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

September 18, 2014

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

SUBJECT: WATTS BAR NUCLEAR STATION, UNIT 2, CLOSEOUT OF GENERIC LETTER 2004-02, "POTENTIAL IMPACT OF DEBRIS BLOCKAGE ON EMERGENCY RECIRCULATION DURING DESIGN BASIS ACCIDENTS AT PRESSURIZED-WATER REACTORS" (TAC NO. MD5560)

Dear Mr. Shea:

The U.S. Nuclear Regulatory (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 for Light Water Reactors." Specifically the GL requested addressees to perform an evaluation of the emergency core cooling system (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 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 letter dated March 4, 2011 (ADAMS Accession No. ML110680248), pursuant to the current application for an operating license at Watts Bar Nuclear Plant (WBN), Unit 2, the Tennessee Valley Authority (TVA) provided its response to GL 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors," for WBN Unit 2. The March 4, 2011, letter supersedes TVA's September 10, 2010, response (ML102580175) to GL 2004-02, including the commitments that were included in that response. Further, responding to requests for additional information and additional evaluation guidance provided by the NRC staff, TVA provided additional information by letters dated April 29, 2011 (ML11124A083); May 17, 2012 (ML12143A345); and September 16, 2013 (ML13262A270).

In its September 16, 2013 letter, TVA stated that the following actions still need to be completed for WBN Unit 2; (1) install sump modifications per the requirements of GL 2004-02 prior to Unit 2 fuel load, (2) complete a confirmatory walkdown for loose debris after containment work is complete, prior to start-up, 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, and (3) install new throttle valves in the chemical volume control system and safety injection system lines to the reactor coolant system, opened sufficiently to preclude downstream blockage. The above required actions are confirmatory inspection items.

The NRC staff performed a thorough review of the TVA responses to GL 2004-02 and concluded that TVA's response to GL 2004-02 is acceptable. The NRC staff conclusions have been documented in the enclosure. Based on the NRC staff conclusions, the NRC staff finds the information provided demonstrates that debris will not inhibit the ECCS or CSS performance of its intended function in accordance with 10 CFR 50.46 to assure adequate long term core cooling following a design-basis accident. Therefore, the NRC staff finds the licensee's responses to GL 2004-04 are adequate and pending completion of the confirmatory items discussed above, considers GL 2004-02 closed for the WBN Unit 2. No further information or action is requested of the applicant.

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

Sincerely,

Justin C. Poole, Senior Project Manager
Watts Bar Special Projects Branch
Division of Operating Reactor Licensing
Office of Nuclear Reactor Regulation

Docket No. 50-391

cc w/ enclosure: distribution via Listserv

NUCLEAR REGULATORY COMMISSION STAFF REVIEW OF THE DOCUMENTATION PROVIDED BY TENNESSEE VALLEY AUTHORITY FOR WATTS BAR NUCLEAR PLANT, UNIT 2 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

In September 2004, the 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," to holders of operating licenses for Pressurized Water Reactors (PWRs), requesting that the licensees perform an evaluation of their emergency core cooling systems (ECCS) and containment spray system (CSS) recirculation functions considering the potential for debris-laden coolant to be circulated by the ECCS and the CSS after a loss-of-coolant accident (LOCA) or high energy line break (HELB) inside containment and, if appropriate, take additional action to ensure system function. The GL required that licensees of operating PWRs provide the NRC a written response describing the results of their evaluation and any modifications made, or planned, to ensure system function. The Tennessee Valley Authority (TVA or the applicant) submitted a response to the GL for Watts Bar Nuclear Plant (WBN) Unit 1. That response is under NRC staff review. Holders of construction permits (CPs), such as WBN Unit 2, were not required to respond to the GL.

On August 3, 2007, TVA informed the NRC that it intended to reactivate construction and licensing activities for WBN Unit 2. Therefore, in response to direction provided by the Commission in its Staff Requirements Memorandum (SRM), SRM-SECY-07-0096, "Staff Requirements - Possible Reactivation of Construction and Licensing Activities for the Watts Bar Nuclear Plant, Unit 2," dated July 25, 2007 (Agencywide Documents Management System (ADAMS) Accession No. ML072060688), the staff established the foundation of a licensing review approach that employs the current licensing basis for WBN Unit 1 as the reference basis for the review and licensing of WBN Unit 2 (WBN Unit 2 is a mirror image of WBN Unit 1). This approach is described in SECY-09-0012, "Status of Reactivation of Construction and Licensing Activities for Watts Bar Nuclear Plant Unit 2" (ADAMS Accession No. ML083100090). In implementing this approach, the staff has formulated the activity topics that remain to be evaluated, along with the framework for the outstanding reviews of generic communications issues and other special programs. GL 2004-02 is included in this review category.

Therefore, by letter dated March 4, 2011 (Reference 1), pursuant to the current application for an operating license at WBN Unit 2, TVA provided a response to GL 2004-02, for WBN Unit 2.

The March 4, 2011, letter supersedes TVA's September 10, 2010, letter (Reference 2) regarding GL 2004-02, including the commitments that were included in that letter. TVA's March 4 letter includes four enclosures consisting of the following: (1) TVA's evaluation of GL 2004-02, based on the guidance provided by the NRC in a letter from W. H. Ruland, NRC, to A. Pietrangelo, Nuclear Energy Institute (NEI), "Revised Content Guide for Generic Letter 2004-02 Supplemental Responses," dated November 21, 2007 (Reference 3); (2) a description of the open items related to the NRC staff's audit of the WBN Unit 1 GL 2004-02 closure efforts, as they apply to WBN Unit 2 (Reference 4); (3) responses to Requests for Additional Information (RAIs) related to the GL 2004-02 closure efforts for WBN Unit 1, as they apply to WBN Unit 2 (References 5 and 6); and (4) a list of regulatory commitments related to the closure of GL 2004-02 at WBN Unit 2. By letters dated April 29, 2011 (Reference 7), May 17, 2012 (Reference 8), and September 16, 2013 (Reference 9), TVA provided additional information in response to (1) RAIs prepared by NRC staff (References 10 and 11), (2) additional evaluation criteria/guidance provided by NRC staff in a letter to NEI on May 2, 2012 (Reference 12), and (3) issuance of Westinghouse Topical Report (TR) WCAP-16793-NP-A, Revision 2 (Reference 13).

2.0 REGULATORY EVALUATION

2.1 System Function

The function of the ECCS at WBN Unit 2 is to supply cooling water to the reactor core following a LOCA to cool the reactor fuel and maintain it in a geometry that can be cooled. The function of the CSS at WBN Unit 2 is to remove heat from the containment building after a LOCA.

The ECCS and CSS operating conditions involve the circulation of water that has been spilled onto the basement floor of the containment building (through a break in the reactor coolant system (RCS) pipe, and by spray from the CSS) back to the reactor and/or containment spray headers after being cooled by the residual heat removal (RHR) system heat exchangers. In the circulation mode of operation with the replacement strainers in place, water from the containment pool is drawn through 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 the stacks are 5.52 feet tall and the remaining stacks are 4.81 feet tall. The 23 strainers provide a total of 4675 square feet of strainer 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 WBN Unit 2 sump strainer design is the same as that used for WBN Unit 1, except that the strainer stack-to-plenum opening is increased for WBN Unit 2 to reduce the strainer pressure drop, thus providing margin to plugging when compared to the WBN Unit 1 strainer.

Because water is drawn from the containment pool, there is a potential for LOCA generated debris and latent debris to be transported to ECCS sump strainers. This debris could block adequate flow through the strainer or pass through the strainer and prevent the ECCS or CSS equipment from performing their safety functions.

2.2 Requested Action

GL 2004-02 requested holders of operating licenses for PWRs (e.g., WBN Unit 1) to perform a mechanistic evaluation, using an NRC-accepted method, of the potential for the adverse effects of post-accident debris blockage and operation with debris-laden fluid to impede or prevent the recirculation function of the ECCS and CSS following all postulated accidents for which the recirculation of these systems is required. The GL also requested that holders of operating licenses for PWRs implement plant modifications that the evaluation identifies as being necessary to ensure system functionality, and provide information regarding planned actions and the schedule for completing the requested evaluation. The GL requested that addressees provide information that includes the following:

a. A description of the method that is used, or will be used, to analyze the susceptibility of the ECCS and CSS recirculation functions for the applicant's reactor to the adverse effects identified in this GL of post-accident debris blockage and operation with debris-laden fluids identified in this GL.

b. A statement of whether the applicant plans to perform a containment building walkdown surveillance in support of the analysis of the susceptibility of the ECCS and CSS recirculation functions to the adverse effects of debris blockage identified in this GL. Provide justification if no containment walkdown surveillance will be performed. If a containment building walkdown surveillance will be performed, state the planned method to be used and the planned completion date.

c. Confirmation that the ECCS and CSS recirculation functions under debris loading conditions are or will be in compliance with the regulatory requirements listed in the Applicable Regulatory Requirements Section of this GL. This submittal should address the configuration of the plant that will exist once all modifications required for regulatory compliance have been made and the licensing basis has been updated to reflect the results of the analysis described above.

d. A general description of and implementation schedule for all corrective actions, including any plant modifications that the applicant identified while responding to this GL.

e. A description of the method that was used to perform the analysis of the susceptibility of the ECCS and CSS recirculation functions to the adverse effects of post-accident debris blockage and operation with debris-laden fluids.

   The submittal may reference a guidance document (e.g., Regulatory Guide (RG) 1.82, Rev. 3), industry guidance, or other methods previously submitted to, and accepted by the NRC. The documents to be submitted or referenced should include, at a minimum, the following information:

   i. The results of any supporting containment walkdown surveillances performed to identify potential debris sources and other pertinent containment characteristics.

   ii. The minimum available net positive suction head (NPSH) margin for the ECCS and CSS pumps assuming an unblocked sump screen.

   iii. The submerged area of the sump screen at this time and the percent of submergence of the sump screen (i.e., partial or full) at the time of the switchover to sump recirculation.

iv. The maximum head loss postulated from debris accumulation on the submerged sump screen, and a description of the primary constituents of the debris bed that result in this head loss. In addition to debris generated by jet forces from the pipe rupture, debris created by the resulting containment environment (thermal and chemical) and CSS washdown should be considered in the analyses. Examples of this type of debris are disbonded coatings in the form of chips and particulates and chemical precipitants caused by chemical reactions in the pool.

v. The basis for concluding that the water inventory required to ensure adequate ECCS or CSS circulation would not be held up or diverted by debris blockage at choke-points in containment ECCS sump return flowpaths.

vi. The basis for concluding that inadequate core or containment cooling would not result due to debris blockage at flow restrictions in the ECCS and CSS flow paths downstream of the sump screen (e.g., a high-pressure safety injection (HPSI) system throttle valve, pump bearing or seal; fuel assembly inlet debris screen; or containment spray nozzles). The discussion should consider the adequacy of the sump screen mesh spacing and state the basis for concluding that adverse gaps or breaches are not present on the screen surface.

vii. Verification that close-tolerance subcomponents in pumps, valves and other ECCS and CSS components are not susceptible to plugging or excessive wear due to extended post-accident operation with debris-laden fluids.

viii. Verification that the strength of the trash racks is adequate to protect the debris screens from missiles and other large debris. The submittal should also provide verification that the trash racks and sump screens are capable of withstanding the loads imposed by expanding jets, missiles, the accumulation of debris, and pressure differentials caused by post-LOCA blockage under predicted flow conditions.

ix. If an active approach (e.g., back-flushing, powered screens) is selected in lieu of or in addition to a passive approach to mitigate the effects of the debris blockage, describe the approach and associated analyses.

f. A description of the existing or planned programmatic controls that will ensure that potential sources of debris introduced into containment (e.g., insulations, signs, coatings, and foreign materials) will be assessed for potential adverse effects on the ECCS and CSS recirculation functions.

2.3 <u>Review Method</u>

The NEI developed an evaluation guidance document titled "PWR [Pressurized-Water Reactor] Containment Evaluation Methodology—Baseline Evaluation" (Reference 14). The NRC issued a safety evaluation (SE) of that document (Reference 15). The final guidance, titled "Pressurized Water Reactor Sump Performance Evaluation Methodology," was subsequently issued in December of 2004 as NEI 04-07. Volume 1 of NEI 04-07 is titled "Pressurized Water Reactor Sump Performance Evaluation Methodology" (Reference 16) and Volume 2 is titled "Safety Evaluation by the Office of Nuclear Reactor Regulation Related to NRC Generic Letter 2004-02," Revision 0, dated December 6, 2004 (Reference 17). Together, these two volumes describe a method acceptable to NRC staff for performing the evaluations requested by GL 2004-02.

In a letter from J. C. Butler to the NRC dated December 22, 2011 (Reference 18), NEI proposed additional guidance that plants with little or no fibrous debris in the circulated coolant could use to expeditiously close Generic Safety Issue (GSI)-191. The NRC staff reviewed the NEI proposed "Clean Plant" criteria and found that the guidance, as clarified in NRC letter from W. Ruland to J. C. Butler, dated May 2, 2012 (Reference 12), provides an acceptable method for closing GSI-191 for operating PWRs. The NRC letter (Reference 12) required that licensees that use the "Clean Plant" criteria supplement their GL 2004-02 submittal with information that describes the basis for the fiber levels to be used in the plant licensing basis.

