UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

September 17, 2015

Mr. Joseph W. Shea
Vice President, Nuclear Licensing
Tennessee Valley Authority
1101 Market Street, LP 3R-C
Chattanooga, Tennessee, TN 37402-2801

SUBJECT: WATTS BAR NUCLEAR PLANT, UNIT 1, CLOSEOUT OF GENERIC LETTER 2004-02, "POTENTIAL IMPACT OF DEBRIS BLOCKAGE ON EMERGENCY RECIRCULATION DURING DESIGN BASIS ACCIDENTS AT PRESSURIZED-WATER REACTORS" (TAC NO. MC4730)

Dear Mr. Shea:

The U.S. Nuclear Regulatory Commission (NRC) issued Generic Letter (GL) 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors" (Agencywide Documents Access and Management System (ADAMS) Accession No. ML042360586) dated September 13, 2004, requesting that licensees address the issues raised by Generic Safety Issue 191, "Assessment of Debris Accumulation on Pressurized-Water Reactor Sump Performance."

The stated purpose of GL 2004-02 was focused on demonstrating compliance with Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50 Section 50.46, "Acceptance Criteria for Emergency Core Cooling Systems [ECCSs] for Light Water Reactors." Specifically, the GL 2004-02 requested addressees to perform an evaluation of the ECCS and Containment Spray System (CSS) recirculation and, if necessary, take additional action to ensure system function, in light of the potential susceptibility of pressurized-water reactor sump screens to blockage during a Design-Basis Accident (DBA) requiring recirculation operation of the ECCS or CSS, and on the potential for additional adverse effects due to debris blockage of flowpaths necessary for ECCS and CSS recirculation and containment drainage.

By letters dated March 7, 2005 (ADAMS Accession No. ML050700255), July 21, 2005 (ADAMS Accession No. ML052080065), and September 1, 2005 (ADAMS Accession No. ML052490347), Tennessee Valley Authority (TVA, the licensee) provided responses to GL 2004-02 for the Watts Bar Nuclear Plant, Unit 1. Additionally, TVA provided supplemental information in response to NRC requests for additional information by letters dated April 11, 2006 (ADAMS Accession No. ML061040219), July 3, 2006 (ADAMS Accession No. ML062910508), August 1, 2007 (ADAMS Accession No. ML072150109), October 2, 2007 (ADAMS Accession No. ML072760449), March 31, 2008 (ADAMS Accession No. ML081090500), March 3, 2009 (ADAMS Accession No. ML090720868), April 1, 2010 (ADAMS Accession No. ML100960020), June 3, 2010 (ADAMS Accession No. ML101590373), August 15, 2011 (ADAMS Accession No. ML11229A783), and April 17, 2015 (ADAMS Accession No. ML15111A065).

The NRC staff performed a thorough review of all TVA submittals and supplements regarding GL 2004-02 for Watts Bar Nuclear Plant, Unit 1 (WBN Unit 1). The NRC staff finds that the TVA provided sufficient information, as requested by GL 2004-02, to demonstrate that debris will not

inhibit the ECCS or CSS performance of its intended safety function in accordance with 10 CFR 50.46 to assure adequate long term core cooling following a DBA. Therefore, the NRC staff concludes that the licensee's response to GL 2004-02 is adequate and considers GL 2004-02 closed for WBN Unit 1. No further information or action is requested of the licensee. The NRC staff's findings are documented in the enclosed summary.

If you have any questions, please call me at 301-415-2048 or via e-mail at Jeanne.Dion@nrc.gov.

Sincerely,

Mark D Clark for

Jeanne A. Dion, Project Manager
Watts Bar Special Projects Branch
Division of Operating Reactor Licensing
Office of Nuclear Reactor Regulation

Docket No.: 50-390

Enclosure:
Staff Review

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U.S. NUCLEAR REGULATORY COMMISSION STAFF REVIEW OF THE DOCUMENTATION PROVIDED BY TENNESSEE VALLEY AUTHORITY FOR THE WATTS BAR NUCLEAR PLANT, UNIT 1 DOCKET NO. 50-390 CONCERNING RESOLUTION OF GENERIC LETTER 2004-02 POTENTIAL IMPACT OF DEBRIS BLOCKAGE ON EMERGENCY RECIRCULATION DURING DESIGN-BASIS ACCIDENTS AT PRESSURIZED-WATER REACTORS

1.0 INTRODUCTION

A fundamental function of the Emergency Core Cooling System (ECCS) is to recirculate water that has collected at the bottom of the containment through the reactor core following a break in the reactor coolant system (RCS) piping to ensure long-term removal of decay heat from the reactor fuel. Hypothetical scenarios, known as loss-of-coolant accidents (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 reactor decay heat following a LOCA to prevent core damage. Long-term cooling following a LOCA is a basic safety function for nuclear reactors. The recirculation sump, in the basement of pressurized-water reactor (PWR) containment buildings, provides a water source to the ECCS once the primary water source has been depleted.

If a LOCA occurs, piping thermal insulation and other materials may be dislodged by the two-phase coolant jet emanating from the broken RCS pipe. This debris may transport, via flows coming from the RCS break or from the containment spray system (CSS), to the pool of water that collects at the bottom of containment following a LOCA. Once transported to the sump pool, the debris could be drawn towards the ECCS sump strainers, which are designed to prevent debris from entering the ECCS and the reactor core. If this debris were to clog the strainers and prevent coolant from entering the reactor core, containment cooling could be lost and result in core damage and containment failure.

It is also possible that some debris would bypass the sump strainer and lodge in the reactor core. This could result in reduced core cooling and potential core damage. If the ECCS strainer were to remain functional, even with core cooling reduced, containment cooling would be maintained and containment functions would not be adversely affected.

Findings from research and industry operating experience raised questions concerning the adequacy of PWR sump designs. Research findings demonstrated that the amount of debris generated by a high-energy line break (HELB) could be greater when compared to other LOCAs. The debris from a HELB could also be finer (and thus more easily transportable) and could be comprised of certain combinations of debris (i.e., fibrous material plus particulate material) that could result in a substantially greater flow restriction than an equivalent amount of either type of debris alone. These research findings prompted the U.S. Nuclear Regulatory

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Commission (NRC) to open Generic Safety Issue (GSI)-191, "Assessment of Debris Accumulation on PWR Sump Performance," in 1996, resulting 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) Section 50.46(b)(5) are met. This deterministic rule 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 operation of the ECCS and CSS in recirculation mode at PWRs during LOCAs or other HELB accidents for which sump recirculation is required. 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.

GSI-191 concluded that debris clogging of sump strainers could lead to recirculation system ineffectiveness as a result of a loss of net positive suction head (NPSH) for the ECCS and CSS recirculation pumps. Resolution of GSI-191 involves two distinct but related safety concerns: (1) potential clogging of the sump strainers that results in ECCS and/or CSS pump failure; and (2) potential clogging of flow channels within the reactor vessel because of debris bypass of the sump strainer (in-vessel effects). Clogging at either the strainer or in-vessel channels can result in loss of the long-term cooling safety function.

After completing the technical assessment of GSI-191, the NRC issued Bulletin 03-01, "Potential Impact of Debris Blockage on Emergency Sump Recirculation at Pressurized-Water Reactors" (Agencywide Documents Access and Management System (ADAMS) Accession No. ML031600259), on June 9, 2003. The Office of Nuclear Reactor Regulation (NRR) requested and obtained the review and endorsement of the bulletin from the Committee to Review Generic Requirements (CRGR) (ADAMS Accession No. ML031210035). As a result of the emergent issues discussed in Bulletin 03-01, the NRC staff requested an expedited response from licensed PWR facilities on the status of their compliance of regulatory requirements concerning the ECCS and CSS recirculation functions based on a mechanistic analysis. The NRC staff asked licensed PWR facilities, who chose not to confirm regulatory compliance, to describe any interim compensatory measures that they had implemented or will implement to reduce risk until an analysis could be completed. All licensed PWR facilities responded to Bulletin 03-01. The NRC staff reviewed all licensed PWR facilities' Bulletin 03-01 responses and found them acceptable.

