001 (Accession Number ML012750149).

Memorandum from Robert B. Elliott to Gary M. Holahan, "Completion of Staff Reviews of NRC Bulletin 96-03, "Potential Plugging of Emergency Core Cooling Suction Strainers by Debris in Boiling-water Reactors," and NRC Bulletin 95-02, "Unexpected Clogging of a Residual Heat Removal (RHR) Pump Strainer While Operating in Suppression Pool Cooling Mode" dated October 18, 2001 (Accession Number ML012970261).

NEI 02-01, "Condition Assessment Guidelines: Debris Sources inside Containment," Revision 1 published in September 2002.

NEI 04-07, PWR Sump Performance Evaluation Methodology, December 2004.

Technical Letter Report LA-UR-02-7562, "The Impact of Recovery from Debris-Induced Loss of ECCS Recirculation on PWR Core Damage Frequency," dated February 2003.

NUREG/CR-6808, "Knowledge Base for the Effect of Debris on Pressurized Water Reactor ECCS Sump Performance" dated February 2003.

Letter from Mario V. Bonaca to Nils Diaz, "Draft Final Revision 3 to Regulatory Guide 1.82, "Water Sources for Long Term Recirculation Cooling Following a Loss of Coolant Accident"," dated September 30, 2003.

Generic Letter 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized Water Reactors," dated September 13, 2004.

GSI-191 Safety Evaluation, "Pressurized Water Reactor Containment Sump Evaluation Methodology," dated December 6, 2004.

NRC Information Notice 2005-26, "Results of Chemical Effects Head Loss Tests in a Simulated PWR Sump Pool Environment" issued September 16, 2005.

NRC Information Notice 2005-26, Supplement 1: "Additional Results of Chemical Effects Tests in a Simulated PWR Sump Pool Environment," issued January 20, 2006.

WCAP-16530-NP, "Evaluation of Post Accident Chemical Effects in Containment Sump Fluids to Support GSI-191," February 28, 2006.

Letter from Catherine Haney to all pressurized water reactor licensees, "Alternative Approach for Responding to the Nuclear Regulatory Commission Request for Additional Information Letter Re: Generic Letter 2004-02," dated March 28, 2006.

SECY-06-0078, Status of Resolution of GSI-191, "Assessment of [Effect Of] Debris Accumulation on PWR Sump Performance," dated March 31, 2006.

WCAP 16406-P, "Evaluation of Downstream Sump Debris Effects in Support of GSI-191," June 2, 2006.

WCAP 16376-NP, "Evaluation of Long-Term Cooling Considering Particulate, Fibrous and Chemical Debris in the Recirculating Fluid," May 2007.