The NEI proposed "Clean Plant" criteria focusses on two aspects of debris plugging: containment sump strainer blockage and core blockage. The NRC clarification letter (Reference 12) states that licensees that adopt the "Clean Plant" criteria also need to address the other areas identified in the revised content guide (Reference 3). WBN Unit 2 is crediting the clean plant criteria for the in-vessel downstream-effects portion of the GSI-191 evaluation. Sump strainer blockage is evaluated by testing.

In addition to the evaluation guidance of NEI 04-07 and the "Clean Plant" criteria, the industry developed the following topical reports to aid licensees in responding to the GL.

1. Westinghouse Topical Report WCAP-16530-NP-A, "Evaluation of Post-Accident Chemical Effects in Containment Sump Fluids to Support GSI-191," March 2008. (Reference 19)

2. Westinghouse Topical Report WCAP-16406-P-A, "Evaluation of Downstream Sump Debris Effects in Support of GSI-191," Revision 1, March 2008. (Reference 20)

3. Westinghouse Topical Report WCAP-16793-NP-A, "Evaluation of Long-Term Cooling Considering Particulate, Fibrous and Chemical Debris in the Recirculating Fluid," Revision 2, July 2013. (Reference 13)

The NRC Staff determined that the reports listed above, subject to the conditions and limitation contained in the NRC SEs for those documents, describe a method acceptable to NRC staff for performing the evaluations and analyses within the scope stated in those documents. The NRC determined that the "Clean Plant" criteria guidance, as clarified in Reference 12, is an acceptable method for addressing sump strainer blockage and core blockage. WBN Unit 2 references the "Clean Plant" criteria only for the core blockage evaluation.

To communicate the NRC staff's expectations for the level of technical detail in the licensees' submittals, the NRC staff issued "Revised Content Guide for Generic Letter 2004-02 Supplemental Responses," dated November 2007 (Reference 3) and "Revised Guidance for Review of Final Licensee Responses to Generic Letter 2004-02, Potential Impact of Debris Blockage on Emergency Recirculation During Design-Basis Accidents at Pressurized Water Reactors," dated March 28, 2008 (Reference 21). The following technical evaluation addresses each critical evaluation parameter (review area) in the sequence listed in the revised content guide.

3.0 TECHNICAL EVALUATION

3.1 ECCS and CSS Description

During the initial phase of a LOCA at WBN Unit 2, the ECCS and CSS pumps draw water from the refueling water storage tank (RWST). Upon exhaustion of this water source, the pump inlets are realigned to take suction from the ECCS sump located in the basement of the containment building. The applicant provided the following description of the operation of the ECCS and CSS.

> In response to a safety injection (SI) signal, the RHR pumps, centrifugal charging pumps (CCP) and SI pumps automatically start injecting water from the RWST. The CSS pumps start if containment pressure reaches a predetermined setpoint. The CSS pumps also inject water from the RWST. When the RWST level reaches a low-level setpoint, the RHR pump suction is realigned to take suction from the ECCS sump (referred to as ECCS switchover). After ECCS switchover, the CSS pump suction is also realigned to the ECCS sump. The system response to a small-break loss-of-coolant accident (SBLOCA) is different from the large-break loss-of-coolant accident (LBLOCA) response. Depending on the break size, the primary system pressure may stabilize at a value too high to allow SI pump or RHR pump injection. Additionally, containment pressure may remain below the CSS setpoint. For these cases, depletion of the RWST may be slow enough that the RCS is cooled down prior to the need for circulation from the ECCS sump.

TVA stated in its March 4, 2011, letter that prior to fuel load, WBN Unit 2 will install sump modifications per the requirements of GL 2004-02 that are very similar to the modifications made for WBN Unit 1. The WBN Unit 2 sump strainer design is the same as that used for WBN Unit 1, with minor modifications. The strainers are manufactured by Performance Contracting, Inc. (PCI) and are of a stacked-disk design. The strainers are comprised of a series of approximately 1-inch thick disks covered with a stainless steel skin that is perforated with 0.085-inch-diameter holes. The discs are stacked on top of each other and are connected through a central flow channel to form a strainer module. The central channel collects the water and routes it to a manifold that connects to the ECCS and CSS pump suction piping. The total strainer area is approximately 4675 square feet. The strainer modules are installed vertically on the floor of the containment such that the disks are horizontally oriented. In its September 16, 2013, letter (Reference 9), TVA reaffirmed that new sump strainers will be installed prior to fuel load and stated that the installation was a confirmatory inspection item.

3.2 Review of Evaluations

3.2.1 Break Selection

The objective of the break selection evaluation is to identify the break location that results in debris generation that produces the most challenging debris loads for the containment recirculation sump strainers.

Summary of Applicant's GL 2004-02 Evaluation

The applicant followed break selection guidance in NEI 04-07 (References 16 and 17) (which is similar to that in RG 1.82) to determine the potential limiting breaks for WBN Unit 2. The applicant stated that the only potential sources of debris in the WBN Unit 2 containment building are Reflective Metal Insulation (RMI), coatings, latent debris, and miscellaneous debris. The latent and miscellaneous debris terms are not affected by the break selection evaluation. The limiting break for each filtering location (screens or core) is determined by examining the debris generation and transport assumptions for each of the remaining debris types.

The applicant stated that the following breaks were analyzed for WBN Unit 2:

- Break 1: Locations in the RCS with the largest potential for debris generation.
- Break 2: Locations with two or more different types of debris.
- Break 3: Locations with the most direct path to the sump.
- Break 4: Locations with the largest potential particulate to insulation ratio.
- Break 5: Locations that would generate debris that could potentially form a thin-bed.

Because the amounts of latent and miscellaneous debris generated and transported to the sump strainers are independent of break location, the only consideration for break selection is RMI and coatings debris. The applicant stated that RMI does not transport as easily as the particulates and is not a major contributor to head loss. Therefore, the bounding case is the one that results in the most destruction of coatings. The debris generation analysis completed by the applicant identified that a break in the crossover leg near the steam generator nozzle generated the most debris. All coatings in the zone of influence (ZOI) are assumed to generate 10 micron [0.39 mils] particulates.

The applicant stated that break locations were selected based on the accident scenarios that could lead to ECCS recirculation, the size of the pipe break, and the proximity of other insulated pipes or equipment. Secondary line breaks were considered in the evaluation but eliminated as bounding events. Secondary line breaks have a smaller ZOI for destruction (due to lower pressure), are terminated by operator action (feedwater and auxiliary feedwater isolation), and do not require sump recirculation for RCS decay heat removal. Only minimal intermittent operation of the containment spray system in the containment sump recirculation mode for long term containment temperature reduction may be required if other means of cooling the containment building are not available.

The applicant stated that various breaks were examined to maximize the amount of debris generated. Each of the five problematic break locations described in the NEI 04-07 guidance (References 16 and 17) were discussed. The applicant used the break selection evaluation to determine the breaks that would result in the maximum amount of coatings debris. The applicant described how the selected breaks present the greatest challenge to post-LOCA sump performance, and stated that the largest quantity of insulation material is installed on the RCS and that the worst case break was selected for each of the four RCS loops. The analysis identified that a break in the crossover leg, near the steam generator nozzle, generated the most particulate debris and, therefore, is considered the limiting break.

The applicant stated that secondary-side line breaks do not require recirculation for mitigation. Therefore, it is not necessary to include secondary-side line breaks in the break selection evaluation.

Staff Review of Applicant's Evaluation

Based on the staff review of the applicant input and the staff guidance, the staff concluded that the applicant had acceptably evaluated the topic. The applicant determined the worst break locations for RMI, and then discounted the ability of the RMI to contribute significantly to head loss. The applicant also identified the worst case break location for coatings. Because (1) WBN Unit 2 contains only RMI, coatings, and latent debris; (2) the RMI is not considered a significant contributor to head loss; and (3) all latent debris is assumed to transport to the strainer, the important break would maximize coatings debris. The coatings, combined with the fibrous and chemical debris, constitute the total debris load on the strainer.

The staff finds that the spectrum of breaks evaluated is acceptable because the evaluation resulted in maximizing the potential problematic debris types. The applicant's procedure meets the intent of NEI 04-07 (Reference 16), the related SE for NEI 04-07 (Reference 17), and Regulatory Position C.1.3.2.3 of RG 1.82, Revision 3. The staff accepts that RMI will not become a significant contributor to head loss for WBN Unit 2 for the reasons cited by the applicant, because the strainer is installed above the floor level, and because the approach velocities are very low such that RMI will not transport and adhere to portions of the strainer located above the floor level. Additionally, the limited amount of fibrous debris in containment is not adequate to interact with the RMI to form a significant debris bed over the surface of the strainer. Therefore, the staff finds that the break selection evaluation was conducted adequately. The applicant stated that some mineral wool is installed inside pipe guards on the main feedwater line piping penetrations and also on the in-core instrument tubes that penetrate the crane wall. These debris sources are evaluated in Section 3.2.2 as being outside the ZOI and, therefore, are not available to interact with the RMI.

Staff's Conclusion

The staff reviewed the applicant's evaluation against the staff-accepted guidance and concludes that the applicant has appropriately identified the break locations that produce the most challenging debris loads for the containment circulation sump strainer. Therefore, staff concludes that the break selection is acceptable.

3.2.2 Debris Generation/Zone of Influence (Excluding Coatings)

The objective of the debris generation/ZOI process is to determine, for each postulated break location: (1) the zone within which the break jet forces would be sufficient to damage materials and create debris; and (2) the amount of debris generated by the force of the jet emanating from the break.

The ZOI is the space surrounding a break in which jet forces would be sufficient to damage a specific material and generate debris that could be transported to the sump. Different materials have different ZOIs because some materials are more robust than others. The debris generation evaluation determines the amount of debris generated by the jet forces as well as the debris characteristics. The debris characteristics are the important properties of this debris as they relate to the ability of the debris to transport to the sump strainer and contribute to head loss across it, or contribute to downstream effects. Important characteristics include the size distribution and material density. Debris characteristics are discussed below within this section. The staff considered Section 3.4 of NEI 04-07 and the related SE (References 16 and 17, respectively) when evaluating this section, which addresses all debris types except coatings. Coatings are discussed in Section 3.2.8 of this evaluation.

NEI 04-07 recommended reshaping ZOIs into spheres in order to simplify quantification of the amount of debris generated by each potential break. It is not anticipated that LOCA jets would be spherical in shape. However, the reshaping of the ZOI into a sphere with its radius dependent on the break size and the relative destruction pressure of the target material was determined to provide, in most cases, an adequate estimate or practical approximation for debris generation.

Summary of Applicant's GL 2004-02 Evaluation

a) Zone of Influence

In its March 4, 2011, letter (Reference 1), the applicant stated that it followed the guidance in NEI 04-02 for WBN Unit 2 by assigning a ZOI of 28.6D (i.e., 28.6 times the break diameter) for RMI insulation.

b) Miscellaneous Debris

The applicant performed a walkdown of WBN Unit 1 to identify the miscellaneous material that could potentially block portions of the sump strainer surface area. Examples of miscellaneous materials are signs, tags, tape, and placards. The results of the walkdown established a conservative estimate of 697 square feet of miscellaneous debris. In the March 4, 2011, letter (Reference 1), the applicant stated that the WBN Unit 2 design is essentially identical to WBN Unit 1 and, therefore, assumed that the amount of miscellaneous debris in WBN Unit 2 would not exceed 1000 square feet. Based on NRC guidance that allows a 25-percent overlap of miscellaneous debris as it deposits on the strainer, the applicant assumed a blockage of 750 square feet in the design and testing of the sump strainer. In a letter dated April 29, 2011 (Reference 7), the applicant responded to NRC RAI number HLV RAI-1, clarifying that the initial design of the strainer considered that 750 square feet of strainer area could be blocked by miscellaneous debris, based on a conservative application of WBN Unit 1 walkdown information for miscellaneous debris. The applicant later performed testing to determine whether the miscellaneous debris would transport to the strainer under post-LOCA conditions. The test results indicated that the miscellaneous debris did not readily transport. Therefore, the miscellaneous debris sacrificial surface area used in testing was set at 200 square feet.

In its March 4, 2011, letter (Reference 1), the applicant stated that mineral wool is installed in a few locations inside the WBN Unit 2 containment building, outside of any LOCA ZOI. In a letter dated April 29, 2011 (Reference 7), the applicant responded to NRC RAI number DG RAI-1, clarifying that approximately 1.57 cubic feet of mineral wool is installed at the location where the in-core instrument tubes penetrate the crane wall, and mineral wool is also installed on the main feedwater lines that are located within the guard pipes routed outside of the crane wall where the feedwater lines penetrate the primary containment. The applicant stated that if failure of this material were to occur due to a LOCA, the material would be transported to the area outside the crane wall and the area outside the crane wall does not communicate with the emergency sump that is located inside the wall.

Staff Review of Applicant's Submittal

The staff finds that the applicant's ZOI for RMI is consistent with the staff guidance found in Table 3-2 of the SE to NEI 04-07 (Reference 17). Also, based on the information provided by the applicant in Reference 7 regarding the location of the mineral wool insulation, the staff concludes that the mineral wool would not contribute to the debris load on the ECCS strainer. Therefore, the staff finds these ZOIs are acceptable and the evaluation is adequate.

The applicant's method for determining miscellaneous debris and its treatment is consistent with NEI 04-07 and the staff's SE. Therefore the staff finds the evaluation of miscellaneous debris to be acceptable.