In developing Bulletin 03-01, the NRC staff recognized that it might be necessary for licensed PWR facilities 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, that information was not requested in Bulletin 03-01, but licensed PWR facilities were informed that the NRC staff was preparing a Generic Letter (GL) that would request this information. GL 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design-basis Accidents at Pressurized-Water Reactors," dated September 13, 2004 (ADAMS Accession No. ML042360586), was the follow-on information request referenced in Bulletin 03-01. This document set the expectations for resolution of PWR sump performance issues identified in GSI-191, to ensure the reliability of the ECCS and CSS at PWRs. NRR requested and obtained the review and endorsement of the GL from the CRGR (ADAMS Accession No. ML040840034).

GL 2004-02 requested that addressees perform an evaluation of the ECCS and CSS recirculation functions in light of the information provided in the letter and, if appropriate, take additional actions to ensure system function. Additionally, addressees were requested to submit the information specified in GL 2004-02 to the NRC. The request was based on the identified potential susceptibility of PWR recirculation sump screens to debris blockage during design-basis accidents (DBAs) requiring recirculation operation of ECCS or CSS and on the potential for additional adverse effects due to debris blockage of flow paths necessary for ECCS and CSS recirculation and containment drainage. GL 2004-02 required addressees to provide the NRC a written response in accordance with 10 CFR 50.54(f).

By letter dated May 28, 2004 (ADAMS Accession No. ML041550661), the Nuclear Energy Institute (NEI) submitted a report describing a methodology for use by PWRs in the evaluation of containment sump performance. NEI requested that the NRC review the methodology. The methodology was intended to allow licensed PWR facilities to address and resolve GSI-191 issues in an expeditious manner through a process that starts with a conservative baseline evaluation. The baseline evaluation serves to provide guidance in developing the analyses and provide a method for quick identification and evaluation of design features and processes that significantly affect the potential for adverse containment sump blockage for a given plant design. The baseline evaluation also facilitates the evaluation of potential modifications that can enhance the capability of the design to address sump debris blockage concerns and uncertainties and supports resolution of GSI-191. The report offers additional guidance that can be used to modify the conservative baseline evaluation results through revision of analytical methods or through modification to the plant design or operation.

By letter dated December 6, 2004 (ADAMS Accession No. ML043280641), the NRC issued an evaluation of the NEI methodology. The NRC staff concluded that the methodology, as approved in accordance with the NRC staff safety evaluation (SE), provides an acceptable overall guidance methodology for the plant-specific evaluation of the ECCS or CSS sump performance following postulated DBAs.

In response to the NRC staff SE conclusions on NEI 04-07 "Pressurized Water Reactor Sump Performance Evaluation Methodology" (ADAMS Accession Nos. ML050550138 and ML050550156), the Pressurized Water Reactor Owners Group sponsored the development of the following Westinghouse Commercial Atomic Power (WCAP) Topical Reports (TRs):

- WCAP-16406-P-A, "Evaluation of Downstream Sump Debris Effects in Support of GSI-191," Revision 1 (not publicly available), to address the effects of debris on piping systems and components.

- WCAP-16530-NP-A, "Evaluation of Post-accident Chemical Effects in Containment Sump Fluids to Support GSI-191," issued March 2008 (ADAMS Accession No. ML081150379), to provide a consistent approach for plants to evaluate the chemical effects that may occur post-accident in containment sump fluids.

- WCAP-16793-NP-A, "Evaluation of Long-Term Cooling Considering Particulate, Fibrous and Chemical Debris in the Recirculating Fluid," Revision 2 issued July 2013 (ADAMS Accession No. ML13239A114), to address the effects of debris on the reactor core.

The NRC staff reviewed the TRs and found them acceptable to use (as qualified by the limitations and conditions stated in the respective SEs).[1] A more detailed evaluation of how the TRs were used by the licensed PWR facilities is contained in the following sections.

After the NRC staff evaluation of licensed PWR facilities' responses to GL 2004-02, the NRC staff found that there was a misunderstanding between the industry and the NRC on the level of detail necessary to respond to GL 2004-02. The NRC staff, in concert with industry and other stakeholders, developed a content guide for responding to requests for additional information (RAIs) concerning GL 2004-02. By letter dated August 15, 2007 (ADAMS Accession No. ML071060091), the NRC issued the content guide describing the necessary information to be submitted to allow the NRC staff to verify that each licensed PWR facilities' analyses, testing, and corrective actions associated with GL 2004-02 are adequate to demonstrate that the ECCS and CSS will perform their intended function following any DBA. By letter dated November 21, 2007 (ADAMS Accession No. ML073110389), the NRC issued a revised content guide.

The content guide described the following information needed to be submitted to the NRC:

- corrective actions for GL 2004-02,
- break selection,
- debris generation/zone of influence (ZOI) (excluding coatings),
- debris characteristics,
- latent debris,
- debris transport,
- head loss and vortexing,
- NPSH,
- coatings evaluation,
- debris source term,
- screen modification package,
- sump structural analysis,
- upstream effects,
- downstream effects – components and systems,
- downstream effects – fuel and vessel,
- chemical effects, and
- licensing basis

Based on the interactions with industry and other stakeholders and the results of the industry testing, the NRC staff in 2012 developed three options to resolve GSI-191. These options were documented and proposed to the Commission in SECY-12-0093, "Closure Options for Generic

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[1] Safety Evaluation by the Office of Nuclear Reactor Regulation, WCAP-16406-P, Revision 1, "Evaluation of Downstream Sump Debris Effects in Support of GSI-191," Pressurized Water Reactors Owners Group Project No. 694 (ADAMS Accession No. ML073520295); Final Safety Evaluation for Pressurized Water Reactor Owners Group WCAP-16530-NP, "Evaluation of Post-Accident Chemical Effects in Containment Sump Fluids to Support GSI-191" (ADAMS Accession No. ML073521072); Final Safety Evaluation by the Office of Nuclear Reactor Regulation, WCAP-16793-NP, Revision 2, "Evaluation of Long-Term Cooling Considering Particulate, Fibrous and Chemical Debris in the Recirculating Fluid," Pressurized Water Reactor Owners Group Project No. 694 (ADAMS Accession No. ML13084A154).

Safety Issue - 191, Assessment of Debris Accumulation on Pressurized-Water Reactor Sump Performance," dated July 9, 2012 (ADAMS Accession No. ML121320270). The options are summarized as follows:

- Option 1 would require licensed PWR facilities to demonstrate compliance with 10 CFR 50.46, "Acceptance criteria for emergency core cooling systems for light-water nuclear power reactors," through approved models and test methods. These will be low fiber plants with less than 15 grams of fiber per fuel assembly.

- Option 2 requires implementation of additional mitigating measures and allows additional time for licensed PWR facilities to resolve issues through further industry testing or use of a risk informed approach.

    - Option 2 Deterministic: Industry to perform more testing and analysis and submit the results for NRC review and approval (in-vessel only).

    - Option 2 Risk Informed: Use the South Texas Project pilot approach currently under review with NRR staff.

- Option 3 involves separating the regulatory treatment of the sump strainer and in-vessel effects.

The options allowed industry alternative approaches for resolving GSI-191. The Commission issued a Staff Requirement Memorandum on December 14, 2012 (ADAMS Accession No. ML12349A378), approving all three options for closure of GSI-191.

By letter dated May 16, 2013 (ADAMS Accession No. ML13142A199), Tennessee Valley Authority (TVA, the licensee) stated that they will pursue Option 1 for the closure of GSI-191 and GL 2004-02 for the Watts Bar Nuclear Plant (WBN) Unit 1.

In 2006, the NRC staff conducted an audit at WBN Unit 1 to help verify the adequacy of corrective actions taken by the licensee to address GL 2004-02. The audit report was issued on February 7, 2007 (ADAMS Accession No. ML070380083). The audit reviewed the licensee's design of the sump modifications, the evaluation of upstream and downstream blockage, and other post-accident debris effects identified in GL 2004-02.

The following is a list of additional documents related to TVA's response to GL 2004-02 for WBN Unit 1:

RESPONSES TO GL 2004-02		
DOCUMENT DATE	ACCESSION NUMBER	DOCUMENT
March 7, 2005	ML050700255	Initial Response to GL
June 5, 2005	ML051520580	1st NRC RAI
July 21, 2005	ML052080065	Licensee Response to RAI
September 1, 2005	ML052490347	Supplemental Information
February 10, 2006	ML060380082	2nd NRC RAI

DOCUMENT DATE	ACCESSION NUMBER	DOCUMENT
April 11, 2006	ML061040219	Licensee Response to RAI
May 10, 2006	ML061010180	3rd NRC RAI
July 3, 2006	ML062910508	Licensee Response to RAI
August 1, 2007	ML072150109	Supplemental Information
October 2, 2007	ML072760449	Supplemental Information
March 31, 2008	ML081090611(non-public proprietary information)	Supplemental Information
March 31, 2008	ML081090500	Cover Letter
March 31, 2008	ML081090508 ML081090506 (non-public) ML081090505 ML081090503 ML081090502 ML081090501 ML081120159	Enclosures
December 3, 2008	ML083370033	4th NRC RAI
March 3, 2009	ML090720868	Licensee Response to RAI
September 29, 2009	ML092650260	5th NRC RAI
April 1, 2010	ML100960020	Supplemental Information
June 3, 2010	ML101590373	Licensee Draft RAI Response
August 15, 2011	ML11229A783	Licensee Final RAI Response
April 17, 2015	ML15111A065	Supplemental Information

The NRC staff reviewed the information provided by the licensee in response to GL 2004-02 and all RAIs. The following summary of the NRC staff review is consistent with the NRC staff's supplemental guidance issued November 21, 2007.

2.0 GENERAL DESCRIPTION OF CORRECTIVE ACTIONS FOR THE RESOLUTION OF GL-2004-02

GL 2004-02 Requested Information Item 2(b) requested a general description of and implementation schedule for all corrective actions. The following is a list of corrective actions completed by the licensee at WBN Unit 1 in support of the resolution of GL 2004-02:

- Evaluation of sump performance using the guidance of NEI 04-07.
- Downstream effects evaluation using the TR-WCAP-16406-P-A, Revision 1 methodology.
- Containment walkdowns using the guidance of NEI 02-01, "Condition Assessment Guidelines: Debris Sources Inside PWR Containments," April 19, 2002 (ADAMS Accession No. ML021490241).
- The modification process and maintenance process have been enhanced relative to GL 2004-02 controls to insure operability of the containment sumps.

- Installation of a new ECCS sump strainer in WBN Unit 1 (≈ 4600 square feet (ft^2) available flow area).

- ECCS sump strainer performance for WBN Unit 1 was confirmed by performing a prototype chemical precipitates head loss test.

- Removal of 3M RES material from inside the crane wall in lower containment to fully address in-vessel effects will be completed by the licensee by the conclusion of the fall 2018 refueling outage.

- Change the Updated Final Safety Analysis Report (UFSAR) in accordance with 10 CFR 50.71(e) to reflect the changes to the plant in support of the resolution to GL 2004-02.

NRC Staff Conclusion:

The NRC staff finds that the licensee provided a general description and schedule for all corrective actions related to GL 2004-02 and concludes that the provided information is acceptable. The NRC staff considers this area closed for GL 2004-02 for WBN Unit 1.

3.0 BREAK SELECTION

The objective of the break selection process is to identify the break size and location that present the greatest challenge to post-accident sump performance. The term zone of influence (ZOI) used in this section refers to the spherical zone representing the volume of space affected by a hypothetical piping rupture.

NRC Staff Review:

The NRC staff review is based on documentation provided by the licensee through April 17, 2015. The guidance documents used for the review include the revised content guide dated November 21, 2007, Regulatory Guide (RG) 1.82, "Water Sources for Long-Term Recirculation Cooling Following a Loss-of-Coolant Accident," and the NEI 04-07 guidance report and associated NRC staff SE, denoted as GR/SE for the remainder of this evaluation.

The licensee used the approved methodology as stated in the GR/SE for break selection, with the exception that the break was not moved incrementally along the pipe to determine the location which resulted in the maximum debris generation. Instead, the licensee analyzed breaks with large ZOIs associated with target debris materials and the limiting characteristics from the GR/SE. The limiting characteristics of break selection analyzed by the licensee include:

- breaks with the largest potential for debris generation,
- large breaks with two or more different types of debris,
- breaks with the most direct path to the sump,
- large breaks with the highest particulate to fibrous debris ratio, and
- breaks that generate a thin bed

When considering the size of piping in the RCS primary loop and quantity of insulation in close proximity to these pipes, a double ended guillotine break in the primary loop piping was concluded to be the limiting break presenting the greatest challenge to post-accident sump performance. The most direct path for debris to reach the sump is beneath the refueling cavity in lower containment for RCS loops 3 and 4. Each of the break areas considered by the licensee have various types of debris, including reflective metal insulation (RMI) and 3M-M20C fire wrap/radiant energy shield (RES). Break locations near 3M-M20C fire wrap insulation are considered to have the most particulate debris for WBN Unit 1. The licensee committed to removing 3M RES material from inside the crane wall in lower containment in the April 17, 2015 submittal to fully address in-vessel effects. These modifications will be completed by the licensee by the conclusion of the fall 2018 refueling outage.

The spectrum of breaks evaluated by the licensee is consistent with that recommended in staff-approved methodology in the GR/SE. Based on results of the limiting characteristics evaluation, the licensee performed debris generation calculations for a break in the 31-inch inner diameter crossover leg at the base of the steam generator for all four RCS primary system loops. The majority of debris generated by the various breaks is RMI, which is not a major contributor to strainer head loss, as verified on an NRC staff audit (ADAMS Accession No. ML062120461). Testing for WBN Unit 1 was bounded by the worst case RMI debris load with the worst case fiber and particulate load. The NRC staff finds the licensee's method of choosing the limiting break locations that present the greatest challenge to post-accident sump performance acceptable.

In addition to the above, secondary breaks were considered in the break selection process. The evaluation resulted in secondary breaks generating much lower debris loading and lower flow rates than considered under LOCA scenarios. Therefore, the break selection for LOCAs is considered to bound any secondary line break.

NRC Staff Conclusion:

The NRC staff finds that the break location analysis completed by the licensee is in accordance with the revised content guide dated November 21, 2007, and the GR/SE while using an acceptable method to determine break locations to analyze for maximum debris generation results. Based on the information provided by the licensee, the NRC staff concludes that the provided information is acceptable and considers this area closed for GL 2004-02 for WBN Unit 1.

4.0 DEBRIS GENERATION/ZONE OF INFLUENCE (EXCLUDING COATINGS)

The objective of the debris generation/ZOI evaluation is to determine the limiting amounts and combinations of debris that can occur from the postulated breaks in the RCS.

NRC Staff Review:

The NRC staff review is based on documentation provided by the licensee through April 17, 2015. The NRC staff initial review found one issue regarding the licensee's testing methodology used to determine the ZOIs for Min-K and fire barrier material.

The licensee's evaluation of debris generation generally used the NEI 04-07 guidance. During the WBN Unit 1 audit, the overall debris generation methodology was accepted by the NRC staff with a single open item. The open item was for WBN Unit 1 to provide their final debris generation calculation for the NRC staff to review and verify that the WBN Unit 1 treatment of robust barriers was conducted properly. This calculation was provided as an attachment to the WBN Unit 1 March 31, 2008, supplement. The calculation was reviewed and this open item was closed.

Subsequent to the audit, ZOI reductions were credited for Min-K with extra bands added and for fire barrier material 3M-M20C based on testing of the target materials in the plant specific configurations. These reductions, which are documented in the final debris generation calculation, were based on testing documented in WCAP-16783-P. The NRC staff was unable to validate some of the assumptions and inputs used in the testing to validate the smaller ZOIs. Therefore, the staff issued an RAI.

RAI Review:

On December 3, 2008, the NRC issued an RAI requesting the licensee to provide a summary description of the reports for the tests conducted that justified the ZOI reductions for banded Min-K and the 3M-M20C fire barrier material and state whether the testing in WCAP-16783-P was specific to the WBN Unit 1 insulation systems. If the testing was not plant specific, the RAI requested the licensee to provide information showing that the WBN Unit 1 banding systems are at least as structurally robust as the system used in the testing. By letter dated March 3, 2009, the licensee provided information regarding the ZOI testing for Min-K and 3M-M20C fire barrier material. The provided information was similar to information the NRC staff reviewed as part of a generic review of ZOI testing in WCAP-16783-P.