Staff's Conclusion

The staff reviewed the applicant's evaluation against the staff-accepted guidance and concludes that the applicant has adequately determined for each postulated break location the zone within which the force of the jet emanating from the break would be sufficient to generate debris and the amount of debris that would be generated. Therefore, staff concludes that the applicant's evaluation of the ZOI and debris generation is acceptable.

3.2.3 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 head loss.

Summary of Applicant's GL 2004-02 Evaluation

The applicant used the NEI 04-07 guidance to determine the debris characteristics for material that could be damaged by a LOCA jet. The applicant stated that RMI is assumed to be destroyed as 75 percent small pieces and 25 percent large pieces, where small pieces are defined as having dimensions less than 4 inches. The applicant then discussed containment coatings and their application. The coatings discussed were Carbozinc 11, Carboline 295, Phenoline 305, and Carboline 4674. The applicant stated that the thicknesses were assumed to be 10 microns [0.39 mils] and that the density values were based on manufacturer's data and standard references. The applicant discussed the properties of latent debris and stated that the properties were as assumed in the staff's SE on NEI 04-07 (Reference 17).

Staff Review of Applicant's Evaluation

The staff concluded that the debris characteristics used by the applicant are acceptable because they are consistent with the SE on NEI 04-07 for RMI and latent debris, and manufacturer's data and standard references for coatings.

Staff's Conclusion

The staff reviewed the applicant's evaluation against the staff-accepted guidance and concludes that the applicant has appropriately characterized the debris for use in determining the transportability of debris and its contribution to sump strainer head loss. Therefore, staff concludes that the applicant's evaluation of debris characteristics is acceptable.

3.2.4 Latent Debris

The objective of the latent debris evaluation process is to provide a reasonable approximation of the amount and types of latent debris existing within the containment and its potential impact on sump screen head loss.

Summary of Applicant's GL 2004-02 Evaluation

In a letter dated May 17, 2012 (Reference 8), the applicant stated that WBN Unit 2 meets the "Clean Plant" criteria as clarified in the NRC letter dated May 2, 2012 (Reference 12). The "Clean Plant" criteria are applied only to the core blockage evaluation. The strainer evaluation is based on strainer flow testing. The applicant's statement is supported by the description of the latent debris discussion contained in the March 4, 2011, letter (Reference 1) and repeated in the May 17, 2012, letter (Reference 8). The following is a summary of the applicant's evaluation.

The applicant stated that the quantity and composition of the latent debris assumed to be in the WBN Unit 2 containment building at the time of commercial operation is based on the results obtained during the WBN Unit 1 quantitative latent debris walkdown. The WBN Unit 1 walkdown was based on the as-found conditions at the start of a refueling outage. The walkdown involved the collection of debris samples from 26 locations inside the containment building, selected to provide a representative sample of the latent debris present in the containment building. The sample collection area for each location varied in size from 1.3 to 104.5 square feet. The samples collected were analyzed for both quantity and type of debris. The latent debris from the sampled areas was then projected for the entire containment building based on the total amount of surfaces similar to those surveyed. The applicant stated that a similar confirmatory walkdown for loose debris will be performed on WBN Unit 2 after containment work is completed and the containment has been cleaned. This walkdown will be completed prior to startup.

The applicant stated that the latent debris walkdown on WBN Unit 1 found small quantities of particulate debris such as dust, dirt, paint chips, wood chips, concrete chips, metal shavings, metal washers, nails, screws, wire powder, tape, and miscellaneous artifacts that equated to a quantity of 69.2 pounds projected to the total containment area. The samples contained only a few fibers and string material, resulting in an estimated fiber loading of 1 percent (total of approximately 0.7 pounds for the entire containment). The applicant cited Section 3.5.2.2 of NEI-04-07 that states that the maximum quantity of latent debris inside containment would be 200 pounds. Therefore, WBN Unit 1 assumed a maximum latent debris load of 200 pounds in its analyses. Further, consistent with the guidance provided in the NRC SE for NEI-04-07 (Reference 17), the latent debris characteristics were assumed to be as follows:

- fiber contributes 15 percent of the mass of the total latent debris inventory with particulate contributing the remaining 85 percent;
- latent fiber material has an average density of 94 pounds per cubic feet;
- latent particulate material has a nominal density of 169 pounds per cubic feet;
- latent fiber material has an as-manufactured density (dry bed bulk density) of 2.4 pounds per cubic feet
- latent fiber has the same diameter as commercial fiberglass (7 μm (0.27 mil) for Nukon per NUREG/CR-6224).

The applicant stated that the latent debris survey results confirmed that the assumptions described above are conservative with respect to both the composition and the quantity of the actual latent debris in the WBN Unit 2 containment buildings.

For WBN Unit 2, the applicant applied the same assumptions as for WBN Unit 1 except that the applicant assumed a maximum latent debris load of 100 pounds, based on the WBN Unit 1 walkdown results. [This translates to latent fiber load of 15 pounds in containment.] The applicant stated that a confirmatory walkdown for loose debris will be performed on WBN Unit 2 after containment work is completed and the containment cleaned. This walkdown will be completed prior to startup.

To address latent debris in the form of signs, placards, tags, tape, and similar miscellaneous materials, the applicant stated that a sacrificial strainer surface area of 750 square feet (1000 square feet times 0.75 loading factor) has been established. In a letter dated April 29, 2011 (Reference 7), the applicant responded to NRC RAI number HLV RAI-1, clarifying that the initial design of the strainer considered that 750 square feet of strainer area could be blocked by miscellaneous debris, based on a conservative application of WBN Unit 1 walkdown information for miscellaneous debris. The applicant later performed testing to determine whether the miscellaneous debris would transport to the strainer under post-LOCA conditions. The test results indicated that the miscellaneous debris did not readily transport. Therefore, the miscellaneous debris sacrificial area used in testing was set at 200 square feet.

Staff Review of Applicant's Evaluation

The NRC staff reviewed the applicant's response and considered the general approach to be consistent with the guidance specified in NEI 04-07 (Reference 16), including the NRC SE (Reference 17) of that document.

The applicant's latent debris evaluation is reasonable and is based on results from a WBN Unit 1 latent debris survey. The WBN Unit 2 assumption for latent debris amount is half of the WBN Unit 1 amount, but still below the WBN Unit 1 survey amount. Further, for a zero fiber plant, the assumption of 100 pounds of latent debris (15 pounds fiber, which is the most critical term) is reasonable. The 15 pound maximum fiber load inside containment also satisfies the "Clean Plant" criteria that are applied to the in-vessel evaluation. The assumption of 1000 square feet of miscellaneous debris is conservatively high compared to most plants and well above the value found during a WBN Unit 1 walkdown. The WBN Unit 2 survey should validate that the containment is as clean as assumed for this evaluation.

Based on the staff review of the applicant's evaluation and the staff guidance, and an application of the guidance to the response, the staff concluded that latent debris assumptions are adequate because there is some margin between the estimated amount of latent debris and the latent debris amount used in the evaluation. However, the staff notes that the magnitude of the margin does not leave significant operational margin for the site. In addition, the applicant has not yet completed construction of the plant and has not performed the latent debris survey of the WBN Unit 2 containment building.

Commitments

In Enclosure 4 of the March 4, 2011, letter, under commitment number 2, the applicant stated that a confirmatory walkdown for loose debris will be performed on WBN Unit 2 after containment work is completed and the containment has been cleaned. This walkdown will be completed prior to startup. In its September 16, 2013, letter (Reference 9), TVA reaffirmed that the walkdown will be completed prior to start-up and stated that the action was a confirmatory inspection item.

Staff's Conclusion

The staff reviewed the applicant's evaluation against the staff-accepted guidance and concludes that the applicant has appropriately identified the amount and types of latent debris existing within the containment and its potential impact on sump screen head loss. Therefore, staff concludes that the applicant's evaluation of latent debris is acceptable.

3.2.5 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.

Summary of Applicant's GL 2004-02 Evaluation

The applicant's method for evaluating debris transport at WBN involves the estimation of the fraction of debris that is transported from debris sources (which can depend on break location) to the sump screens. The four major debris transport modes used in the WBN methods are:

- Blowdown transport: the vertical and horizontal transport of debris to all areas of containment by the break jet.
- Washdown spray transport: the vertical (downward) transport of debris by the containment sprays and break flow.
- Pool fill transport: the horizontal transport of debris by break and containment spray flows from the refueling water storage tank to areas that may be active or inactive during recirculation.
- Recirculation transport: the horizontal transport of debris from the active portions of the recirculation pool to the sump screen by the flow through the ECCS and CSS.

The applicant analyzed the specific effect of each mode of transport for each type of debris generated and developed a logic tree to determine the total transport to the sump screens. The purpose of this approach is to break a complicated transport problem down into specific smaller problems that can be more easily analyzed.

The debris transport analysis was based on the NEI 04-07 guidance report for refined analyses (Reference 16), as supplemented by the associated NRC SE (Reference 17), as well as the refined methodologies suggested by Appendices III, IV, and VI of the SE. The general arrangement inside the WBN Unit 1 and WBN Unit 2 containments are mirror images and the pump capacities and flow rates are the same. Thus, the applicant stated that the WBN Unit 1 transport analysis applies to WBN Unit 2.

The applicant built a three-dimensional model of the containment building using computer aided drafting software, collected and calculated input parameters to support a computational fluid dynamic (CFD) simulation of containment pool flows during the recirculation phase of the LOCA, performed a CFD analysis, and used the CFD results, along with the analysis of blowdown, washdown, and pool fill, to define transport fractions using a logic tree approach. The applicant stated that no transport assumptions deviated from the approved guidance. The applicant stated that the CFD code used was Flow-3D, Version 8.2. Flow-3D is a commercially available general-purpose computer code for modeling of dynamic behavior of liquids and gases influenced by a wide variety of physical processes. The program is based on the fundamental laws of mass, momentum and energy conservation. It has been constructed for the treatment of time-dependent multi-dimensional problems and is applicable to most flow processes. ALION Science and Technology (TVA Contractor) validated and verified Version 8.2 of Flow-3D under its Quality Assurance program. Various aspects of the inputs and modeling assumptions were provided in the response. As a conservative measure, the applicant did not credit debris interceptors in its transport analysis. Based on the method summarized above, the applicant calculated a worst case debris transport rate of 96 percent for fibrous debris and 48 percent overall for RMI. A bounding quantity of debris at the strainers was applied using the most limiting amount of each debris type from each of the four reactor coolant loop break locations examined. In establishing the debris quantities at the strainer, the applicant used conservatively higher transport fractions for RMI and fibrous debris (71 percent and 100 percent, respectively) based on an earlier analysis that remained bounding.

<u>Staff Review of Applicant's Evaluation</u>

The NRC staff reviewed the applicant's response and considers the general approach taken by the applicant to be consistent with the guidance specified in NEI 04-07. In particular, consistent with the approved guidance, the applicant did not credit settlement of fine debris. All debris types, other than RMI, were considered to consist of fines, resulting in 100 percent transport for all debris other than RMI (i.e., latent debris and coatings particulate). The transport percentage calculated for RMI is conservative, based on the results of the CFD analyses as well as not crediting debris interception. This calculation is not directly relevant for acceptance of strainer performance because RMI was not added to the strainer qualification testing, due to its inability to climb onto and adhere to strainer surfaces as well as its potential to lower the test measured head loss when it is transported to the strainer.

The NRC staff concluded that the debris transport evaluation prepared by the applicant, as summarized above, is acceptable because the general approach taken by the applicant is consistent with NEI 04-07 (Reference 16), and the NRC SE of that document (Reference 17), and because the associated debris transport results have been conservatively calculated.

Staff's Conclusion

The staff reviewed the applicant's evaluation against the staff-accepted guidance and concludes that the applicant has appropriately estimated the fraction of debris that would be transported from debris sources within containment to the sump suction strainers. Therefore, staff concludes that the applicant's evaluation of debris transport is acceptable.

3.2.6 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 possibility of a vortex to form above the strainer.

Summary of Applicant's GL 2004-02 Evaluation

In a letter dated May 17, 2012 (Reference 8), the applicant stated that the WBN Unit 2 plant currently meets the "Clean Plant" criteria with respect to strainer head loss by strainer head loss testing as accepted by NRC staff in a letter dated May 2, 2012 (Reference 12). The WBN Unit 2 strainer and the head loss testing of the strainer are described below. Although WBN Unit 2 meets the "Clean Plant" criteria, the licensing basis for the strainer is based on head loss testing.

WBN Unit 2 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 the stacks are 5.52 feet tall and the remaining stacks are 4.81 feet tall. The 23 strainers provide a total of 4675 square feet 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 WBN Unit 2 sump strainer design is the same as that used for WBN Unit 1, except that the strainer stack-to-plenum opening was increased for WBN Unit 2 to reduce the strainer pressure drop, thus providing margin to plugging when compared to the WBN Unit 1 strainer.