The NRC staff reviewed the licensee's response and found that it did not contain adequate information for the NRC staff to determine if the testing bounded plant conditions. On September 29, 2009, the NRC issued another RAI.

By letter dated August 15, 2011, the licensee responded, stating that WCAP-16783-P will not be used to justify the Min-K ZOI value for WBN Unit 1. Instead, a ZOI radius/break diameter of 28.6D, consistent with the recommended value in the GR/SE, will be used for Min-K and 3M-M20C. Since WCAP-16783-P is not used to justify the ZOI value for Min-K and 3M-M20C, the information requested in the RAI related to ZOI testing is no longer required. On April 17, 2015, the licensee also provided a commitment to remove the 3M-M20C from inside the cranewall in lower containment in order to achieve a latent fiber load of less than 15 grams per fuel assembly.

NRC Staff Conclusion:

The licensee committed to use staff approved guidance to address debris generation/ZOI. Therefore, the NRC staff concludes that the debris generation/ZOI evaluation for WBN Unit 1 is acceptable. The NRC staff considers this item closed for GL 2004-02.

5.0 DEBRIS CHARACTERISTICS

The objective of the debris characteristics determination process is to establish a conservative debris characteristics profile for use in determining the transportability of debris and its contribution to strainer head loss.

NRC Staff Review:

The initial NRC staff review is based on documentation provided by the licensee through March 31, 2008, which was the last revision to this review area submitted by the licensee.

In the RAI responses, the licensee provided size distribution information for the different debris types (i.e., insulation, coatings, and latent debris) applicable to WBN Unit 1 ECCS debris evaluation. The licensee also provided bulk and material densities for fibrous and particulate debris, assumed specific surface areas for fibrous and particulate debris, and the technical basis for any debris characterization assumptions that deviate from NRC-approved guidance.

The NRC staff initial review found one issue concerning the licensee's treatment of 3M-M20C radiant energy barrier material. Based on the 2007 audit review, this material was considered fiberglass-type material. However, in the licensee's March 31, 2008, response, this information was revised to identify that the 3M-M20C material actually contains a significant fraction of vermiculite particulate. The NRC staff was concerned that this material could have a significant impact on strainer head loss, since vermiculite contains silicon dioxide, as do Min-K and Microtherm insulation materials.

RAI Review:

On December 3, 2008, the NRC issued an RAI requesting that the licensee provide a basis to support its conclusion that the revisions made to the assumed characteristics of 3M-M20C do not affect the conclusions of the strainer performance analysis.

By letter dated on March 3, 2009, the licensee provided additional information and pictures regarding the 3M-M20C material. Specifically, the licensee stated that the 3M-M20C material was assumed to be 35-percent low-density fiberglass and 65 percent vermiculite, which was verified by a laboratory analysis. The strainer design was based on 9.15 cubic feet (ft^3) rather than 8.45 ft^3 of 3M-M20C, which represents the plant quantity. The licensee stated that the strainer design is based on 51.2 pounds (lbs) of Min-K rather than 31.7 lbs, which increases the amount of silicon dioxide particles added to the test. Thus, the licensee stated that any impacts on strainer head loss would have been accounted for based on actual test results instead of imposed assumptions.

The licensee also provided some conservatisms assumed within the debris generation and transport calculations that make it highly unlikely that a thin bed of fiber would form. The licensee assumed the following: 3M-M20C will have a ZOI of 11D (11 times the break diameter), 3M-M20C will fail as 100-percent fines, 100 percent of the fiber will transport to the sump, and a 1/8-inch uniform thin bed forms to filter particulate.

Therefore, the licensee stated that based on these conservative assumptions and test results using actual materials, the refinements made to the assumed characteristics of 3M-M20C do not affect the conclusions of the strainer performance analysis.

NRC Staff Conclusion:

On July 12-14, 2010, NRC staff conducted an audit and observed ECCS strainer head loss tests including chemical effects for WBN Unit 1 at Alden Research Laboratory; details of the audit may be found in the NRC staff's memorandum dated August 19, 2010 (ADAMS Accession No. ML102160226). This testing was performed using a new test protocol implemented to address NRC staff concerns with previous methods. The NRC staff also observed that the licensee performed testing using the actual fire barrier material (3M-M20C) and did not use another material to simulate the 3M-M20C. Since the actual material was used in testing, its contribution to potential head loss was adequately modeled during strainer head loss testing. Therefore, the NRC staff concludes that the debris characteristics evaluation for WBN Unit 1 is acceptable. The NRC staff considers this item closed for GL 2004-02.

6.0 LATENT DEBRIS

The objective of the latent debris evaluation process is to provide a reasonable approximation of the amount and types of latent debris (e.g., miscellaneous fiber, dust, dirt) existing within the containment and its potential impact on sump screen head loss. The guidance documents used for the review include the Revised Content Guide dated November 2007, the GR/SE, and NEI 02-01.

NRC Staff Review:

The NRC staff review is based on documentation provided by the licensee through March 3, 2009, which was the last revision to this review area submitted by the licensee.

The licensee performed a detailed walkdown for transportable debris in the containment building. In accordance with recommendations in NEI 02-01, actual samples of discreet locations were collected and documented in the walkdown reports. The walkdowns inventoried the amount and types of materials that could become transportable that would contribute to the sump blockage and cause detrimental effects if allowed to pass the sump strainer. Latent debris calculations and the latent debris head loss properties used by the licensee were based on NRC staff approved methodologies.

The NRC staff found that the licensee conservatively assumed that all latent debris is in lower containment. Some of this debris could be transported to the sump strainer during fill-up, but the remainder was assumed to be uniformly distributed in the containment pool at the beginning of recirculation. This is a conservative assumption since no credit is taken for debris remaining on structures and equipment above the pool water level.

The licensee assumed that the quantity of latent debris at WBN Unit 1 is equal to 200 lbs. The latent debris survey performed by the licensee found a total latent debris load of 69.2 lbs. The licensee used a conservative value of 200 lbs of latent debris in the strainer head loss testing. The licensee assumed that 15 percent of the latent debris to be fibrous, and the remaining

85-percent to be particulate in accordance with the GR/SE. Thus, 170 lbs was assumed to be dirt/dust and the remaining 30 lbs was assumed to be latent fiber.

A sacrificial surface area of 750 ft^2 (1000 ft^2 x 0.75 loading) has been established for latent debris in the form of signs, placards, tags, tape, and similar miscellaneous materials in accordance with the GR/SE was used for chemical effects testing and head loss analysis.

Based on the above, the NRC staff finds that the licensee used conservative values and approved methodologies in the evaluation of latent debris at WBN Unit 1.

NRC Staff Conclusion:

The NRC staff concludes that the latent debris area was adequately evaluated by the licensee. Therefore, the NRC staff considers this item closed for GL 2004-02 for WBN Unit 1.

7.0 DEBRIS TRANSPORT

The objective of the debris transport evaluation process is to estimate the fraction of debris that would be transported from debris sources within containment to the sump suction strainers.

NRC Staff Review:

The NRC staff review is based on documentation provided by the licensee through March 3, 2009, which was the last revision to this review area submitted by the licensee.

In its response to GL 2004-02, the licensee provided the information requested in the content guide. No significant deficiencies or uncertainties were identified in licensee's debris transport analysis based upon the NRC staff's review. The licensee assumed 100-percent transport for all types of debris except RMI. For RMI, reasonable transport fractions of 48 percent for large pieces and 71 percent for small pieces were assumed.

The licensee stated that the transport calculation followed guidance from NEI 04-07 and the GR/SE. The licensee stated that the four major debris transport modes were considered: blowdown, washdown, pool fill-up, and recirculation. The licensee's evaluation of each phase is discussed briefly below.

- Blowdown: The licensee stated that fines were assumed to be blown upward into the ice condenser during the blowdown.

- Washdown: The licensee stated that all debris blown upward would be trapped by the ice baskets and subsequently washed back down to the lower containment with flows from the melting ice.