TVA applied the head loss and vortexing test results obtained during the WBN Unit 1 strainer testing to WBN Unit 2. The applicant stated that WBN Unit 1 conducted head loss testing using debris loads and flow rates specific to WBN Unit 1 to demonstrate the adequacy of the WBN Unit 1 containment sump strainers. Tests were designed to determine the maximum head loss that could develop across the strainer with the design basis debris loading. The applicant stated that the WBN Unit 1 debris loads bound the WBN Unit 2 debris loads because WBN Unit 2 does not contain two of the problematic materials found in WBN Unit 1–Min-K® insulation and Interam® fire barrier. The debris used in the latest series of WBN Unit 1 head-loss evaluations consisted of particulate, fiber, Interam, Min-K, and chemical precipitates. Additionally, the evaluation assumed that a portion of the strainer could be blocked by miscellaneous materials.

Sump strainer testing was conducted using a test strainer consisting of an array of four modules of the same design as the plant modules. Testing used a debris load scaled from the plant design basis load to the test strainer surface area. Flow through the test strainer was also scaled to the test strainer surface area. For test scaling purposes, the applicant reduced the strainer area to account for the potential for miscellaneous materials to block a portion of the strainer. In the March 4, 2011, letter (Reference 1), Section 3.b, the applicant stated that WBN Unit 2 assumed that the amount of miscellaneous debris would not exceed 1000 square feet and based on a 25 percent overlap of miscellaneous debris deposited on the strainer, the applicant assumed a blockage of 750 square feet for design and testing of the sump strainer. In a letter dated April 29, 2011 (Reference 7), TVA responded to NRC RAI number HLV RAI-1, clarifying that the initial design of the strainer considered that 750 square feet of strainer area could be blocked by miscellaneous debris, based on a conservative application of WBN Unit 1 walkdown information for miscellaneous debris. The applicant later performed testing to determine whether the miscellaneous debris would transport to the strainer under post-LOCA conditions. The test results indicated that the miscellaneous debris did not readily transport. Therefore, the miscellaneous debris was not included in the test and an area of 200 square feet was subtracted from the total strainer area as margin for the testing.

Testing was performed at Alden Research Laboratory, Inc.; AREVA NP, Inc. (AREVA) provided technical and logistical support for the testing. The NRC staff witnessed one of the tests and found the method used during testing acceptable. However, the test witnessed by staff (Test 4) resulted in excessive head loss across the debris bed. The staff's findings are documented in a memorandum from S. J. Smith to M. L. Scott dated August 19, 2010 (Reference 22). The applicant conducted two additional tests (4B and 4C) with reduced debris loads. The final test, Test 4C, was conducted using the WBN Unit 2 design basis debris load, plus Interam® fire-barrier material that is not installed in WBN Unit 2 but will likely remain installed in WBN Unit 1. The applicant stated that Test 4C is the design basis test for WBN Unit 2. The test is considered to be conservative for WBN Unit 2 because it contained significant amounts of problematic material that will not be in WBN Unit 2 and, therefore, will not be part of the WBN Unit 2 design basis debris load.

The test facility was designed to add sufficient turbulence to minimize any settling of debris in the tank to ensure that the majority of debris transported to the strainer during the test. The test facility also implemented features to ensure that debris characteristics were consistent with testing guidance and were well mixed and diluted prior to reaching the strainer.

Prior to the introduction of debris, clean strainer head loss (CSHL) measurements were attained. The tested clean strainer head loss value is used to correct test head loss measurements to ensure that only debris head loss is reported. Note that a calculated CSHL for the plant is added to the measured debris head loss to determine the overall plant head loss. The flow rate for the testing was scaled based on the strainer design maximum flow rate of 19,100 gallons per minute. The CSHL was calculated to be 0.338 feet of water.

After the CSHL for the test arrangement is determined, debris is added to the loop according to the test plan. Particulate debris surrogates are added first, followed by fibrous debris and finally, chemical debris surrogates. Flow and head loss parameters are continuously monitored and recorded during the test. Details of a test performed for WBN Unit 1 that is similar to the WBN Unit 2 test is documented in a NRC staff trip report dated August 19, 2010 (Reference 22). The applicant provided additional details on Test 4C (the design basis test for WBN Unit 2) as well as the test method described in their March 2011 letter on GL 2004-02 (Reference 1).

The final debris head loss determined by Test 4C was 1.88 feet of water. Applying a viscosity correction factor to account for a post-LOCA water temperature of 190 °F, the applicant calculated the expected head loss to be 1.09 feet of water at the onset of circulation.

The applicant stated that the calculations for sump water level validate that the strainers will be submerged under all conditions during which circulation could be required. There are two different height strainer stacks installed in the WBN Unit 2 containment building. Under the most limiting conditions the tall strainers are submerged by at least 0.26 foot. The shorter strainer stacks are submerged by at least 0.97 foot. The applicant stated that the strainers remain submerged under all accident scenarios.

The applicant provided information regarding the potential for vortex formation, a condition under which air could be drawn into the suction of the pumps that are drawing water from the strainer. The original sump intake structure contained vortex prevention features that were shown by scaled testing to be effective. The sump intake had to be modified to attach the new strainer assemblies, but the vortex suppression features were retained. The applicant's evaluation also stated that the construction of the strainer would prevent vortices from forming because of the multiple components within the strainer that reduce the probability of vortex formation. The applicant stated that the flow velocity near the strainer was 50 percent of that required to initiate air ingestion. Although the staff did not validate the applicant's calculation, the staff concludes (based on the submergence information contained in the applicant's evaluation and on observations of head loss testing at prototypical submergence and flow rates) that a vortex would not form. The applicant also stated that air ingestion would likely be less than 2 percent and that it would remain less than 3 percent at expected containment conditions.

The applicant provided information regarding the ability of the strainer to accommodate the maximum amount of debris predicted to arrive at the screen, and information regarding the ability of the strainer to handle the formation of a thin bed without developing excessive head loss. The design basis debris load calculated for WBN Unit 2 does not challenge the maximum debris load performance of the strainer because the quantity of fibrous debris in the containment building is small compared to the strainer area. The testing conducted for WBN Unit 2 resulted in a thin bed because the amount of fiber in the design basis debris load is small. The resulting head loss did not cause a challenge to NPSH margins for the ECCS or CSS pumps. In a letter dated April 29, 2011 (Reference 7), the applicant responded to NRC RAI number HLV RAI-2, by providing a plot of the head-loss versus time data (Figure 6-6 from AREVA document 66-9144025-000 "Watts Bar, Unit 1 Emergency Core Cooling System Strainer Performance Test report") for the entire duration of Test 4C. The applicant also stated that a thin-bed test, representing the design-basis test for WBN Unit 2, was performed on July 16, 2010.

The applicant provided information regarding the method used to determine the total strainer head loss. The debris head loss from the head loss testing discussed in this section was added to the calculated CSHL. The final viscosity-corrected debris head loss was calculated to be 1.09 feet of water at a temperature of 190 °F. The scaling was based on a straight temperature/viscosity correction. The applicant stated that flow sweeps were conducted to verify that the flow through the debris bed was laminar and that no pressure driven bed discontinuities were present. Therefore, the total strainer head loss including debris and clean strainer components is 1.428 feet of water.

In a letter dated April 29, 2011 (Reference 7), the applicant responded to NRC RAI number HLV RAI-3, by describing, the method used to perform the extrapolation of test data to the required mission time. The response included excerpts from a vendor calculation that performed the extrapolation. The response included a graph of the last portion of the head loss test and a linear fit of the data near the end of the test. The data show that the head loss was stable and not increasing or decreasing at the end of the test. The final head loss value is high enough that the statistically significant data taken during the test are bounded by the value.

The applicant stated that near-field settling was not credited during testing. The testing performed for WBN Unit 1 and WBN Unit 2, discussed above, has been reviewed and found to be acceptable from a near-field settlement perspective.

The applicant stated that containment accident pressure was not credited in evaluating the potential for flashing across the debris bed.

Staff Review of Applicant's Evaluation

The staff evaluated the applicant's GL 2004-02 response against the March 28, 2008, guidance for head loss and vortexing and chemical effects as (Reference 21).

WBN Unit 2 has a relatively large strainer and a small, non-problematic debris source term. The design basis debris load for the strainer is unlikely to result in high head losses because (1) the debris mix contains no fibrous debris (except latent), (2) historically problematic debris generating materials are not present within the containment building, and (3) the strainer is relatively large. Even if a small amount of additional debris were added to the source term the strainer would likely function adequately under post-LOCA conditions. The staff has adequate assurance that the strainer will perform its function without adding significant head loss to the ECCS and CSS pump suction. This assurance is based on the large strainer, small debris source term, and lack of problematic materials within the containment building. The staff also considered its knowledge of numerous strainer tests at varying debris loads and conservatism present in the applicant's evaluation. The staff also noted that the WBN Unit 2 strainer design basis head loss test included problematic material that will not present in the WBN Unit 2 containment.

The applicant's RAI response number HLV RAI-1 in its letter dated April 29, 2011 (Reference 7), clarifying the apparent discrepancy in the sacrificial area assigned to account for miscellaneous debris, is found to be acceptable based on staff's observations of similar transport testing performed by other licensees. The staff finds that the applicant's testing program was conducted properly because similar tests have shown that the majority of miscellaneous debris does not readily transport under typical post-LOCA conditions. Therefore, the inclusion of 200 square feet of sacrificial area is adequate to account for any miscellaneous debris that enters the pool near the strainer such that it could transport to the strainer and block part of the strainer area. Therefore, the staff finds the response to this RAI acceptable.

The staff reviewed the applicant evaluations supporting the conclusion that (1) a vortex would not form at the strainer such that air could be drawn into the suction of the pumps, and (2) that air ingestion would likely be less than 2 percent and would remain less than 3 percent at expected containment post-LOCA conditions. The staff concluded that vortex formation for the WBN Unit 2 strainers would not occur since the strainers are fully submerged under all conditions when recirculation is required. The staff's conclusion is based on previously accepted vortex evaluations for similar strainers and plant-specific testing for the WBN Unit 1 and WBN Unit 2 strainers. Further, the staff recognizes that the WBN Unit 2 strainer is of a uniform flow design and, therefore, the flow through the strainer surfaces is equalized so that no one section of the strainer incurs significantly higher velocities than the average for the strainer. Preventing areas of high flow reduces the potential for vortex formation.

The applicant's statement that air ingestion will be limited was confirmed by staff. Staff performed a calculation using bounding conditions for WBN Unit 2 and determined that deaeration would not contribute significantly to air ingestion. Additionally, based on strainer testing, the formation of a vortex and subsequent air ingestion is not expected. Therefore, the staff concluded that air ingestion from these sources will not adversely affect ECCS or CSS pump performance.

The staff reviewed the applicant's sump strainer head loss evaluation, including the applicant's response to RAI number HLV RAI-2 in the applicant's letter dated April 29, 2011 (Reference 7). The staff reviewed the head loss plot provided in the RAI response and determined that the head-loss test did not exhibit any behavior that would cause the staff to question the applicant's test results or the use of those results as applied to the WBN Unit 2 strainer evaluation. Therefore, the staff finds the results of the test and the application of the results acceptable.

The staff reviewed the applicant's evaluation of the susceptibility of the strainer to thin-bed formation that could result in excess head loss. The staff performed a calculation for the potential theoretical bed thickness for the WBN Unit 2 strainer. Considering that latent debris provides the only fibrous source term for the strainer, and that all the latent fiber reaches the strainer, the calculated theoretical bed thickness is about 0.02 inch. Although the staff has not defined a theoretical bed thickness below which a filtering bed cannot form, a 0.02-inch thick bed would likely not result in a filtering bed over a significant portion of the strainer. Therefore, the staff finds the applicant's evaluation acceptable.

Staff reviewed the applicant's calculation of the CSHL and found that the applicant used methods acceptable to the staff. Therefore, the calculation is considered to be satisfactory.

The staff reviewed the applicant's method used to determine the total strainer head loss, adding the head loss obtained from testing with debris to the calculated CSHL and correcting for viscosity changes due to temperature. The staff validated that a correction from 120 degrees Fahrenheit (°F) (test temperature) to 190 °F (design temperature) would result in a viscosity corrected head loss of the magnitude stated by the applicant. Therefore, the staff accepts the applicant's viscosity correction method since it was conducted per staff guidance. The staff finds that the applicant's calculated total head loss of 1.428 feet of water is acceptable.

The staff reviewed the applicant's method for extrapolating the test results to the 30-day mission time, as described in response to RAI number HLV RAI-3 in the applicant's letter dated April 29, 2011 (Reference 7). The staff agreed with the applicant's statement that the final head loss value is high enough that the statistically significant data taken during the test are bounded by the value. Therefore, the staff finds the applicant's extrapolation acceptable.

The staff reviewed the applicant's position of not taking credit for containment accident pressure when evaluating the potential for flashing across the debris bed. The staff concluded that because the debris source term for the plant is small (resulting in little head loss) and the maximum sump temperature is predicted to be 190 °F (significant subcooling), flashing across the strainer would not occur. The staff also considered that by the time a debris bed forms on the strainer, the temperature would likely be reduced, resulting in additional subcooling such that flashing will not occur. Therefore, not crediting accident pressure is conservative.

Staff's Conclusion

The staff reviewed the applicant's evaluation against the staff-accepted guidance and concludes that the applicant has appropriately determined the head loss across the sump strainer and evaluated the potential for formation of a vortex at the strainer. Therefore, staff concludes that the applicant's evaluation of head loss and vortexing is acceptable.

3.2.7 Net Positive Suction Head

The objective of the NPSH evaluation is to validate that the plant design provides adequate margin between the NPSH available and the NPSH required for each pump taking suction from the recirculation sump. The evaluation calculates the NPSH available at the pump suctions and compares it to a manufacturer's value for NPSH required. The available NPSH is affected by several factors; including the elevation of the containment pool surface, elevation of the pump suction, friction losses in the piping, temperature of the water, and head loss through the strainer.

The NRC staff's acceptance criteria for the analysis of the available NPSH to the ECCS and CSS pumps are based on the guidance and regulatory requirements described in Section 6.2.2, "Containment Heat Removal Systems," of the Standard Review Plan (SRP), NUREG-0800 (Reference 23).

Summary of Applicant's GL 2004-02 Evaluation

The applicant provided the pump flow rates for the pumps taking suction from the ECCS sump. There are two ECCS trains and two CSS trains. Each ECCS train is capable of a flow of 5000 gallons per minute. Each CSS train is capable of 4600 gallons per minute flow. Other assumptions and inputs to the NPSH calculation are as follows:

- Both trains of RHR and CSS are in service
- Sump fluid temperature is 190 °F
- Containment pressure is zero pound-per-square-inch, gage
- The SBLOCA evaluation uses the sump level at the time of RHR switchover to recirculation
- The SBLOCA evaluation assumes full 5000 gallons per minute RHR flow even though the flow will be less
- The full CSS flow (4600 gallons per minute, per train) is assumed for all cases

The applicant stated that the required ECCS and CSS pump NPSH required values were determined by factory testing and that the testing typically used a decrease in pump head of 3 percent to define NPSH required.

The applicant used a computer flow simulation model to determine the suction line piping losses for the ECCS and CSS pumps. The applicant stated that the input parameters conservatively maximized flow through the piping to establish the bounding friction losses used in the NPSH analysis.

The applicant stated that the limiting single failure assumption for transients that require containment sump recirculation is the complete loss of one train of ECCS equipment.

The applicant described the method used to determine the containment sump levels listed in the NPSH section of his evaluation. The process calculated the minimum volume of water available from various sources for different scenarios, subtracted potential water holdup volumes from the source total, and finally determined the lower containment free volume that would be filled by the inventory. The potential water sources, depending on the scenario, are the RCS, cold leg accumulators, RWST, and ice melt from the ice condensers. Volumes that could trap or holdup water are the reactor cavity, operating floor, refueling canal, containment atmosphere, CSS piping, and the pocket sump. The applicant also stated that for the LBLOCA, water volume greater than 367,000 gallons in the sump would spill into a raceway where it would no longer be available for recirculation. No spillage is calculated to occur prior to ECCS recirculation. The assumptions were made to ensure that the water level credited for the NPSH and strainer evaluations is minimized for added conservatism.

The assumptions for the minimum water level evaluation are as follows:

- During the injection phase, ECCS and CSS pump flows are maximized. This minimizes the time to switchover and minimizes the contribution from ice melt. The applicant stated that this minimizes the sump level at both the ECCS switchover point (RWST low level) and the CSS switchover point (RWST low-low level).
- The initial water level in the RWST is the "minimum full" level.
- Water droplet size remains constant and was chosen to maximize the amount of water held up in the containment atmosphere.
- The lower containment volume was reduced to account for equipment and structures in the lower containment.
- All CSS flow is assumed to fall onto the operating deck prior to flowing into the refueling canal. This maximizes holdup on the operating deck.

Additional assumptions for the SBLOCA are as follows:

- Two SBLOCA cases were evaluated; a 120 gallon per minute break and a 2000 gallon per minute break.
- Limited credit is taken for ice melt for the SBLOCA.
- The break flow is assumed to fill the reactor cavity first, thus minimizing volume reaching the containment sump.
- The volume of accumulators is not added to the sump inventory.
- The only credit taken for RCS volume added to the inventory is based on the assumed break flow rate (120 or 2000 gallons per minute).

The applicant provided the following table summarizing the sources for sump pool inventory.

Sump Recirculation Pool Source Inventory Summary (RHR switchover)

	LBLOCA	SBLOCA (high flow rate[1])	SBLOCA (low flow rate[2])
Primary System Inventory (gallon)	50,500	0	0
Cold Leg Accumulator Inventory(gallons)	22,900	0	0
RWST Inventory to ECCS switchover (gallons)	202,000	202,575	202,575
Ice Melt Inventory (gallons)	147,240	46,516	3,048
Total (gallons)	422,640	249,091	205,623

Notes: 1. Volume based on 2000 gallons per minute flow rate through pipe break.
2. Volume based on 120 gallons per minute flow rate through pipe break.

The applicant stated that no credit is taken for accident pressure in the determination of NPSH available for pumps taking suction from the containment sump. The assumption is that the containment pressure remains at the minimum internal building pressure of 14.3 pounds per square inch, absolute. The maximum calculated sump temperature of 190 °F is used for the NPSH available calculations. The NPSH calculations assume that the vapor pressure of the water is 9.34 pounds per square inch, absolute, which corresponds to the maximum sump temperature of 190 °F.

The applicant provided the most limiting NPSH margins calculated for the RHR and CSS pumps for two separate points in time following a LOCA. At RHR switchover, the NPSH margin is 10.5 feet of water for the RHR pumps and 4.8 feet of water for the CSS pumps. Note that the CSS pumps are not taking suction from the recirculation sump at this time so the CSS NPSH margin is for information only. At CSS switchover, the NPSH margin is 8.5 feet of water for the CSS pumps and 14.2 feet of water for the RHR pumps. Per Enclosure 2, Open Item 4, of Reference 1, these values include sump strainer and debris head losses. Additionally, the values indicate that the NPSH margins increase as time progresses due to the increase in sump pool elevation.

Staff Review of Applicant's Evaluation

NRC staff reviewed the applicant's assumptions used to determine the ECCS and CSS pump flow rates and the required pump NPSH, as described above, and determined that the assumptions meet staff guidance and, in some cases, represent conservatism with respect to the guidance documents.

The staff also evaluated the applicant's use of computer models to calculate the line losses in the ECCS and CSS pump suction lines. The staff found these methods acceptable as the staff accepts the use of hand calculations and computer models for determination of hydraulic flow losses in piping systems.

The staff reviewed the criteria used by the licensee to determine the ECCS and CSS flow rates through the sump strainer. Although the applicant stated that the limiting single failure assumption for transients that require containment sump recirculation is the complete loss of a train of ECCS equipment, the applicant performed the head loss evaluation using maximum flow rates assuming both trains of ECCS and CSS operating. The staff notes that assuming a failure of single train is limiting from the perspective of core cooling, but from a strainer head loss perspective, maintaining operation of all the pumps is more limiting. Because the applicant performed the head loss evaluation using maximum flow rates (all trains operating), the staff finds the evaluation acceptable.

The staff reviewed the applicant's method for determining the containment sump water level and determined that the applicant properly accounted for the sources of water and the water hold-up volumes. The staff considers the calculated minimum water level to be conservative.

The staff reviewed the applicant's assumptions and inputs for calculating the available NPSH for the ECCS and CSS pump, including the applicant's decision to not credit containment accident pressure. The staff finds that these assumptions are in accordance with staff guidance for calculating the available NPSH and, therefore, are acceptable. The staff noted that the margins reported for RHR switchover time and CSS switchover time were not consistent with the strainer submergence values reported in Section 3.f.2 of Enclosure 1 of the WBN Unit 2 response (Reference 1). For the limiting case (SBLOCA), the minimum sump level is stated to increase from 5.78 feet at the time of initiation of ECCS recirculation to 6.91 feet at the time of initiation of CSS recirculation. This would contribute to an NPSH margin of 1.1 feet of water. However, the NPSH section of the final response states that NSPH margin increases by about 3.7 ft when comparing similar conditions. The change in submergence reported in Section 3.f.2 for a LBLOCA (3.4 feet) is closer to this value. In a letter dated April 29, 2011 (Reference 7), the applicant responded to NRC RAI number NPSH RAI-1, by providing corrected strainer submergence values for the SBLOCA condition. In addition, the applicant provided the method used to calculate the increase in NPSH margin. The updated submergence levels correspond to those expected by the staff for an increase in NPSH margin of 3.7 feet of water. The correction to the SBLOCA sump level contained in the head loss and vortexing section is adequate for the staff to conclude that the NPSH margins were calculated correctly, including the increased margin for the SBLOCA case.

In Enclosure 3 of the March 4, 2011, letter (Reference 1), the applicant stated that the calculation for determining the minimum water level for SBLOCAs assumes that the RCS will contribute inventory to the reactor cavity and that RCS shrinkage (due to cooling of the primary inventory) will reduce the available water volume in the containment sump. The leakage into the reactor cavity is greater than the shrinkage calculated for the 2000 gallon per minute SBLOCA case. From the information initially provided in the March 4, 2011, letter (Reference 1), the NRC staff could not determine whether the stated amounts provide for conservative estimates of minimum sump level. In a letter dated April 29, 2011 (Reference 7), the applicant responded to NRC RAI number NPSH RAI-2, by providing, additional information regarding the method used and assumptions made to calculate the minimum sump water level. The RAI response clarified that for the 2000 gallon per minute SBLOCA case, the RCS cooldown is only carried out to the point where the RCS pressure reaches 600 pounds per square inch, absolute. At that point, the accumulators would discharge their volumes, adding to the RCS and sump pool volume. For the 120 gallon per minute SBLOCA case, the RAI response stated that the RCS is continuing to cool at the time ECCS recirculation is initiated. The RCS pressure at the initiation of recirculation was calculated to be 1167 pounds per square inch, absolute. The applicant carried out the analysis until the RCS achieved the accumulator injection setpoint pressure of 610 pounds per square inch. At that point, the contents of the accumulators are assumed to be discharged to the RCS and sump pool. The staff determined that the LOCA cases considered by the applicant demonstrated that a minimum sump level had been determined. The staff concluded that the discharge of the accumulators would add adequate volume to the pool such that any additional RCS shrinkage would be compensated. The staff also recognizes that ice melt will continue to add inventory to the sump pool since ice melt was minimized for the SBLOCA evaluations. Therefore, the staff concludes that the containment pool elevation has been conservatively calculated.

Based on the NRC staff's review of the information provided by the applicant for this review area, the staff has concluded that the applicant's evaluations and assumptions for determining available NPSH margin meet NRC staff guidance and, in some areas, are more conservative. The hand calculations and computer models used to determine hydraulic flow losses in the piping systems are also found to be acceptable. Therefore, the staff finds the method for determining NPSH margin for the ECCS and CSS pumps to be acceptable and in accordance with standard engineering practice.

Staff's Conclusion

The staff reviewed the applicant's evaluation against the staff-accepted guidance and concludes that the applicant has appropriately validated that the plant design provides adequate margin between the NPSH available and the NPSH required for each pump taking suction from the recirculation sump. Therefore, staff concludes that the applicant's evaluation of NPSH is acceptable.

3.2.8 Coatings Evaluation

This review area is associated with the applicant's evaluation of various protective coatings used inside the containment that can become debris as a result of a postulated pipe break inside the containment building.

Summary of Applicant's GL 2004-02 Evaluation

WBN Unit 2 calculated the amount and type of debris that could be generated considering such evaluation parameters as the coatings characteristics and ZOI of the LOCA jet. TVA stated that it made the following assumptions when determining the types and quantities of coatings debris that could be generated by the various LOCA scenarios.

- The ZOI for qualified coatings is 10D,
- All qualified coatings in the ZOI fail as fine particulate
- All unqualified coatings in containment fail as fine particulate,
- All coating debris transports to the sump.

The applicant used silicon carbide and tin particles as surrogate for coatings debris in the strainer testing.

Staff Review of Applicant's Evaluation

The staff found the approach for testing and the treatment of coatings to be consistent with the NRC SE on NEI 04-07. The staff found the surrogates used for testing to be acceptable because the density and particle size of the surrogates are similar to the properties of the expected coatings debris. Also, the applicant's coating assessment program met the staff's expectations since WBN Unit 2 will visually inspect Service Level I coatings every refueling outage with qualified personnel and any coating issues would be reported and put into the corrective actions program. During the review, the staff noted that for some coatings, the 10D ZOI assumed by the applicant was in excess of the 5D ZOI permitted by TR-WCAP-16568-P that was endorsed by the staff in its SE on NEI 04-07. The larger 10D ZOI results in approximately seven times as much epoxy debris than that generated using the 5D ZOI that the applicant could have justified. Therefore, the larger ZOI assumption made by the applicant adds additional conservatism.

The staff review found that the WBN Unit 2 coatings assessment was consistent with the NRC SE on NEI 04-07 and in accordance with the coating review guidance contained in the letter from W. H. Ruland, NRC, to A. R. Pietrangelo, NEI, dated March 28, 2008 (Reference 21). The staff reviewed the types of coatings applied inside the containment building, the condition assessment program, the assumptions for debris generation, the debris characteristics, the assumptions for paint debris transport, and the sump strainer head-loss testing. Based upon the satisfactory finding associated with the review of these factors, the staff finds that the impact of coatings on sump strainer performance was adequately addressed.

In its September 16, 2013, letter (Reference 9), TVA stated that the protective coatings program for conducting visual examinations of Service Level I and Service Level II coatings at WBN Unit 2 are the same as that approved for WBN Unit 1: WBN Procedure MAI-5.3 for visual examination of Service Level I and II protective coatings now also applies to WBN Unit 2.