- Pool Fill-Up: No debris was assumed to transport to hold-up volumes in the incore tunnel or reactor cavity, since communication points with these volumes are above the containment minimum water level.

- Recirculation: The licensee performed a Computational Fluid Dynamics (CFD) analysis of the containment pool to determine the flow patterns in the containment pool during recirculation. Flow-3D, Version 8.2, was the CFD code used.

Transport metrics were specified for the various debris types in containment. The NRC staff determined that 48 percent and 71 percent debris transport fractions for RMI are reasonable; the highest quantity of debris at the sump resulted from 71 percent debris transport fraction for a total of 60,458 ft^3. The NRC staff noted that significant head loss is not typically expected for RMI debris, even if it can climb up and adhere to the strainers. The remainder of debris was assumed to be fines with full transport to the sump.

No transport to inactive containment pool volumes was modeled.

NRC Staff Conclusion:

For the transport area, the licensee has provided adequate information for the NRC staff to conclude that the area was appropriately addressed. Therefore, the NRC staff considers this area closed for GL 2004-02 for WBN Unit 1.

8.0 HEAD LOSS AND VORTEXING

The objectives of the head loss and vortexing evaluations are to calculate head loss across the sump strainer and to evaluate the susceptibility of the strainer to vortex formation.

NRC Staff Review:

The NRC staff review is based on documentation provided by the licensee through April 17, 2015. The guidance documents used for the NRC staff review include the Revised Content Guide dated November 2007 and the GR/SE.

The licensee calculated the minimum submergence of the strainer under small break LOCA (SBLOCA) and large break LOCA (LBLOCA) conditions. Initially, the calculation was performed without crediting additional ice melt which occurs after residual heat removal (RHR) switchover. The initial results showed a minimum submergence of 3.50 feet (ft) for LBLOCA, however, a small portion of the strainer (3/4 inch) would be uncovered during some SBLOCA cases. Due to NRC staff concerns regarding vortexing with these analyses, as detailed in RAI 4 of the September 29, 2009, RAI, the licensee performed a new submergence analysis including the additional fluid from ice melt after RHR switchover. The results of the new submergence analyses show a minimum submergence of 0.056 ft for SBLOCA conditions, thus eliminating vortexing concerns.

The licensee completed five tests at Alden Research Laboratory during the week of July 12, 2010, to determine the head loss across the strainer based on the postulated debris load present in containment following a LOCA. Descriptions of each test are as follows:

1. Test 1 - Clean Strainer Head Loss Test - This test determined the head loss of the clean strainer in the test tank. This data is subtracted from the latter tests to determine the "debris loaded" head loss for the strainer.

2. Test 2 - Fiber Bypass Test (No Particulate) - This test includes fiber only to establish the transport characteristics of fibers introduced incrementally up through the maximum design fiber basis to determine the fiber bypass rate. Visual observation was performed to evaluate the formation of a fibrous debris bed. Note that debris bypass sampling was performed during this test.

3. Test 4, 4B, and 4C - Design Basis Debris Loaded Thin Bed Tests - These tests determined if a higher head loss is possible with a thin bed of fibers, particulate, and chemical debris present, rather than with the design basis quantity of debris. This test included all particulates, chemical debris, and that fiber quantity determined to form a thin bed of fibers on the surface of the strainer. (Three of these tests were performed with each test using a revised debris load.)

Conservative assumptions and acceptable testing methods and procedures were used throughout the tests including:

- The debris load was scaled for WBN Unit 1 tests.
- A design basis debris loaded strainer head loss test using the design accident debris load was not performed by the licensee. Test 4C is assumed to bound the results of a design basis test.
- Debris settling was prevented using two upstream variable-speed pipe mixers.
- Water inventory was monitored to ensure prototypical strainer submergence was not exceeded by more than 1 inch during testing.
- The termination criteria for the head loss tests were 15 tank turnovers and a percent change of less than 1 percent over 30 minutes.
- An acceptable statistical approach was performed to determine an upper limit head loss for WBN Unit 1.

Test 4C establishes the design basis debris load with a thin bed debris loaded head loss of 1.88 ft of water. The head loss results for Test 4C were calculated using the clean strainer head loss as the average head loss before debris was introduced during Test 4C instead of the results of Test 1. This is conservative because Test 1 shows a higher head loss (4.32 ft) than Test 4C (3.88 ft) resulting in a larger overall debris loaded head loss. After a temperature correction, the debris loaded head loss is 1.09 ft of water. For test 4C, the flow rate and water level were reduced to SBLOCA conditions and vortexing was not observed. A flow sweep, reducing flow to approximately 50 percent of design, was completed to verify bore holes were not present. The head loss performed as expected confirming that bore holes were not present during testing.

There were no signs of vortex formation in any of the tests. If a strainer were to be unsubmerged at the plant after switchover, vortexing in the core tube does not pose a risk for air entrainment due to the design of the sump pit and strainer assembly. These design attributes include a slotted core tube, ECCS piping being at a 90 degree angle to the strainers, depth of the sump pit, and the mesh screen across the piping intakes.

RAI Review:

There were numerous RAIs regarding head loss and vortexing throughout the review. After multiple rounds of RAIs in this review area, the licensee performed full scale testing in July 2010 as a means to resolve repetitive staff concerns. The August 15, 2011, supplement addressed the final RAIs of the review regarding head loss and vortexing using results from the July 2010 testing.

NRC Staff Conclusion:

Based on the test results provided by the licensee, the NRC staff concluded that the head loss portion of the analysis has been completed adequately. Testing and analysis was conducted using approved guidance in the Revised Content Guide dated November 2007 or alternate methods determined acceptable by the NRC staff. The other information provided by the licensee, either previously or in the recent submittals, provide adequate documentation that the strainer will perform its function during any required recirculation operation at WBN Unit 1. Therefore, the NRC staff concludes that the licensee's evaluation of this area is acceptable. Based on the information provided by the licensee, the NRC staff considers this area closed for GL 2004-02 for WBN Unit 1.

9.0 NET POSITIVE SUCTION HEAD

The objective of the NPSH section is to calculate the NPSH margin for the ECCS and CSS pumps that would exist during a LOCA considering a spectrum of break sizes.

NRC Staff Review:

The NRC staff review is based on documentation provided by the licensee through April 17, 2015. The guidance documents used for the NRC staff review include the Revised Content Guide dated November 21, 2007 and Regulatory Guide 1.82.

The licensee presented a summary of their NPSH analyses. The discussion of the methodology, and the assumptions and parameters in the NPSH analyses was clear. Each of the technical issues specified in the Revised Content Guide dated November 2007 was addressed by the licensee. Detail concerning the parameters, assumptions, and conservatisms in the NPSH and minimum flood level analyses was presented. The methodology used was standard industry practice for the calculation of NPSH margin. The NPSH analyses were performed with conservative and realistic assumptions.

ECCS and CSS flow rates used by the licensee for the sump recirculation NPSH calculation are:

	LBLOCA	SBLOCA
WBN Unit 1 CSS	4600 gallons per minute (gpm)	4600 gpm
WBN Unit 1 ECCS (RHR)	5000 gpm	5000 gpm
Total Recirculation Flow	9600 gpm	9600 gpm

For NPSH analysis, the licensee used a constant temperature of 190 degrees Fahrenheit for the sump recirculation inventory temperature. This temperature represents the maximum post-accident sump temperature, which is a conservative approach.

The containment sump water level was established by comparison of the sump and lower containment volumes which are available to collect water for recirculation to the minimum volume of water discharged during the event reduced by the volume that is unavailable to the sump/lower containment. The sump and lower containment volumes available to collect recirculation inventory was established by calculation of the available free volume in the areas that communicate with the event discharge sources and the recirculation sump intake. Discharge sources for the sump recirculation inventory are based on the nature of the event and the safety system responses. The sources include 1) primary system inventory, 2) cold leg accumulator inventory, 3) Refueling Water Storage Tank (RWST) inventory and 4) ice condenser ice melt inventory. Discharge volumes that are unavailable to the sump recirculation volume include 1) water held up in the reactor cavity, 2) water held up on the operating deck floor, 3) water in the upper containment atmosphere, 4) refueling canal holdup, 5) water in the containment spray piping, and 6) pocket sump holdup.