Staff's Conclusion

The staff reviewed the applicant's evaluation against the staff-accepted guidance and concludes that the applicant appropriately identified the various protective coatings that can be a source of debris inside the containment building following a postulated pipe break inside containment. Therefore, staff concludes that the applicant's evaluation of coatings is acceptable.

3.2.9 Debris Source Term

The objective of the debris source term evaluation 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.

Summary of Applicant's GL 2004-02 Evaluation

The applicant provided information regarding the programs in place at WBN Unit 1 to maintain containment cleanliness, control foreign material and control design changes that could alter the debris source term. The applicant stated that, collectively, the listed programs 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. In its September 16, 2013, letter (Reference 9), TVA stated that procedures are in place at WBN Unit 2 that address material control and containment cleanliness.

Staff Review of Applicant's Evaluation

Staff reviewed the description of the procedures, instructions, and programmatic controls cited by the applicant and find them acceptable for maintaining latent debris levels and debris sources within the assumptions used in the sump recirculation evaluations. These programs and procedures are similar to those used throughout the industry for controlling containment cleanliness, plant design configuration and debris sources. Further, the procedures have been shown to be effective at maintain reasonable cleanliness by maintaining the latent debris load in WBN Unit 1 at less than 70 pounds.

Staff's Conclusion

The staff reviewed the applicant's evaluation against the staff-accepted guidance and concludes that the applicant has significant design and operational measures in place to control or reduce the plant debris source term. Therefore, staff concludes that the applicant's evaluation of debris source terms is acceptable.

3.2.10 Screen Modification Package

Summary of Applicant's GL 2004-02 Evaluation

The applicant stated that the ECCS sump strainer installed in WBN Unit 2 will be identical to the strainer installed in WBN Unit 1 with minor modifications. A detailed description of the strainers is provided in Section 3.1 of this safety evaluation.

Staff Review of Applicant's Evaluation

The purpose of this section of the applicant's evaluation is to provide a general description of the proposed strainer. The adequacy of these modifications is determined through the review of the strainer performance parameters contained in Sections 3.2.6, 3.2.7, and 3.2.11 of this SE.

Commitments

In Enclosure 4 of the March 4, 2011, letter, under commitment number 1, the applicant stated that WBN Unit 2 will install sump modifications per the requirements of GL 2004-2 prior to WBN Unit 2 fuel load. In its September 16, 2013, letter (Reference 9), TVA reaffirmed that new sump strainers will be installed prior to fuel load and stated that the installation was a confirmatory inspection item.

Staff's Conclusion

The applicant has provided an adequate description of the ECCS sump strainer to be installed in WBN Unit 2. The adequacy of the strainer performance is addressed in Sections 3.2.6, 3.2.7, and 3.2.11 of this SE. Therefore, the staff finds the applicant's ECCS sump strainer acceptable.

3.2.11 Sump Structural Analysis

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

Summary of Applicant's GL 2004-02 Evaluation

The containment sump strainer assembly at WBN Unit 2 was described by the applicant as consisting of 23 vertically oriented strainer modules, each consisting of a number of stacked, 1-inch-thick disks with 0.085-inch diameter flow openings throughout each disk. In order to address item 3.k of the Revised Content Guide for GL 2004-02 Supplemental Responses (Reference 3), the applicant's evaluation (Reference 1) stated that a combination of manual calculations and computational finite element analyses (FEA), using the GTSTRUDL and ANSYS computer programs, were used in order to demonstrate the abilities of the strainer assembly and flow plenum to maintain their structural integrity in the event of a design basis accident. In a letter dated April 29, 2011 (Reference 7), the applicant responded to NRC RAI number EMCB RAI-1, stating that the damping values used in the development of the operating basis earthquake (OBE) and safe shutdown earthquake (SSE) seismic response spectra used in the structural analyses of the sump strainer structures were 2 percent and 3 percent, respectively.

Using the analysis methods described above, the applicant evaluated the strainer assembly and flow plenum by subjecting the structures to the loads described on page E1-60 of Reference 1 in order to determine the maximum stresses induced in the individual components making up these structures. These loads, combined, make up the design basis loading combinations applicable to the sump strainer and flow plenum assembly. The stresses induced by the loads are then compared against the corresponding limits outlined on page E1-60. In its evaluation, the applicant stated that the analysis for the strainer and the flow plenum considered the following loads: dead weight of the structure and supports, thermally induced loads under accident conditions, debris weight, differential pressure, and seismic loads induced by OBE and SSE.

The NRC staff issued two RAIs on the WBN Unit 1 GL 2004-02 submittal regarding the loading combinations considered in the structural analysis of the sump strainer and flow plenum assembly. The applicant noted on page E1-60 of the March 4, 2011, letter (Reference 1) that debris impact loads need not be considered in the structural analysis of the sump strainer and flow plenum assembly. In the letter dated April 29, 2011 (Reference 7), the applicant responded to NRC RAI number EMCB RAI-2, stating that the debris impact loads were not incorporated into the applicable loading combinations because the location of the strainer precludes the strainer from the effects of loadings due to debris impacts resulting from potential pipe breaks. In Reference 1, TVA stated that loads due to jet impingement, pipe whip, or missile impacts from high energy line breaks inside containment were not considered in the structural evaluation because a review of pertinent Final Safety Analysis Report (FSAR) figures determined that the location of the sump strainers was such that the strainers were not subject to such loads. WBN Unit 1 FSAR Amendment 6, Figures 6.3-6 and 6.3-6a, show that the strainers are located in a relatively protected area of the lower containment below the refueling cavity. TVA stated that the WBN Unit 2 strainers are in the same location with respect to other WBN Unit 2 structures as the WBN Unit 1 strainer is to WBN Unit 1 structures and that the WBN Unit 2 FSAR will be revised to reflect the new sump strainer. Further, the applicant noted that in accordance with the WBN Unit 2 licensing basis for leak-before-break (LBB) criteria, dynamic effects due to primary system pipe breaks need not be considered as additional loads.

The applicant also indicated on page E1-61 of the March 4, 2011, letter (Reference 1) that the loading combinations that the structures were evaluated against did not require the consideration of hydrostatic and hydrodynamic loads in order to demonstrate compliance with the code requirements. In the letter dated April 29, 2011 (Reference 7), the applicant responded to NRC RAI number EMCB RAI-3, clarifying the application of hydrostatic and hydrodynamic loads in the analyses. The applicant stated that the design and licensing basis requirements related to the design of the strainer structures do not require the combining of loads due to seismic forcing functions, such as hydrodynamic loads due to sloshing, with other loads applicable to the period of recovery from a design-basis accident. Additionally, the applicant indicated that hydrostatic loads were included within the differential pressure loads.

Using the analyses methods described above, the applicant compared the maximum stresses in the evaluated members and welds to the appropriate American Institute of Steel Construction (AISC) Manual of Steel Construction, 7th Edition, allowable stress limits to demonstrate compliance. The applicant also stated that there are certain instances where the AISC manual does not provide adequate guidance for the qualification of particular components. For these cases, other codes or standards were employed accordingly and are described in detail on page E1-59 of the March 4, 2011, letter (Reference 1). The most significant examples of these divergences from the AISC code are the use of the equations from Appendix A, Article A-8000 of the American Society of Mechanical Engineers Boiler & Pressure Vessel Code, Section III, 1989 Edition, which deals with perforated plate stresses, and the utilization of Structural Engineering Institute/American Society of Civil Engineers 8-02, "Specification for the Design of Cold-Formed Stainless Steel Structural Members," for the qualification of thin-gauge and cold-formed stainless steel sections.

The applicant noted on page E1-60 of Reference 1 that the AISC standard allows an increase of 33 percent in allowable stresses for steel due to seismic or wind loadings. However, the applicant did not credit this increased allowable stresses when comparing the induced stresses to the allowable stress indicated in the March 4, 2011, letter (Reference 1). The applicant also stated that the allowable stresses for carbon steel provided in the AISC code were utilized to qualify the stainless steel structure for tensile, shear, bending, and bearing loads, due to the lack of well-defined material properties for stainless steel in the AISC standard.

As indicated above, the design basis loading combinations, to which the strainer assembly and flow plenum were subjected, are in accordance with the WBN Unit 2 design and licensing basis requirements. Pages E1-61 and E1-62 of the March 4, 2011, letter (Reference 1) provide the results of the structural evaluation of the WBN Unit 2 strainer and flow plenum components in the form of maximum stress ratios which compare the maximum induced stresses in a component, due to the aforementioned loading combinations, with the appropriate allowable stress (ratio equals maximum stress divided by allowable stress). These results indicate that all of the components included in the evaluation satisfy the design code requirements (i.e., all stress ratios are less than 1.0).

Staff Review of Applicant's Evaluation

The NRC staff's review of the applicant's assessment of the structural integrity of the sump strainer and flow plenum assemblies included a number of items as follows:

The NRC staff reviewed the applicant's general method used in the structural analyses of these components to ensure that the analyses were performed consistent with the acceptance criteria in GL 2004-02, the NRC revised content guide (Reference 3), and the design and licensing basis requirements of WBN Unit 2, with a specific focus on the loading combinations for which the structures must be qualified against.

The NRC staff reviewed the results of the applicant's structural analyses to ensure that compliance with the industry codes, standards and design and licensing basis requirements was adequately demonstrated.

NRC staff reviewed the applicant's dynamic effects assessment to ensure that the applicant adequately considered whether any potential exists for dynamic effects loads due to pipe whip and/or jet impingement to impact the sump strainer and flow plenum assemblies at WBN Unit 2.

The NRC staff reviewed the open items associated with the WBN Unit 1 audit to confirm that any items deemed open as a result of the WBN Unit 1 GL 2004-02 closure audit were adequately addressed for the WBN Unit 2 GL 2004-02 closure efforts.

a. Structural Analysis

Paragraph 2(d)(vii) of GL 2004-02 specifically requested that sump strainers used to support ECCS and CSS have adequate structural margin against design basis loading combinations such that the structural integrity of the strainers was not compromised during a design basis accident. Item 3.k of Reference 3 provided additional specificity regarding the required information relative to the verification of the structural integrity of sump strainers, with respect to the closure efforts associated with GL 2004-02.

The review performed by the NRC staff covers the structural integrity of the sump strainers and associated flow plenum assemblies installed at WBN Unit 2. As such, the NRC staff's review focused on verifying that the applicant has provided reasonable assurance of the structural integrity of the sump strainers and flow plenum under normal and abnormal loading conditions, including postulated accidents and natural phenomena such as earthquakes. The design basis loading combinations used in the structural analyses of the structures at WBN Unit 2 are located in Chapter 3 of the WBN Unit 2 FSAR.

The NRC staff's acceptance criteria in the areas of civil and mechanical engineering are based on the guidance and regulatory requirements described in Section 3.8.4, "Other Seismic Category I Structures," of the SRP (Reference 24). The regulatory requirements described in SRP Section 3.8.4, Revision 3, include the following:

Title 10 of the *Code of Federal Regulations* (10 CFR) Section 50.55a and 10 CFR Part 50, Appendix A, General Design Criterion (GDC) 1, as they relate to safety-related structures being designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety function to be performed; GDC 2 as it relates to the design of the safety-related structures being capable to withstand the most severe natural phenomena such as wind, tornadoes, floods, and earthquakes and the appropriate combination of all loads; and GDC 4 as it relates to safety-related structures being protected against dynamic effects, such as the loads imposed on structures by postulated missiles. The WBN Unit 2 FSAR references Revision 2 of SRP Section 3.8.4 as the guidance used in the design of "Other Seismic

Category I Structures" at WBN Unit 2. Although Revision 3 to SRP Section 3.8.4 has been issued, the reference to Revision 2 is acceptable because the acceptance criteria related to the design of these structures remains unchanged between the Revision 2 and Revision 3 versions.

Additional guidance related to the structural integrity of sump strainers installed in PWRs to address GL 2004-02 can be found in Section 7.1 of the NEI 04-07 report (Reference 8). The NRC staff's associated SE (Reference 9), includes additional conditions and limitations and required modifications, including alternative guidance, with respect to the use of NEI 04-07 in resolving GL 2004-02.

The NRC staff considers the applicant's assessment of the structural integrity of the sump strainers and flow plenum acceptable based on a number of factors. The applicant demonstrated that the results of the structural analyses of the sump strainer and flow plenum satisfied the applicable design code requirements for the individual components making up each structure. All interaction ratios are below a value of 1.0. The NRC staff considers the general method used for the structural analyses of these components acceptable based on the fact that the use of manual hand calculations, supplemented with computational FEA, is standard industry practice for the structural evaluation of these types of structures and provides an adequate level of accuracy and conservatism. The applicant's RAI response number EMCB RAI-1 in the letter dated April 29, 2011 (Reference 7) regarding the damping values used in the seismic analyses for the sump strainer and flow plenum is acceptable given that it is consistent with the design basis requirements associated with the design of Seismic Category I structures at WBN Unit 2. Additionally, the NRC staff notes that the values used at WBN Unit 2 are conservative compared to the damping values which are deemed acceptable for use in the design of steel structures in the NRC staff guidance found in RG 1.61, "Damping Values for Seismic Design of Nuclear Power Plants," Revision 1.