Assumptions used to determine the minimum containment water level were evaluated by the NRC staff and are determined to be reasonable for the NPSH calculation. The licensee used minimum containment water levels ranging from 5.48-12.07 ft for the NPSH analyses depending on either ECCS or CSS recirculation being accounted for either a LBLOCA or SBLOCA scenario evaluated (these are the same containment water levels used for the head loss analysis).

The required NPSH values were obtained from vendor requirements based on factory NPSH testing. A computer flow simulation model was used to determine suction piping losses for the ECCS and CSS pumps. Flow through the piping was maximized to establish bounding friction losses, which is conservative.

Equipment and structures that have the potential to be submerged during sump recirculation operations were accounted for when calculating pool level. This equipment included primary system piping, primary system piping supports, reactor coolant pumps, and RHR system piping.

The sources of water and the contributions of each source to the sump minimum level calculations in containment were provided. The water sources credited by the licensee are:

Water Source	LBLOCA (gallons)	SBLOCA (gallons)
Primary System	54,610	42,810
Cold Leg Accumulator	22,900	0
RWST	202,000	202,000
Ice Melt	154,500	50,752
Total Inventory	434,000	295,561

The minimum design basis NPSH margin for each pump during recirculation at WBN Unit 1 is as follows:

Pump	NPSH Margin for LBLOCA [ft]	NPSH Margin for SBLOCA [ft]
A RHR Pump	13.5	12.0
B RHR Pump	14.6	13.1
A CSS Pump	10.6	9.1
B CSS Pump	8.8	7.2

RAI Review:

There were several RAIs regarding NPSH throughout the review. Of significance were RAIs relating to providing a technical basis for the volume of water credited in the SBLOCA water level calculation and not considering a stuck open pressurizer relief valve during RCS depressurization. The licensee's final responses to these RAIs are presented on pages E1-12 and E1-13 of the August 15, 2011, submittal. The response states that if the volume of water reached the elevation of a pressurizer relief valve and the valve is stuck open, the scenario becomes recognized by the operators as a SBLOCA. Other SBLOCA scenarios bound the results of a stuck open pressurizer relief valve; therefore, these items are considered resolved.

NRC Staff Conclusion:

The NRC staff concludes that the licensee's evaluation of this area is acceptable. Based on the information provided by the licensee, the NRC staff considers this area closed for GL 2004-02 for WBN Unit 1.

10.0 COATINGS EVALUATION

The objective of the coatings evaluation section is to determine the plant-specific ZOI and debris characteristics for coatings for use in determining the eventual contribution of coatings to overall head loss at the sump screen.

NRC Staff Review:

The NRC staff review is based on documentation provided by the licensee through March 3, 2009, which was the last revision to this review area submitted by the licensee.

The content guide called for the dry film thicknesses for coating to be provided, but this information was not listed in the licensee's response. Although missing, the NRC staff does not consider this a significant gap in information since conservative quantities of coating debris were provided.

The ZOI used by the licensee was 10D, which was based on the GR/SE approving NEI 04-07. Coatings in the ZOI and all unqualified coatings in containment failed as fine particulate to maximize transport.

Debris transport was based on Stokes Law and CFD. For head loss testing, 100 percent of the coating debris particulate would transport to the sump.

From testing, the licensee did not observe a thin bed with 100 percent coatings debris treated as particulate. In additional testing, the licensee used 100 percent coating debris treated as paint chips of a size equivalent to the area of the sump screen openings to maximize head loss for strainer testing. This is conservative and acceptable based on the GR/SE.

NRC Staff Conclusion:

The licensee's coating assessment program is acceptable to the NRC staff since the licensee's assessment is conducted during each refueling outage, is conducted by qualified personnel, and if degraded coatings are identified, these areas are documented and additional tests and remediation may be performed. Therefore, the NRC staff concludes that the coatings evaluation for WBN Unit 1 is acceptable. The NRC staff considers this item closed for GL 2004-02 for WBN Unit 1.

11.0 DEBRIS SOURCE TERM

The objective of the debris source term section is to identify any significant design and operational measures taken to control or reduce the plant debris source term to prevent potential adverse effects on the ECCS and CSS recirculation functions.

NRC Staff Review:

The NRC staff review is based on documentation provided by the licensee through April 17, 2015.

Design and administrative controls are in place at WBN Unit 1 to ensure that potential quantities of post-accident debris are maintained within the bounds of the analyses and design bases that support ECCS and CSS recirculation functions.

The licensee listed summaries of the procedures and engineering specifications that constitute the present containment material control and inspection requirements at WBN Unit 1 that pertain to ensuring operability of the containment sump.

Collectively, these documents provide the technical and programmatic controls necessary to ensure that design change, maintenance, and modification activities are conducted in a manner that assures operability of the containment sump. Additionally, by letter dated April 17, 2015, the licensee committed to remove the 3M-M20C from inside the cranewall in lower containment in order to achieve a fiber load of less than 15 grams per fuel assembly.

NRC Staff Conclusion:

The licensee has provided information necessary for the NRC staff to conclude that the debris source term is controlled to an acceptable level such that the recirculation function will not be adversely affected. Therefore, the NRC staff concludes that the debris source term evaluation for WBN Unit 1 is acceptable. The NRC staff considers this item closed for GL 2004-02 for WBN Unit 1.

12.0 SCREEN MODIFICATION PACKAGE

The objective of the screen modification package section is to provide a basic description of the sump screen modification.

NRC Staff Review:

The NRC staff review is based on documentation provided by the licensee through February 29, 2008, which was the last revision to this review area submitted by the licensee.

The licensee provided a basic description of the major features of the sump screen modification, in addition to a listing rerouting of piping and other components modifications necessitated by the sump strainer modification. A summary of the modifications to the ECCS sump strainer installations appears below:

The WBN Unit 1 advanced design containment sump strainers are based on a "stacked disk" strainer design manufactured by Performance Contracting, Incorporated. The "stacked disk" design is comprised of a series approximately 1-inch thick disks covered with a stainless steel skin that is punched with 0.085-inch diameter flow openings. After passing through the strainer skin, intake flow is directed to a central flow channel. The strainer disks are stacked upon top each other to form strainer modules.

WBN Unit 1 has one recirculation strainer assembly that feeds a common suction sump via a plenum. The single strainer assembly consists of 23 vertically oriented strainer stacks, 14 of which are taller Type "A" strainers and 9 of which are shorter Type "B" strainers. Each of the Type "A" strainers consists of 4 strainer modules that are vertically stacked on top of each other. The first module has 7 disks and the other three modules have 6 disks. Each of the Type "B" strainers consists of 3 strainer modules that are vertically stacked on top of each other with each having 7 disks. The 23 strainers provide a total of $\approx$ 4,675.1 ft^2 of flow area. Flow leaves each of the strainers where it enters a rectangular, horizontally oriented, collection plenum that is positioned over the top of the sump pit.

The only modifications required to support installation of the advance design sump strainers were demolition of the original flat plate sump intake screen and the minor rerouting of electrical conduit to establish the required clearances.

The objective of the new strainer design is to provide acceptable flow with minimal head loss at the specified debris loads and to ensure adequate NPSH to the RHR/CSS pumps during the post-LOCA recirculation phase. The new strainer offers ≈ 4,675.1 ft^2 of surface area versus the original ≈ 200 ft^2 total for the original sump screens. As a conservatism, the licensee assumed 4600 ft^2 of flow area in calculations.

NRC Staff Conclusion:

The NRC staff finds that the licensee provided information in accordance with the content guide. Based on its review, the NRC staff concluded the licensee has provided sufficient information as required by GL 2004-02, and considers this item closed for GL 2004-02 for WBN Unit 1.

13.0 SUMP STRUCTURAL ANALYSIS

The objective of the sump structural analysis section is to verify the structural adequacy of the sump strainer including seismic loads and loads due to differential pressure, missiles, and jet forces.

NRC Staff Review:

The NRC staff's review is based on Section 3k, *Sump Structural Analysis*, of the licensee's March 31, 2008, submittal as well as the update submitted April 17, 2015. The guidance documents used for the review include the Revised Content Guide from November 2007 and RG 1.82.