The NRC staff considers the loading combinations used in the structural analyses acceptable given that they are consistent with the guidance provided in SRP Section 3.8.4 (Reference 4) and NEI 04-07 and they are consistent with the design and licensing basis requirements for WBN Unit 2. This acceptance also applies to the applicant's responses to NRC staff RAIs regarding the loads used in the design basis loading combinations used to structurally qualify the strainers. The applicant demonstrated that debris impact loads are not required to be included in the loading combinations due to the fact that the WBN Unit 2 replacement strainer structures are located such that debris impact loads resulting from a postulated pipe rupture would not affect the strainers. Additionally, the NRC staff considers the applicant's response regarding the omission of hydrodynamic loads acceptable based on the fact that the design and licensing basis requirements applicable to the structural design of the strainers does not require these seismically-induced loads to be postulated coincident with design basis accident recovery loads.

With respect to the stress limits specified in the applicant's response, the applicant's use of carbon steel material properties is acceptable given that at low temperatures (the maximum accident temperature is 190 °F, as indicated on page E1-59 of the March 4, 2011, letter (Reference 1), carbon steel has a lower allowable stress than that of stainless steel as provided in the AISC standard.

b. Dynamic Effects

The NRC staff considers the applicant's assessment of potential dynamic effects acceptable. This acceptance is based on the fact that the applicant presented adequate justification that demonstrates that the location of the sump strainers and the application of LBB criteria preclude the ability of the strainers to be affected by potential dynamic effects loads, resulting from jet impingement, pipe whipping, and/or missile impacts (see evaluation regarding debris impact loads in Section 3.2.1.11.a above). As such, the NRC staff considers the applicant's exclusion of these loads from the loading combinations previously described acceptable, given that there is reasonable assurance that the sump strainers would not be impacted by the aforementioned potential dynamic effects.

c. Audit Open Items

The NRC staff considers Audit Open Item 5 closed, as it relates to the WBN Unit 2. The NRC staff notes that this audit item was first identified for WBN Unit 1 due to the fact that the structural analyses for the sump strainers had not been completed at that time. Given that the applicant has completed the structural analyses for the WBN Unit 2 sump strainers and flow plenum, as summarized in Enclosure 1 to the March 4, 2011, letter (Reference 1), the NRC staff considers the applicant's assessment of the open item as it relates to WBN Unit 2 acceptable.

Staff's Conclusions

The staff reviewed the applicant's evaluation against the staff-accepted guidance and concludes that the applicant has appropriately verified the structural adequacy of the sump strainer under seismic, differential pressure, missiles, and jet impingement loads. Based on the above discussion, the NRC staff concludes that the applicant has provided reasonable assurance that the strainer assembly and flow plenum will maintain their structural integrity in the event of a design-basis accident. This acceptance is outlined above and is based on the applicant's use of a standard structural analysis method and the applicant's demonstration that the strainer assembly and flow plenum components meet the applicable design code structural acceptance criteria when these components are subjected to design basis loading combinations. The NRC staff also considers the applicant's assessment of the WBN Unit 1 GL 2004-02 closure Audit Open Item 5 acceptable and closed for WBN Unit 2 based on the fact that the applicant has provided the information originally requested. Furthermore, based on its review described above, the NRC staff has concluded that the regulatory requirements have been satisfied for the sump strainer and flow plenum assemblies. Therefore, staff concludes that the applicant's evaluation of the structural analysis is acceptable.

3.2.12 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 and possibly starve the pumps which take suction from the sump. An evaluation of upstream effects ensures that flow necessary for recirculation is not held up by debris blockage at drains or other narrow pathways.

Summary of Applicant's GL 2004-02 Evaluation

The applicant stated that walkdowns of the WBN Unit 1 containment had been completed following the guidance of NEI 02-01 (Reference 25) and that the WBN Unit 2 containment is similar to WBN Unit 1. The walkdowns identified three potential choke points that required evaluation. These potential holdup points are the refueling canal and accumulator rooms 3 and 4. The evaluation of these potential hold-up points was described as follows:

The applicant identified accumulator rooms 3 and 4 as a potential location for water hold-up. The rooms could have a small amount of containment spray enter through the openings for the air return fans. These rooms have drains that are designed to return the spray-water back to the containment pool. These accumulator rooms also have curbs at all openings to prevent the entry of water and debris flowing along the floor. Therefore, the only water that can enter the room is from spray. Because the containment spray is sourced either from the RWST or downstream of the sump strainer, any debris in these water sources would be too small to block the drains in the accumulator rooms. Therefore, the applicant assumed that only failed coatings debris could migrate to the interior of the accumulator rooms and that the failed coatings particles would be too small to block the drains.

The applicant identified the refueling canal as a potential location for water hold-up. The refueling canal has two 14-inch drains that discharge to lower containment at opposite sides of the sump strainer. These drains are designed to route almost all the spray water flow from upper containment to the lower containment. The applicant stated that a small amount of debris fines could be blown to upper containment by bypassing the ice baskets but the debris would not be a significant contributor to the potential source for blockage of the drain lines. The other debris types that could reach the drains are latent and coatings particles that also are assumed to be insufficient to block the drains.

The applicant identified the ice condenser compartment as a potential location for water hold-up if the drains become blocked. The applicant stated that there are 20 drains in the ice condenser compartment and that if any-one drain becomes blocked, the water would flow to other drains. The applicant also stated that if all the ice condenser drains were to become blocked, the water could overflow the ice condenser compartment bay doors (which is the normal drainage flow-path early in the LOCA event when the ice melt rate is high).

The applicant additionally stated that prior to restart from each refueling outage the containment is inspected for material that could inhibit the flow of water during recirculation or be washed to the sump.

Staff Review of Applicant's Evaluation

NRC staff reviewed the applicant's designation of potential water hold-up locations and found that the significant potential hold-up locations had been identified.

Staff reviewed the applicant's rationale for concluding that accumulator rooms 3 and 4 would not hold up a significant volume of water. The NRC staff concluded that plugging of the drains with fine debris would not occur because the size of the debris that could enter the rooms is significantly smaller than the drain lines and, therefore, could not plug the drains.

Staff reviewed the applicant's rationale for concluding that the refueling canal would not hold up a significant volume of water. The staff considered the size of the drain lines and the size of the debris that could reach the drains and concluded that it is not credible that the lines would become blocked by debris generated during a LOCA.

Staff reviewed the applicant's rationale for concluding that ice-condenser compartment would not hold up a significant volume of water. The staff considered that although blockage of all of the ice condenser drains is extremely unlikely, a small amount of water hold-up could occur in the ice condenser compartment late in the LOCA event. However, at this stage in the accident, the strainers would already be fully submerged. Therefore, the effect of this very unlikely water hold-up would be inconsequential.

NRC staff's review of the information provided by the applicant, as described above, against the staff's review guidance and the WBN Unit 1 audit report, considering the similarity of the two units. The staff concludes that the applicant performed an adequate upstream effects evaluation and that adequate water would not be prevented from reaching the sump following a LOCA.

Staff's Conclusions

The staff reviewed the applicant's evaluation against the staff-accepted guidance and concludes that the applicant has appropriately evaluated the flow-paths upstream of the containment sump for holdup of inventory that could reduce flow to the sump and possibly starve the pumps that take suction from the sump. Therefore, staff concludes that the applicant's evaluation of upstream effects is acceptable.

3.2.13 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.

Summary of Applicant's GL 2004-02 Evaluation

The applicant stated that with minor exceptions, WBN Unit 2 is a mirror image of WBN Unit 1. The exceptions are:

- WBN Unit 2 uses modified throttle valves in the chemical and volume control system (CVCS) and HPSI to control flow split instead of the restriction orifice/throttle valve combination used in WBN Unit 1.
- WBN Unit 2 does not contain Min-K insulation or 3M fire-wrap found in WBN Unit 1.

Therefore, the applicant concluded that the WBN Unit 1 downstream effects evaluations for components and systems generally bounds WBN Unit 2. A separate evaluation was performed to address blockage and wear of the CVCS and HPSI control valves. The applicant provided a description of the methods and design inputs used in the evaluations to assess the effects of debris carried downstream of the containment sump screen on the function of the ECCS and CSS in terms of wear of components and blockage of flow streams. The applicant stated that the evaluation incorporates methods from the NRC approved Topical Report WCAP-16406-P-A, Revision 1, "Evaluation of Downstream Sump Debris Effects in Support of GSI -191" (Reference 20). The applicant stated that the results of the revised evaluation indicate that the WBN Unit 2 ECCS equipment will perform adequately during the required mission time.

The applicant calculated the concentration of debris assumed to passes through the WBN Unit 2 sump strainer to be 835 parts per million (ppm). The primary constituents are:

- Fibrous debris: 1 ppm
- Particulate debris: 241 ppm
- Coatings debris: 593 ppm

As stated in WCAP-16406-P-A, Revision 1, the effects of debris ingested through the containment sump screen during the recirculation mode of the ECCS and CSS include erosive wear, abrasion and potential blockage of flow paths. The applicant provided the following evaluation results for these phenomena:

a) Blockage Evaluations

For the evaluation of the WBN heat exchangers, orifices, and spray nozzles in the recirculation flow path, the applicant stated that the smallest clearance found for these components is 0.375 inch (containment and RHR spray nozzles). No blockage of flow paths in these ECCS components is expected because the WBN Unit 2 sump screen opening size is much smaller (0.085 inch).

The instrumentation tubing was also evaluated for potential blockage of the sensing lines. The applicant stated that the transverse velocity past this tubing was determined to be sufficient to prevent debris settlement into these lines, so no blockage will occur. The reactor vessel level instrumentation system (RVLIS) was also evaluated. The WBN RVLIS is a Westinghouse design and, based on this evaluation, no effect on its performance is expected from the debris.

The applicant evaluated valves for plugging. The applicant stated that 12 valves in the SI and CVCS met the WCAP-16406-P, Revision 1 (Reference 20) criteria for specific plugging evaluation. The applicant stated that these valves were being positioned to ensure that no plugging will result; therefore, all 12 valves passed the evaluation.

The applicant evaluated valves for sedimentation. The applicant stated that 23 valves in the SI, RHR and reactor building spray systems meet the requirements in WCAP-16406-P-A for a specific sedimentation evaluation. The applicant stated that all the valves passed the evaluation.

b) Wear Evaluations

The applicant evaluated the WBN heat exchangers, orifices, and spray nozzles for the effects of erosive wear caused by a constant debris concentration of 835 ppm over a mission time of 30 days. The applicant stated that the erosive wear on these components was determined to be insufficient to affect the system performance.

The applicant evaluated valves for wear. Twelve valves in the SI system and CVCS met the TR-WCAP-16406-P-A, Revision 1 (Reference 20) criteria for a detailed wear evaluation. Using the depleting debris wear model detailed in TR-WCAP-16406-P-A, Revision 1, all valves passed the evaluation.

The applicant evaluated the SI, CSS, centrifugal charging (CC) and RHR pumps for the effects of debris ingestion through the sump screen. Three aspects of operability (hydraulic performance, mechanical shaft seal assembly performance, and mechanical performance (vibration) of the pump) were evaluated. The hydraulic and mechanical performances of the pumps were determined to not be affected by the circulating sump debris. The change in the pump wear ring gap due to abrasive wear was calculated and the resulting reduction in the pump discharge flow evaluated. For all of the pumps, the hydraulic flow margin was assumed to be positive at the start of containment recirculation. The increased clearance for the pumps was calculated to be within the TR-WCAP-16406-P-A, Revision 1, acceptance criterion of three-times the design clearance. Therefore, no effect on the hydraulic performance of the 12 ECCS and CSS pumps is expected.

For the pump seal evaluation of the SI, CSS, CC, and RHR pumps, the applicant stated that WBN Unit 2 has an engineered safety feature atmospheric filtration system, the auxiliary building gas treatment system, and the emergency gas treatment system. Therefore, evaluation of a primary seal passive failure is not required by NUREG-0800, and so the backup seal is not necessary to limit the leakage. Infrequent minor ECCS pump seal leakage that may occur during normal operation is bounded by the existing offsite dose analysis. The total ECCS recirculation loop leakage evaluated in the offsite dose analysis is 3760 cubic centimeters per hour. Since no primary seal failure is imposed by the LOCA dose analysis and primary seal failure is unlikely under these conditions, no adverse effect on the backup bushing is expected.

Staff Review of Applicant's Evaluation

NRC staff reviewed the evaluation methods, the evaluation results, and the applicant's conclusions contained in the applicant's GL 2004-02 responses (Reference 1) and concluded that the applicant followed the NRC staff-accepted guidance contained in TR-WCAP-16406-P-A, Revision 1, including the NRC SE of that document, for evaluating the effect of debris contained in the circulated sump pool on safety-related components located in the ECCS and CSS. Based on the staff review of the information provided by the applicant and a comparison of this information to the review guidance, a review of the WBN Unit 1 audit report, and the fact that the two containment and insulating system designs are very similar, the staff concluded that the applicant had performed an adequate downstream effects evaluation of components and systems and that the components would be capable of performing their safety-related design functions for their required mission times after a LOCA.

Commitments

In Enclosure 4 of the March 4, 2011 letter, under commitment number 3, the applicant stated that WBN Unit 2 will install new throttle valves in the CVCS and SI injection lines to the RCS and that the new valves will be opened sufficiently to preclude downstream blockage. In its September 16, 2013, letter (Reference 9), TVA reaffirmed that new throttle valves will be installed in the CVCS and SI system injection lines and stated that the installation was a confirmatory inspection item.