The licensee presented a summary of their strainer structural analysis. The discussion of the methodology, and the assumptions and parameters in the structural analysis was clear. Each of the technical issues specified in the GL content guidance document was addressed by the licensee. Information concerning the design inputs, codes, loads, and load combinations used for the strainer structural analysis was presented. The methods used were standard industry practice for structural analysis and the assumptions were conservative and realistic.

The licensee stated that the components making up the replacement strainers and flow plenum assemblies were generally designed and fabricated to meet the code allowable stress requirements of the American Institute of Steel Construction (AISC) Manual of Steel Construction, 7th Edition, the American Society of Mechanical Engineers (ASME) Boiler & Pressure Vessel Code (BPVC), Section III, ANSI [American National Standards Institute]/AWS [American Welding Society] D1.6, "Structural Welding Code-Stainless Steel," and "ANSI/AISC N690-1994, "Specification for the Design, Fabrication, and Erection of Steel Safety Related Structures for Nuclear Facilities." Additionally, the concrete anchor bolts utilized in TVA's replacement strainer design were analyzed by the licensee and were stated to meet the requirements of TVA Design Standard DS-C1.7.1. The licensee noted that the load combinations and acceptance criteria considered the appropriate design basis loads and were in accordance with the strainer design specification.

The licensee noted that the structural analysis established that the assemblies meet the acceptance criteria for all the applicable load combinations. A summary table of the limiting interaction ratios (calculated stress divided by allowable stress) was provided and all of the interaction ratios remained below the acceptable limit of 1.0. The information provided by the licensee shows that the sump structural evaluation contains inherent conservatism by complying with plant guidance and accepted design standards (e.g., AISC 9th Edition, ASME BPVC).

The licensee also provided an acceptable explanation regarding the possibility of dynamic effects affecting the structural integrity of the replacement strainers by providing figures and citing the plant's licensing basis regarding primary system pipe breaks and the strainers' distant proximities from components which could produce missiles, pipe whipping, or jet impingement loads. Finally, the licensee stated that the containment sump strainer design does not credit back flushing, and; therefore, the structural analysis does not consider reverse flow.

During a public meeting held on May 12, 2011, the licensee discussed a different head loss value than the value provided in the original 2008 submittal. This discussion was summarized in an RAI response, dated August 15, 2011. The change in head value led the NRC staff to question the accuracy of the original strainer structural analysis summary. This issue was discussed with the licensee during a call on March 26, 2015, which led the licensee to update their response to items 3.k.1 and 3.k.2. The update referenced the appropriate differential pressure across the strainer and provided acceptable interaction ratio results, as discussed above.

The NRC staff concludes the licensee has sufficiently addressed all issues related to the strainer structural analysis, and there are no outstanding concerns related to the structural analysis.

NRC Staff Conclusion:

Based on the above, the NRC staff finds that the licensee's structural analysis of the sump strainers and flow plenum is adequate because it was conducted in accordance with standard industry guidance and contains associated conservatisms. The NRC staff concludes that the strainer assembly will remain structurally adequate under normal and abnormal loading conditions such that they will be able to perform their intended design functions. The NRC staff considers this item closed for GL 2004-02 for WBN Unit 1.

14.0 UPSTREAM EFFECTS

The objective of the upstream effects assessment is to evaluate the flow paths upstream of the containment sump for holdup of inventory, which could reduce flow to the sump.

NRC Staff Review:

The NRC staff review is based on the November 22, 2006, audit report and documentation provided by the licensee through March 31, 2008, which was the last revision to this review area submitted by the licensee.

The NRC staff's audit report concluded that the licensee's upstream effects evaluation was acceptable because it was performed in a manner consistent with the approved methodology in

Section 7.2 of the GR/SE. Minimum water level cases were calculated for input to the ECCS and NPSH calculations. Minimum water level for LBLOCA cases was also calculated for input to the debris transport and head loss calculations. The containment evaluation review determined that reasonable assumptions were used regarding flow path clearance or blockage specifically for the minimum flood elevation cases. The NRC staff found that assumptions were based on conservative judgments about the flow paths leading to the sump, which result in the minimum volume.

Based on the audit conclusions and the review of information provided in the licensee response, the NRC staff concluded that the licensee adequately reviewed the flow paths leading to the emergency sump screen for choke points, considered the entrapment of debris upstream of the sump screen with regard to the holdup of water, and considered the effect of holdup in planned modifications. Therefore, the NRC staff found the licensee's treatment of upstream effects acceptable.

In accordance with NEI 02-01, containment walkdowns were performed. These walkdowns showed three potential chokepoints that could prevent adequate water inventory from reaching the containment sump. The potential chokepoints are the two refueling canal drains and the drains in the accumulator rooms.

The licensee stated that the 14-inch drains in the refueling canal discharge on opposite sides of the sump strainer area. The plant was designed such that almost all the spray water flows to lower containment through these two drain lines. If these drain lines became clogged with debris, the sump could eventually starve. However, given the size of these lines and the debris that would wash down with the sprays (latent debris, paint chips, and possibly a small amount of LOCA generated fines blown past the ice baskets), these lines are unlikely to clog.

The licensee stated that the debris transport analysis also identified one additional "set" of potential chokepoints that could prevent adequate water inventory from reaching the containment sump. That "set" of chokepoints is the 20 ice condenser drains that drain ice melt water from the ice condenser to the lower compartment. If 1 of the 20 ice condenser drain lines were to clog, the water would flow to one of the other drains. It is unlikely that all 20 drains would clog, and if all drains would clog, the ice melt water would spill over through the ice condenser bay doors (the normal path early in the event when the ice melt overwhelms the drain lines). Therefore, this chokepoint is not considered a problem.

The licensee further stated that the drains in the accumulator rooms allow the small amount of spray flow that directly hits the air return fans to be returned inside the polar crane wall. Curbs are present in the upper compartment around the fan suction that prevents spray water on the refueling floor from spilling through the fans. Thus, the only potential debris from the spray system entering the accumulator rooms is very small debris that has traveled through the strainers. The licensee claimed that neither the upper compartment nor the accumulator rooms are subjected to high energy jets. The only potential for debris in these compartments is failed coatings. The licensee also claimed that the size of the failed coatings or debris passing through the spray pumps is small and will not block any of these drains. RMI debris (large or small) will not be present to block these drains. Therefore, the licensee concluded that there will be no water inventory holdup or diversion due to debris blockage at chokepoints.

NRC Staff Conclusion:

The NRC staff concludes that the upstream effects area has been adequately addressed by the licensee since the licensee has shown that the drainage paths from the refueling canal drains and accumulator rooms cannot credibly become blocked. The NRC staff considers this item closed for GL 2004-02 for WBN Unit 1.

15.0 DOWNSTREAM EFFECTS - COMPONENTS AND SYSTEMS

The objective of the downstream effects, components and systems section is to evaluate the effects of debris carried downstream of the containment sump screen on the function of the ECCS and CSS in terms of potential wear of components and blockage of flow streams.

The NRC staff review is based on documentation provided by the licensee through April 17, 2015.

The licensee's March 31, 2008, submittal contained the information requested in the Revised Content Guide dated November 2007. The licensee stated that they evaluated the downstream effects of debris ingested into the ECCS during containment sump recirculation operation using the methods described in Revision 1 of WCAP-16406-P-A, including the limitations and conditions contained in the associated NRC SE. The evaluation addressed the effect of debris ingestion on equipment in the ECCS and CSS, including valves, pumps, heat exchangers, orifices, spray nozzles, and instrumentation. The equipment evaluations included erosive wear, abrasion, and potential blockage of flow paths. The evaluations show that the ECCS equipment at WBN Unit 1 will remain capable of passing sufficient flow to the reactor to adequately cool the core during the recirculation phase of a postulated LOCA.

NRC Staff Conclusion:

Because the licensee demonstrated that the ECCS equipment downstream of the ECCS sump strainers can perform their safety-related functions to mitigate the consequences of a HELB or LOCA using analytical methods prescribed in WCAP-16406-P-A, Revision 1 and the associated NRC SE (including limitations and conditions), the NRC staff concluded that the downstream effects of debris-laden recirculated sump fluid on ex-vessel downstream components and systems had been adequately addressed at WBN Unit 1.