Staff's Conclusions

The staff reviewed the applicant's evaluation against the staff-accepted guidance and concludes that the applicants evaluation of 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 is acceptable. Therefore, staff concludes that the applicant's evaluation of the downstream effects on components and systems is acceptable.

3.2.14 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 core cooling.

Summary of Applicant's GL 2004-02 Evaluation

The applicant's evaluation of in-vessel downstream effects is based on two guidance documents: the "Clean Plant" criteria as clarified in the NRC letter dated May 2, 2002 (Reference 12) and TR WCAP-16793-NP-A, Revision 2 (Reference 13).

In a letter dated May 17, 2012 (Reference 8), the applicant provided information that demonstrated that WBN Unit 2 containment fibrous debris load meets the "Clean Plant" criteria and that the quantity of fibrous debris reaching the core inlet is calculated to be 11.9 grams per fuel assembly—less than the 15 grams per fuel assembly limit stated in TR-WCAP-16793-NP-A (Reference 13). Also, in a letter dated September 16, 2013 (Reference 9), the applicant provided results of its maximum post-quench fuel clad temperature and maximum fuel clad deposit thickness–398 °F and 11.6 mils, respectively. These values are considerably below the TR-WCAP-16793-NP-A allowable temperature of 800°F and deposit thickness of 50 mils.

Staff Review of Applicant's Evaluation

Staff reviewed the information provided by the applicant and determined that the evaluations meet the staff-accepted "Clean Plant" criteria and TR-WCAP-16793-NP-A, Revision 2. Based on the limited quantity of transportable debris at WBN Unit 2, and the available margins, the staff concluded that the applicant had performed an adequate evaluation of the downstream effects of debris on the fuel and reactor vessel to demonstrate that debris in the circulated post-LOCA coolant would not result in blockage at the core inlet that could prevent adequate coolant flow to the core.

Staff's Conclusions

The staff reviewed the applicant's evaluation and concludes that the applicant has satisfactorily resolved the issue of downstream, in-vessel effects. The applicant followed the guidance and acceptance criteria in staff-approved TR-WCAP-16793-NP-A, Revision 2 and the "Clean Plant" criteria. Therefore, NRC staff accepts the applicant's evaluation.

3.2.15 Chemical Effects

The objective of the chemical effects evaluation is to evaluate how chemical precipitates affect suction strainer head loss. (The NRC staff review of chemical effects within the reactor vessel is contained in Section 3.2.14 of this SE, using the TR-WCAP-16793-NP-A acceptance criteria.)

Summary of Applicant's GL 2004-02 Evaluation

The applicant used NRC staff approved methods of TR-WCAP-16530-NP-A, "Evaluation of Post-Accident Chemical Effects in Containment Sump Fluids to Support GSI-191" (Reference 19) to predict the amount of chemical precipitates formed in the sump pool after a LOCA, to generate the surrogate precipitates used in testing, and to perform a head loss test with the surrogate precipitates.

The applicant stated that due the small amount of reactive materials in the containment building, the moderate pH, the low sump pool temperatures, and the current buffering agent, the predicted total amount of precipitates formed for WBN Unit 2 over the assumed 30-day post-accident period was 13.08 kilograms.

Staff Review of Applicant's Evaluation

The applicant's analysis and testing are consistent with the staff's expectations as described in the chemical effects review guidance contained in the letter from W. H. Ruland, NRC, to A. R. Pietrangelo dated March 28, 2008 (Reference 21). The applicant determined the chemical precipitate source term at WBN Unit 2 using an NRC-approved method described in TR-WCAP-16530-NP-A) (Reference 19). The applicant performed strainer head loss testing with plant-specific debris, including chemical precipitate types and quantities determined per the guidance in in the topical report, to demonstrate that adequate ECCS recirculation flow can be maintained with this debris load. Therefore, the applicant's overall chemical effects evaluation is acceptable.

Staff's Conclusion

The staff reviewed the applicant's evaluation against the staff-accepted guidance and concludes that the applicant's evaluation of the effect that chemical precipitates have on suction strainer head loss is acceptable. Therefore, staff concludes that the applicant's evaluation of chemical effects is acceptable.

3.2.16 Licensing Basis

The objective of the licensing basis evaluation is to provide information regarding any changes to the plant licensing basis due to the sump evaluation or plant modifications

Summary of Applicant's GL 2004-02 Evaluation

In its letter dated September 16, 2013 (Reference 9), the applicant stated that the design basis of the modified emergency sump strainer has been incorporated into the plant's current licensing basis and that the WBN Unit 2 FSAR has been amended to include this information.

Staff Review of Applicant's Evaluation

The staff finds the applicant's response to this review topic acceptable because the applicant has updated the WBN Unit 2 licensing basis to include the licensing basis for the modified ECCS sump strainer.

Staff's Conclusion

The staff reviewed the applicant's actions against the staff-accepted guidance and concludes that the applicant has satisfied the requirement to reflect the design basis of the modified ECCS sump strainer in the plant design bases. Therefore, staff concludes that the applicant's response is acceptable and that the applicant has satisfied this requirement.

4.0 OVERALL CONCLUSIONS

Based on the staff review of the applicants GL 2004-02 evaluations and responses to RAIs (References 1, 7, 8, and 9) as discussed in Section 3 above, the NRC staff concludes that the applicant has provided reasonable assurance that the issues identified in GL 2004-02 have been adequately addressed at WBN Unit 2. Therefore, the NRC staff finds the applicant's response to GL 2004-02 acceptable. The open items identified in this SE are being tracked in the WBN Unit 2 Engineering Document Construction Release program and are confirmatory inspection items, ensuring that the committed actions will be completed prior to fuel load or startup, as applicable.

5.0 REFERENCES

1) Letter from D. Stinson, Tennessee Valley Authority, to NRC Document Control Desk, "Watts Bar Nuclear Plant (WBN), Unit 2 – Response to Generic Letter (GL) 2004-02, Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors," dated March 4, 2011. (ADAMS Accession No. ML110680248)

2) Letter from Masoud Bajestani, Tennessee Valley Authority, to NRC Document Control Desk, "Watts Bar Nuclear Plant (WBN), Unit 2 – Response to Generic Letter (GL) 2004-02, Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors," dated September 10, 2010. (ADAMS Accession No. ML102580175)

3) Letter from W. H. Ruland, NRC, to A. Pietrangelo, Nuclear Energy Institute, "Revised Content Guide for Generic Letter 2004-02 Supplemental Responses," dated November 21, 2007. (ADAMS Accession Nos. ML073110269 (letter) and ML073110278 (enclosure))

4) TVA letter to NRC dated July 3, 2006, "Watts Bar Nuclear Plant (WBN), Unit 1 - Generic Letter 2004-02 - Request for Additional Information Regarding the Nuclear Regulatory Commission Staff Audit on the Containment Sump Modifications (TAC No. MC4730)." (ADAMS Accession No. ML062120472)

5) TVA Letter to NRC dated March 3, 2009, "Watts Bar Nuclear Plant (WBN), Unit 1 - Response to Request for Additional Information Regarding Generic Letter 2004-02, Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors (TAC. No. 4730)." (ADAMS Accession No. ML090720868)

6) TVA Letter to NRC dated June 3, 2010, "Draft Responses to Requests for Additional Information Related to NRC Generic Letter 2004-02, Potential Impact of Debris Blockage During Design Basis Accidents at Pressurized-Water Reactors." (ADAMS Accession No. ML101590373)

7) Letter from D. Stinson, Tennessee Valley Authority, to NRC Document Control Desk, "Watts Bar Nuclear Plant (WBN), Unit 2 – Response to Requests for Additional Information (RAIs) Regarding Generic Letter 2004-02, Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors (TAC No. MD6726)," dated April 29, 2011. (ADAMS Accession No. ML11124A083)

8) TVA letter to NRC dated May 17, 2012, "Watts Bar (WBN), Unit 2-Additional Information to Generic Letter 2004-02, Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors (TAC No. MD6726)." (ADAMS Accession No. ML12143A345)

9) TVA letter to NRC dated September 16, 2013, "Watts Bar (WBN), Unit 2-Additional Information to Generic Letter 2004-02, Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors (TAC No. MD6726)." (ADAMS Accession No. ML13262A270)

10) NRC letter to TVA dated April 19, 2011, "Watts Bar Nuclear Plant, Unit 2 - Request for Additional Information Regarding Generic Letter 2004-02, Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors (TAC No. MD6726)." (ADAMS Accession No. ML110950406)

11) NRC letter to TVA dated April 25, 2011, "Watts Bar Nuclear Plant, Unit 2 - Request for Additional Information Regarding Generic Letter 2004-02, Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors Round 2 (TAC No. MD6726)." (ADAMS Accession No. ML111091048)

12) Letter from W. H. Ruland, NRC, to J. C. Butler, Nuclear Energy Institute, "NRC Review of Nuclear Energy Institute Clean Plant Acceptance Criteria for Emergency Core Cooling Systems," dated May 2, 2012. (ADAMS Accession Nos. ML120730181)

13) Westinghouse Topical Report WCAP-16793-NP-A, "Evaluation of Long-Term Cooling Considering Particulate, Fibrous and Chemical Debris in the Recirculating Fluid," Revision 2, July 2013. (ADAMS Accession Nos. ML13239A114 and ML13239A115)

14) Letter from A. R. Pietrangelo, Nuclear Energy Institute, to J. N. Hannon, NRC, "PWR Containment Sump Evaluation Methodology – Baseline Evaluation," dated April 19, 2004. (ADAMS Accession No. ML041120516)

15) NRC Staff Safety Evaluation for Nuclear Energy Institute Report, "PWR Containment Sump Evaluation Methodology – Baseline Evaluation," December 6, 2004. (ADAMS Accession Nos. ML043280007 and ML043280008)

16) NEI 04-07 "Pressurized Water Reactor Sump Performance Evaluation Methodology," Rev. 0, December 2004, Volume 1. (ADAMS Accession No. ML050550138)

17) NEI 04-07 "Pressurized Water Reactor Sump Performance Evaluation Methodology," Rev. 0, December 2004, Volume 2, Safety Evaluation by the Office of Nuclear Reactor Regulation Related to NRC Generic Letter 2004-02, Rev. 0, December 6, 2004. (ADAMS Accession No. ML050550156)

18) Letter from J. C. Butler, Nuclear Energy Institute, to S. N. Bailey, NRC, "Transmittal of GSI [Generic Safety Issue] 191 Resolution Criteria for "Low Fiber Plants," dated December 22, 2011. (ADAMS Accession No. ML113570219)

19) Westinghouse Topical Report WCAP-16530-NP-A, "Evaluation of Post-Accident Chemical Effects in Containment Sump Fluids to Support GSI-191," March 2008. (ADAMS Accession No. ML081150379)

20) Westinghouse Topical Report WCAP-16406-P-A, "Evaluation of Downstream Sump Debris Effects in Support of GSI-191," Revision 1, March 2008. (ADAMS Accession No. ML081000027)

21) Letter from W. H. Ruland, NRC, to A. R. Pietrangelo, Nuclear Energy Institute, "Revised Guidance for Review of Final Licensee Responses to Generic Letter 2004-02, 'Potential Impact of Debris Blockage on Emergency Recirculation During Design-Basis Accidents at Pressurized Water Reactors,'" dated March 28, 2008. (ADAMS Accession Nos. ML080230112 (letter), ML080230038 (Enclosure 1), ML080230462 (Enclosure 2), and ML080380214 (Enclosure 3))

22) Memorandum from Stephen J. Smith to Michael L. Scott, Branch Chief, "Staff Observation of Testing for Generic Safety Issue 191 During July 12 to July 14, 2010, Trip to the Alden Test facility for PCI Strainer Tests," dated August 19, 2010. (ADAMS Accession No. ML102160226)

23) U.S. Nuclear Regulatory Commission, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition – Engineered Safety Features," NUREG-0800, Section 6.2.2.

24) U.S. Nuclear Regulatory Commission, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition - Design of Structures, Components, Equipment, and Systems – Other Seismic Category I Structures," NUREG-0800, Section 3.8.4.

25) Nuclear Energy Institute Document NEI 02-01, Revision 1, "Condition Assessment Guidelines: Debris Sources Inside PWR Containments," September 30, 2002. (ADAMS Accession No. ML030420318)

maintained within the bounds of the analyses and design-bases that support ECCS and CSS recirculation functions, and (3) install new throttle valves in the chemical volume control system and safety injection system lines to the reactor coolant system, opened sufficiently to preclude downstream blockage. The above required actions are confirmatory inspection items.

The NRC staff performed a thorough review of the TVA responses to GL 2004-02 and concluded that TVA's response to GL 2004-02 is acceptable. The NRC staff conclusions have been documented in the enclosure. Based on the NRC staff conclusions, the NRC staff finds the information provided demonstrates that debris will not inhibit the ECCS or CSS performance of its intended function in accordance with 10 CFR 50.46 to assure adequate long term core cooling following a design-basis accident. Therefore, the NRC staff finds the licensee's responses to GL 2004-04 are adequate and pending completion of the confirmatory items discussed above, considers GL 2004-02 closed for the WBN Unit 2. No further information or action is requested of the applicant.

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

Sincerely,

/RA/

Justin C. Poole, Senior Project Manager
Watts Bar Special Projects Branch
Division of Operating Reactor Licensing
Office of Nuclear Reactor Regulation

Docket No. 50-391

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