Therefore, the NRC staff concludes that the licensee's evaluation of this area is acceptable. Based on the information provided by the licensee, the NRC staff considers this area closed for GL 2004-02 for WBN Unit 1.

16.0 DOWNSTREAM EFFECTS - FUEL AND VESSEL

The objective of the downstream effects, fuel and vessel section, is to evaluate the effects that debris carried downstream of the containment sump screen and into the reactor vessel has on long-term core cooling.

NRC Staff Review:

The licensee proposed to use the low fiber approach to resolving GSI-191 for WBN Unit 1. In a letter from the licensee dated May 16, 2013, the licensee committed to resolve the downstream in-vessel effects within two refueling outages after May 2013. The licensee revised this regulatory commitment in a letter dated April 17, 2015, requiring additional time to complete modifications necessary for WBN Unit 1 to be a low-fiber plant. The April 17, 2015, letter states:

> "To fully address in-vessel effects, 3M Radiant Energy Shield (RES) material will be removed from inside the cranewall in lower containment resulting in a latent fiber load of less than 15 grams/fuel assembly. TVA proposes to complete the modifications on WBN Unit 1 by the conclusion of the Fall 2018 refueling outage."

The NRC staff final review is based on the licensee's April 17, 2015, submittal. The guidance documents used for the review include the Revised Content Guide dated November 2007 and WCAP-16793-NP-A.

The licensee performed a plant-specific evaluation for WBN Unit 1 using WCAP-16793-NP-A and the associated NRC SE. The evaluation results for WBN Unit 1 are:

1. The maximum calculated cladding temperature is 337.3 °F. This is less than the WCAP-recommended maximum cladding temperature of 800 °F.

2. The total deposition thickness is 0.017 inch (4.3 mils). This is less than the recommended total debris deposition thickness of 0.050 inch.

3. Based on strainer bypass testing specific to WBN Unit 1, the fiber calculated to bypass the strainers and reach the fuel assembly is 14.8 grams per fuel assembly. This quantity is less than the WCAP-16793-NP acceptance criteria of 15 grams per fuel assembly.

Also, in the submittal dated April 17, 2015, the licensee satisfactorily addressed the 14 limitations and conditions of the NRC SE of WCAP-16793-NP-A.

Based on the above information, the NRC staff concludes that WBN Unit 1 meets the recommendations specified in WCAP-16793-NP-A and the specifications, limitations, and conditions listed in the associated NRC SE.

NRC Staff Conclusion:

The NRC staff concludes that the licensee's evaluation of this area is acceptable. Based on the information provided by the licensee, the NRC staff considers this area closed for GL 2004-02 for WBN Unit 1.

17.0 CHEMICAL EFFECTS:

The objective of the chemical effects section is to evaluate the effect that chemical precipitates have on head loss and core cooling.

Initial NRC Staff Review:

The initial staff review is based on documentation provided by the licensee through March 31, 2008, which was the last revision to this review area submitted by the licensee.

The licensee performed plant-specific flume testing with debris that included 3M-M20C Fire Wrap, Min-K, and shredded NUKON fiberglass to simulate latent fiber. The initial plant-specific flume testing for WBN Unit 1 was performed prior to the PWR Owners Group sponsored chemical effects testing. Therefore the licensee added commercially available chemicals in particulate form. The NRC staff expressed several concerns about this in the audit report.

Watts Bar 1 uses sodium tetraborate to buffer a postulated post-LOCA containment pool. The licensee increased the available containment sump strainer area from approximately 200 ft^2 to approximately 4600 ft^2.

Final NRC Staff Review:

The final NRC staff review is based on the licensee's letter dated August 15, 2011, more specifically Attachment 2 of Enclosure 1, "Watts Bar, Unit 1 ECCS Strainer Performance Test Report" which contains proprietary information that is withheld from public disclosure. In this test report the licensee provided supplemental information including greater detail about their thin bed test. The final staff review is also based on review of the licensee's letter dated May 16, 2013, which confirms that the licensee removed all Min-K insulation from the ZOI.

Testing of the WBN Unit 1, containment emergency sump strainer was performed at Alden Labs from July 12, 2010 to July 16, 2010. Areva NP, Inc. (AREVA) and Alden Research Laboratory, Inc. performed testing to determine the head loss (pressure drop) across the strainer based on the postulated debris load present in containment post-LOCA.

The design basis debris loaded thin bed test 4C (Enclosure 1, Attachment 2, Section 6.5), included all particulates, chemical debris, and the fiber quantity determined to form a thin bed of fibers on the surface of the strainer. The simulated chemical precipitate was prepared using the WCAP-16530-NP-A methodology. This method has been previously accepted by NRC staff in letter dated December 21, 2007 (ADAMS Accession No. ML073521072). The thin bed test 4C resulted in acceptable head loss values.

Test 4C is credited as the test of record (see letters dated May 16, 2013, and August 15, 2011 (ADAMS Accession Nos. ML13142A199 and ML11229A783). Since the time of the NRC staff's initial review, the licensee removed all Min-K insulation from the ZOI during the fall of 2012 refueling outage.

NRC Staff Conclusion:

The licensee performed containment emergency sump strainer testing and simulated chemical effects by adding particulates, chemical debris, and the appropriate fiber quantity. The NRC staff finds that the use of WCAP-16530 precipitate is acceptable since the NRC staff previously reviewed and approved this protocol for evaluating chemical effects. The NRC staff concludes that the licensee had adequately addressed effect that chemical precipitates have on head loss and core cooling. Based on the information provided by the licensee, the NRC staff considers this area closed for GL 2004-02 for WBN Unit 1.

18.0 LICENSING BASIS

The objective of the licensing basis section is to provide information regarding any changes to the plant licensing basis due to the changes associated with GL 2004-02.

The licensee committed to change the UFSAR in accordance with 10 CFR 50.71(e) to reflect the changes to the plant in support of the resolution to GL 2004-02. In addition, the licensee stated that changes would be made to the UFSAR describing the new licensing basis to reflect the revised debris loading as it affects ECCS and CSS sump strainer performance and in-vessel effects, including the following:

- Break Selection
- Debris Generation
- Latent Debris
- Debris Transport
- Head Loss
- Additional Design Considerations

NRC Staff Conclusion:

Based on the licensee's commitment, the NRC has confidence that the licensee will affect the appropriate changes to the WBN Unit 1 UFSAR, in accordance with 10 CFR 50.71(e), that will reflect the changes to the licensing basis as a result of corrective actions made to address GL 2004-02. Therefore, the NRC considers this item closed for GL 2004-02 for WBN Unit 1.

19.0 CONCLUSION

The NRC staff has performed a thorough review of all licensee's responses and supplements to GL 2004-02. The NRC staff conclusions are documented in each section above. Based on the above evaluations, the NRC staff finds the licensee has provided adequate information as requested by GL 2004-02.

The stated purpose of GL 2004-02 was focused on demonstrating compliance with 10 CFR 50.46. Specifically the GL requested addressees to perform an evaluation of the ECCS and CSS recirculation and, if necessary, take additional action to ensure system function in light of the potential for debris to adversely affect long-term core cooling. The NRC staff finds the information provided by the licensee demonstrates that debris will not inhibit the ECCS or CSS performance of its intended safety function in accordance 10 CFR 50.46 to assure adequate long-term core cooling following a DBA.

Therefore, the NRC staff concludes that the licensee's responses to GL 2004-02 are adequate and considers GL 2004-02 closed for WBN Unit 1.

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inhibit the ECCS or CSS performance of its intended safety function in accordance with 10 CFR 50.46 to assure adequate long term core cooling following a DBA. Therefore, the NRC staff concludes that the licensee's response to GL 2004-02 is adequate and considers GL 2004-02 closed for WBN Unit 1. No further information or action is requested of the licensee. The NRC staff's findings are documented in the enclosed summary.

If you have any questions, please call me at 301-415-2048 or via e-mail at Jeanne.Dion@nrc.gov.

Sincerely,

/RA MOrenak for/

Jeanne A. Dion, Project Manager
Watts Bar Special Projects Branch
Division of Operating Reactor Licensing
Office of Nuclear Reactor Regulation

Docket No.: 50-390

Enclosure:
Staff Review

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